

# Powder-Metallurgy Experiments and Manufacturing Studies on $\text{DUO}_2$ -Steel Cermet for SNF Casks

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# Outline

- **Cermet Cask Description**
- **Manufacturing Options**
- **Laboratory Tests**
- **Conclusions**



*GNS Storage and Transport Cask*

# Cermets Combine the Best Properties of Ceramics (Shielding, Hardness, etc.) and Metals (Strength, Ductility, etc.)

*Cermets Are Used for Demanding Applications*



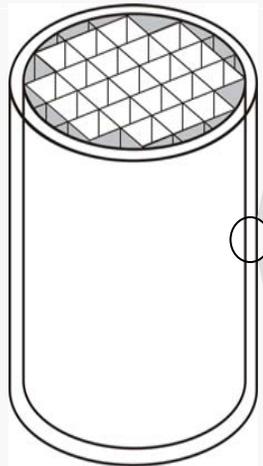
Brake Shoes



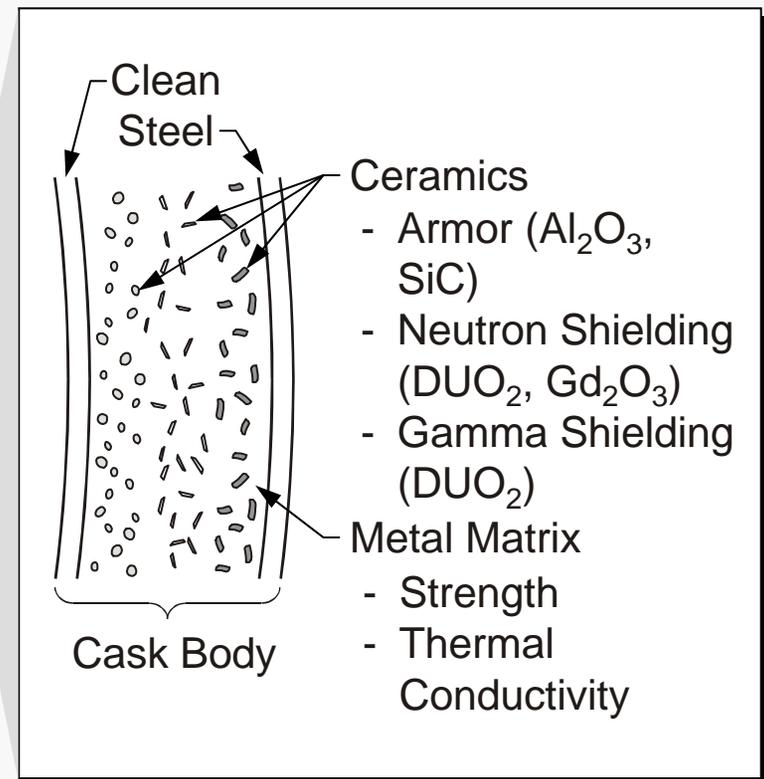
Main Battle Tank Armor



