Nuclear Science and Technology Division

Document Review Record

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Division Director Approval: ______ **Date**

Revision Date: 12/01/2003 NSTD-DRR-01

UT-BATTELLE

Cask Size and Weight Reductions Through the Use of DUO_2-Steel Cermet Materials

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C. H. Mattus, and Chad Hasbrouck

Russian–American Workshop on Use of Depleted Uranium and Review of International Science and Technology Center (ISTC) Projects
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