Cutting Tools



*Cermet Body Cross Section*



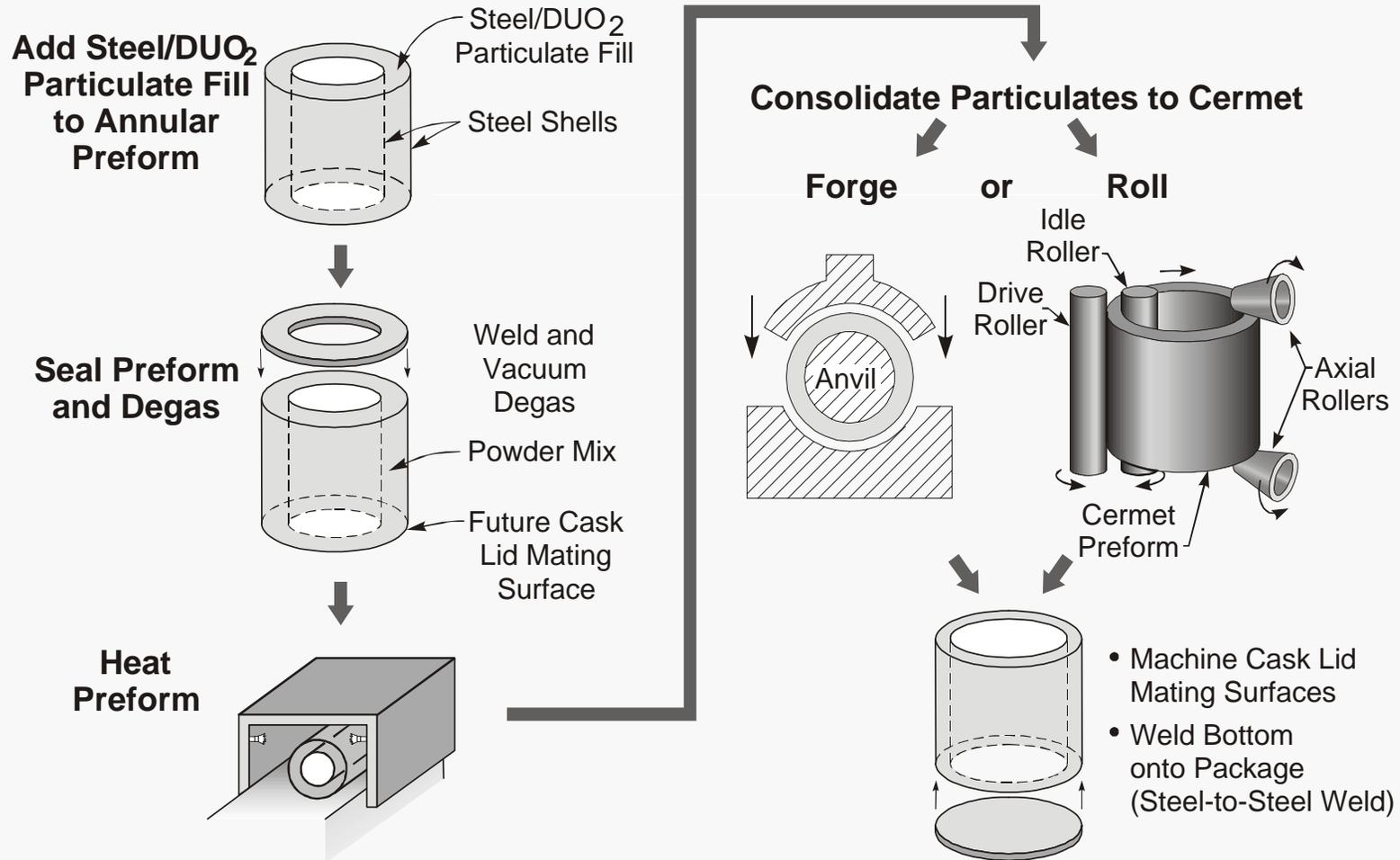
# **Cermet Casks will be Adopted if Manufacturing Costs are Low**

- **Two manufacturing options are being examined in the United States**
  - **Forged Cermet Cylinder (FCC) Process**
  - **Cermet Extrusion Section (CES) Process**
- **Both processes use powder metallurgy techniques**
- **Manufacturing studies are underway to understand the economics**

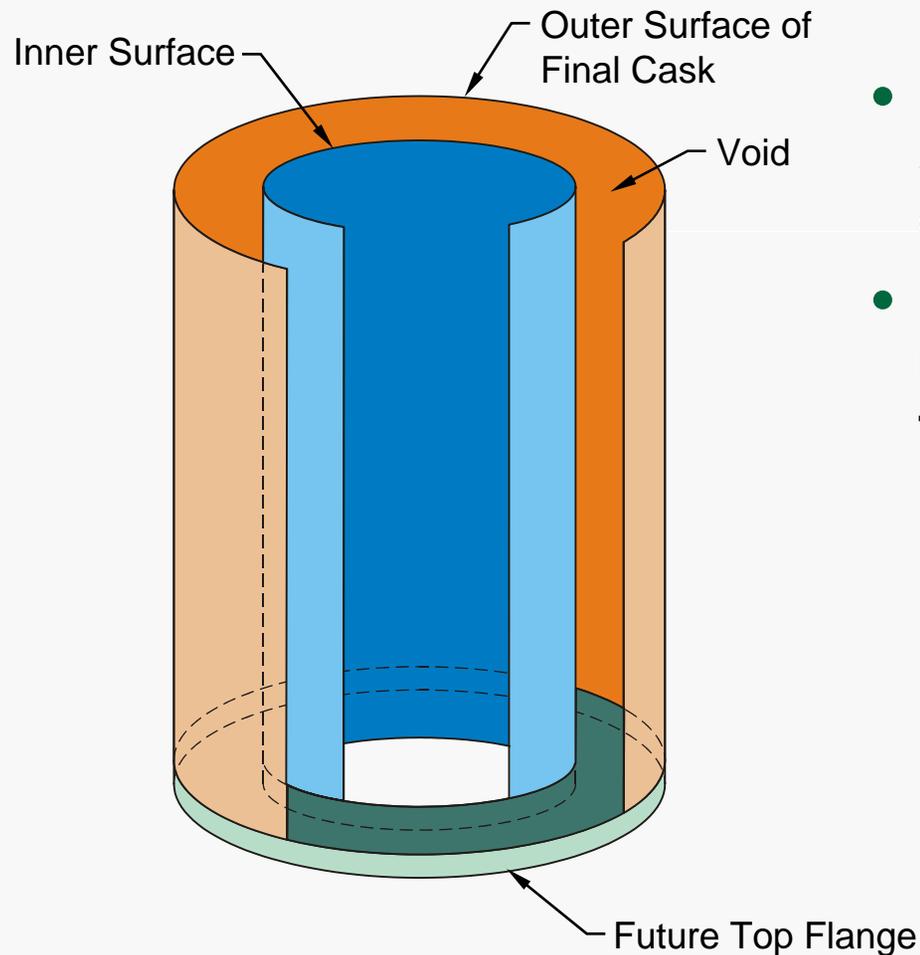
# FCC Process

# Forged Cermet Cylinder Process

(United States Patent: 6,811,745: November 2, 2004)

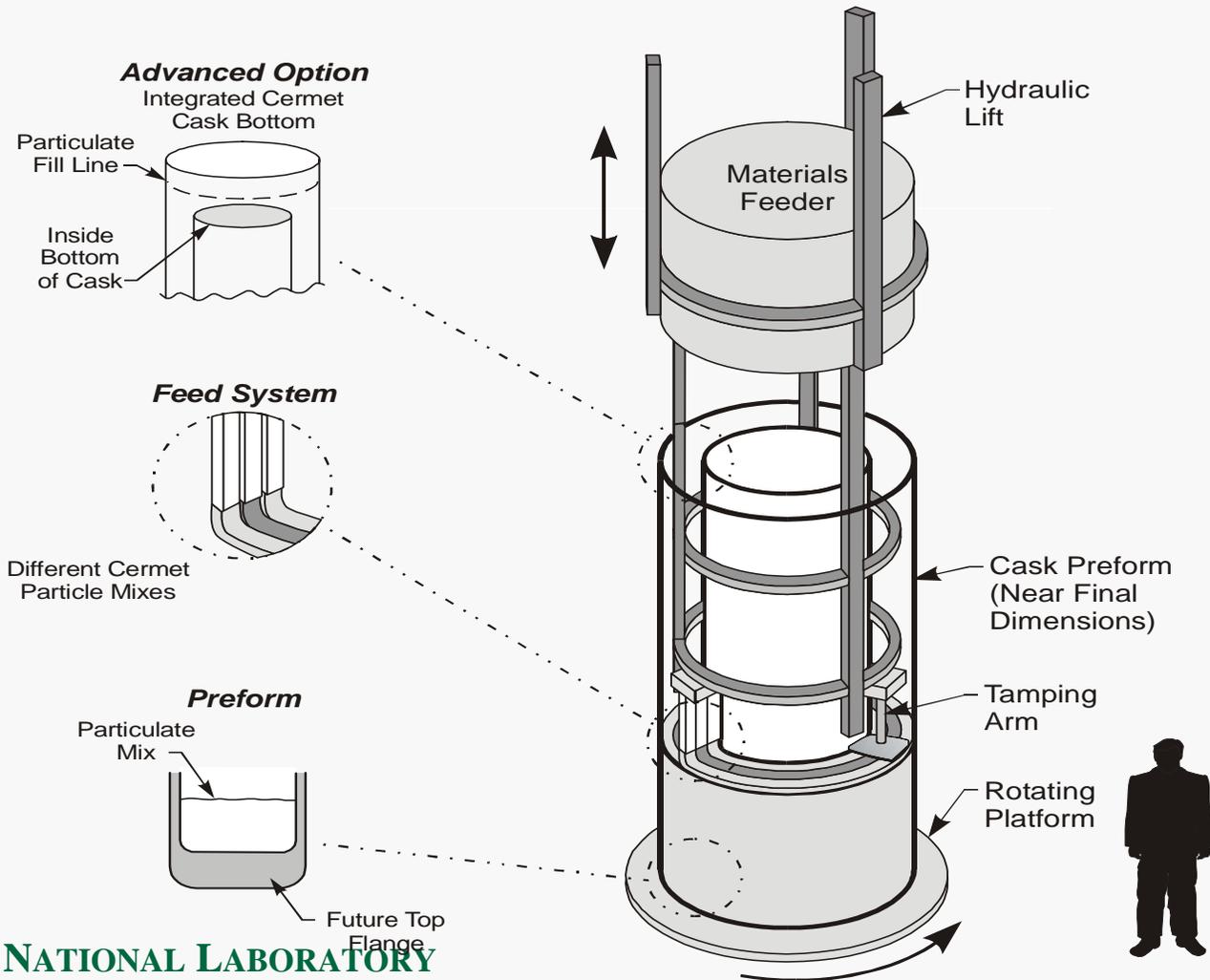


# Step 1: Manufacture of Cask Preform

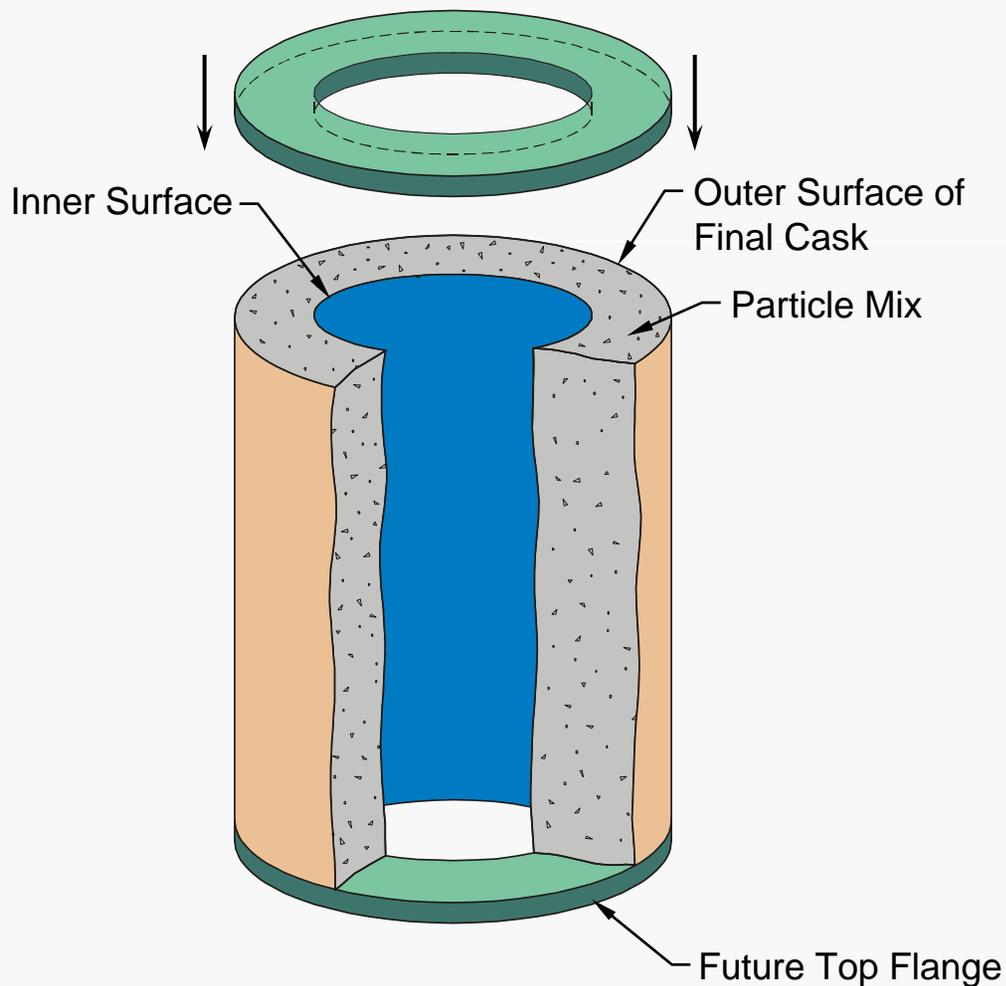


- Preform dimensions are slightly larger than the final cask
- Preform becomes the final inner and outer surfaces of the cask
  - Wall thickness: 1–3 cm
  - Flange
    - Thickness: 10–20 cm
    - Face for lid

# Step 2: Empty Preform is Mounted Upside Down on Turntable and Filled with Cermet Particulate Mixture

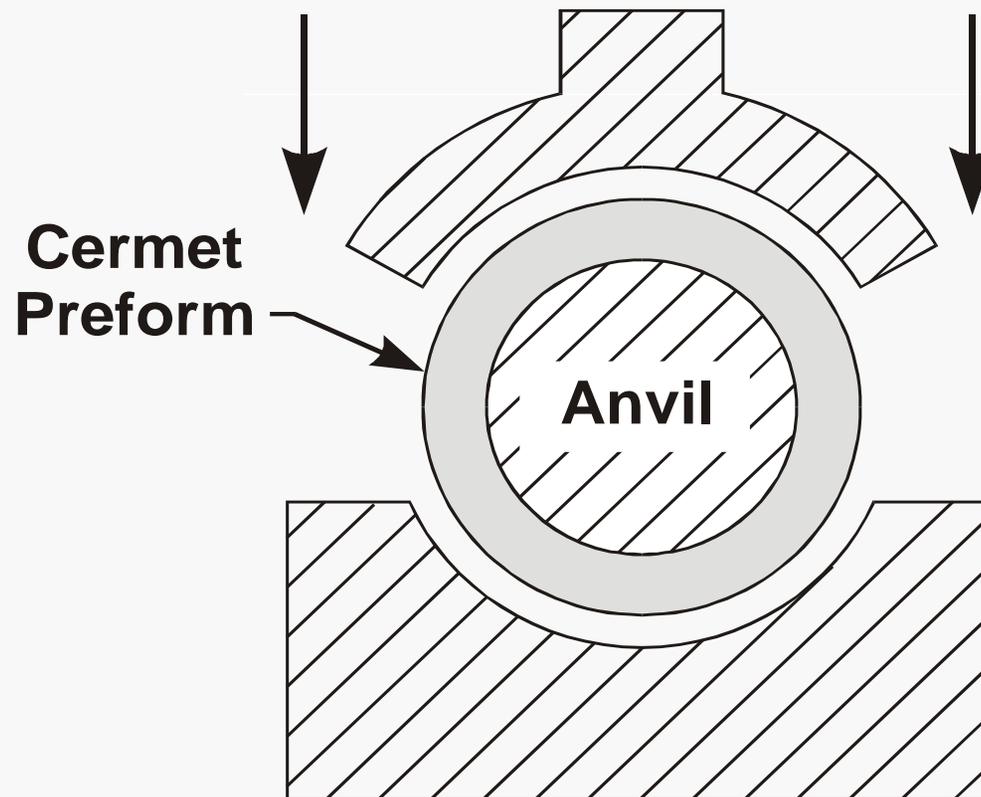


# Step 3: Loaded Preform is Sealed and Degassed

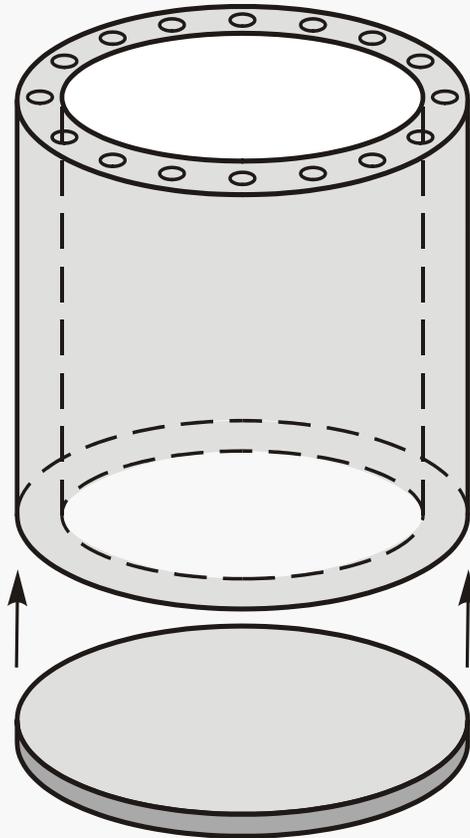


- Weld annular ring to seal preform
- Degas
  - Heat
  - Vacuum
- Send sealed package to forging operations

# Step 4: Cermet Consolidation by Hot Forging (Several Forging Options)



# Step 5: Cask Finishing Operations

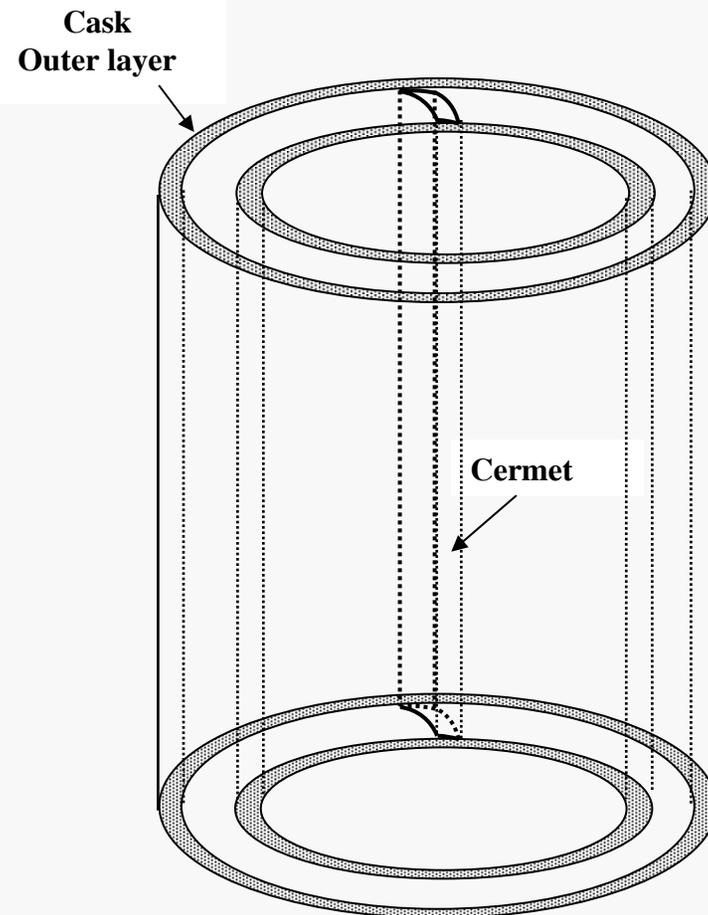


- All finishing operations involve steel preform (No contact with cermet)
- Cask bottom is welded to the cask body
  - Option for integrated cask bottom
  - Option requires complex forging operation
- Cask machining
  - Machine lid surface and bolt holes
  - Cask surfaces

# CES Process

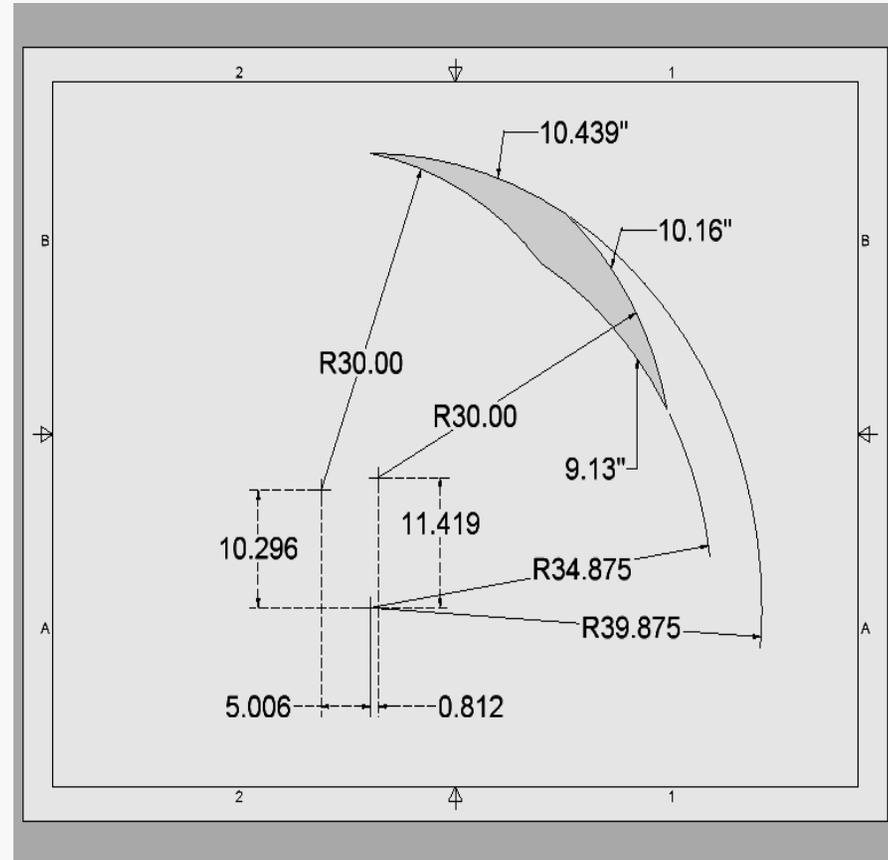
# CES Production Process (Assembly)

- **Cask consists of:**
  - External steel shell
  - Internal steel shell
  - Cermet sections
- **Cermet sections have a steel exterior and a cermet interior**
- **Considering 12 to 48 cermet sections per cask**



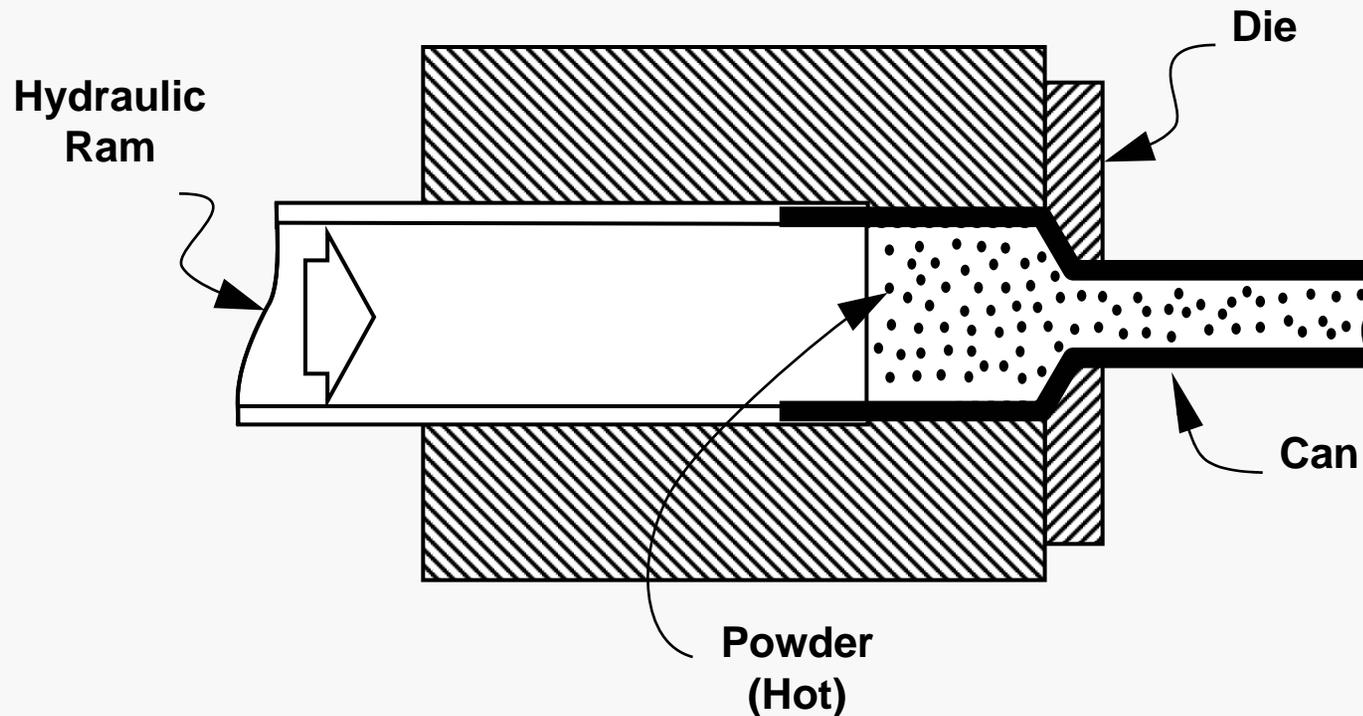
# Modern Extrusion Techniques Allow Production of Cermet Segments

- Cermet mixture placed in long rectangular box
  - Layer of powder mixture added
  - Layer compressed
  - Steps repeated until box is full
- Box welded shut
- Box heated and gases removed
- Box heated and extruded to final form



# Powder Extrusion Process

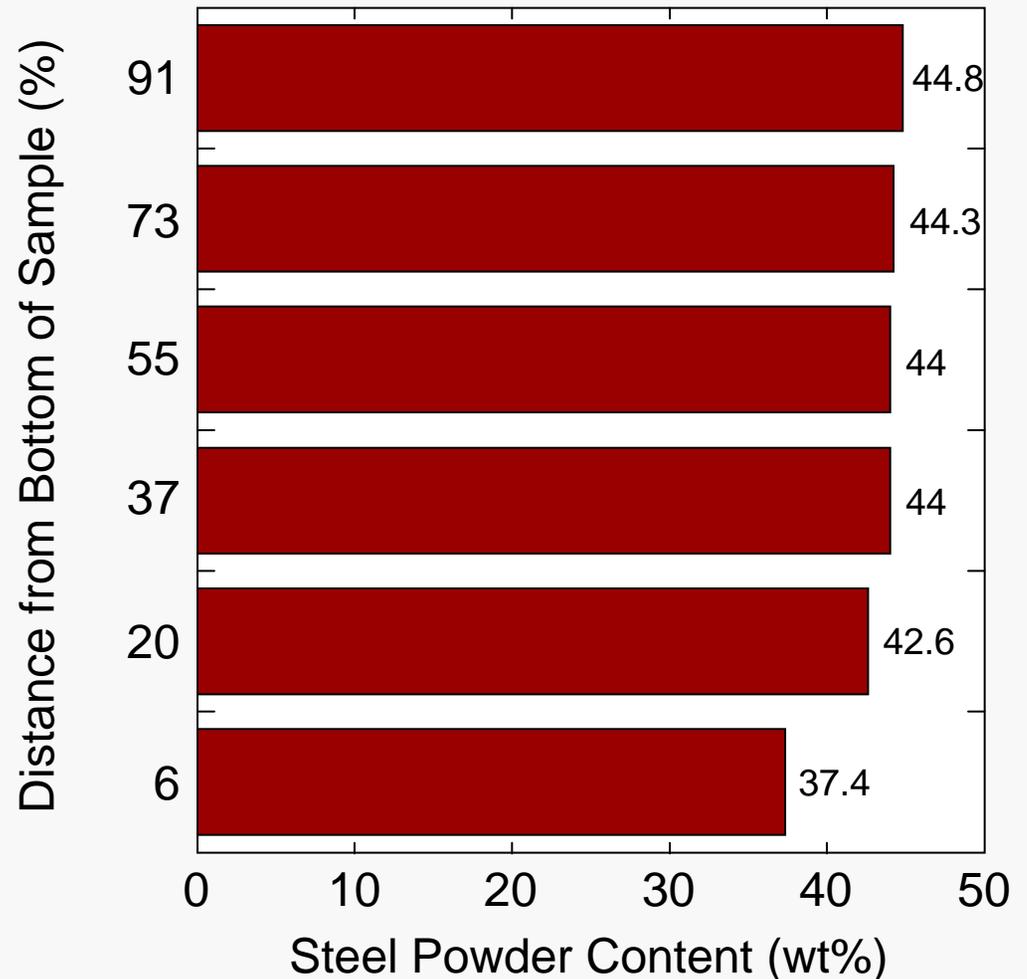
## (Ram Pushes Heated, Canned Powder Through a Die)



**Laboratory Experiments to  
Define Manufacturing  
Conditions for Both Processes**

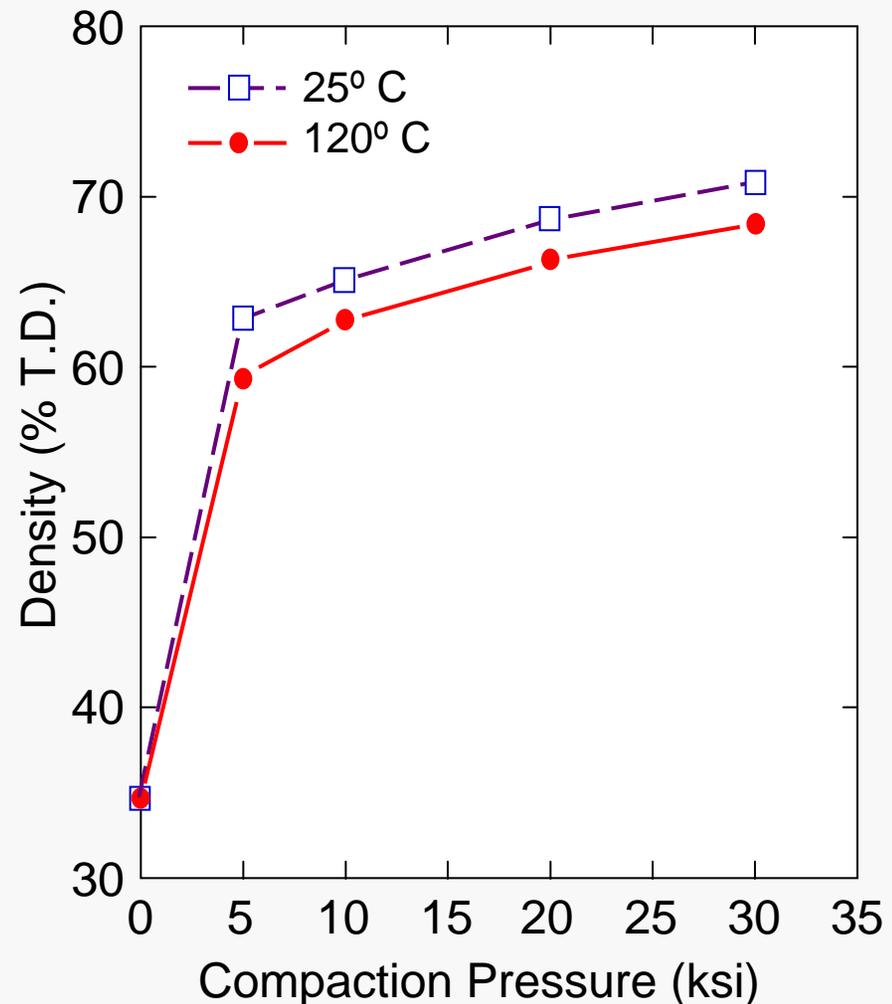
# Powder Mix Segregation Tests

- Powder mixtures can separate on handling
- Tests define allowable thickness of powder before compression
  - 7-cm cylinder of HfO<sub>2</sub> mix and iron powder
  - 2-hours on vibration table
  - Limited segregation
- Tests define maximum layer of powder mixture before pre-compaction



# Compression Testing

- Powder mix compressed to minimize high-temperature consolidation
- Tests to determine optimum forces for compression
  - Low pressure minimizes cost
  - High pressure maximizes density
  - Warm compaction above  $T_g$  of binder improves density



# Advantages For Each Process

## FCC Process

- **Maximize cermet content of cask (no steel inside cask body)**
  - Maximize performance
  - Maximize DUO<sub>2</sub> usage
- **Minimum number of process steps**
  - Advantage for large volume production

## CES Process

- **Small manufacturing equipment (low capital cost)**
  - Attractive for limited production runs
- **Lower research and development costs**

# Conclusions

- **Two methods for cask manufacturing are being investigated**
- **Both methods use powder metallurgical fabrication processes**
- **Each has specific advantages and disadvantages**
- **Experiments are required to determine manufacturing times to allow reliable estimates of manufacturing costs**
- **Cost estimates to be developed latter this year**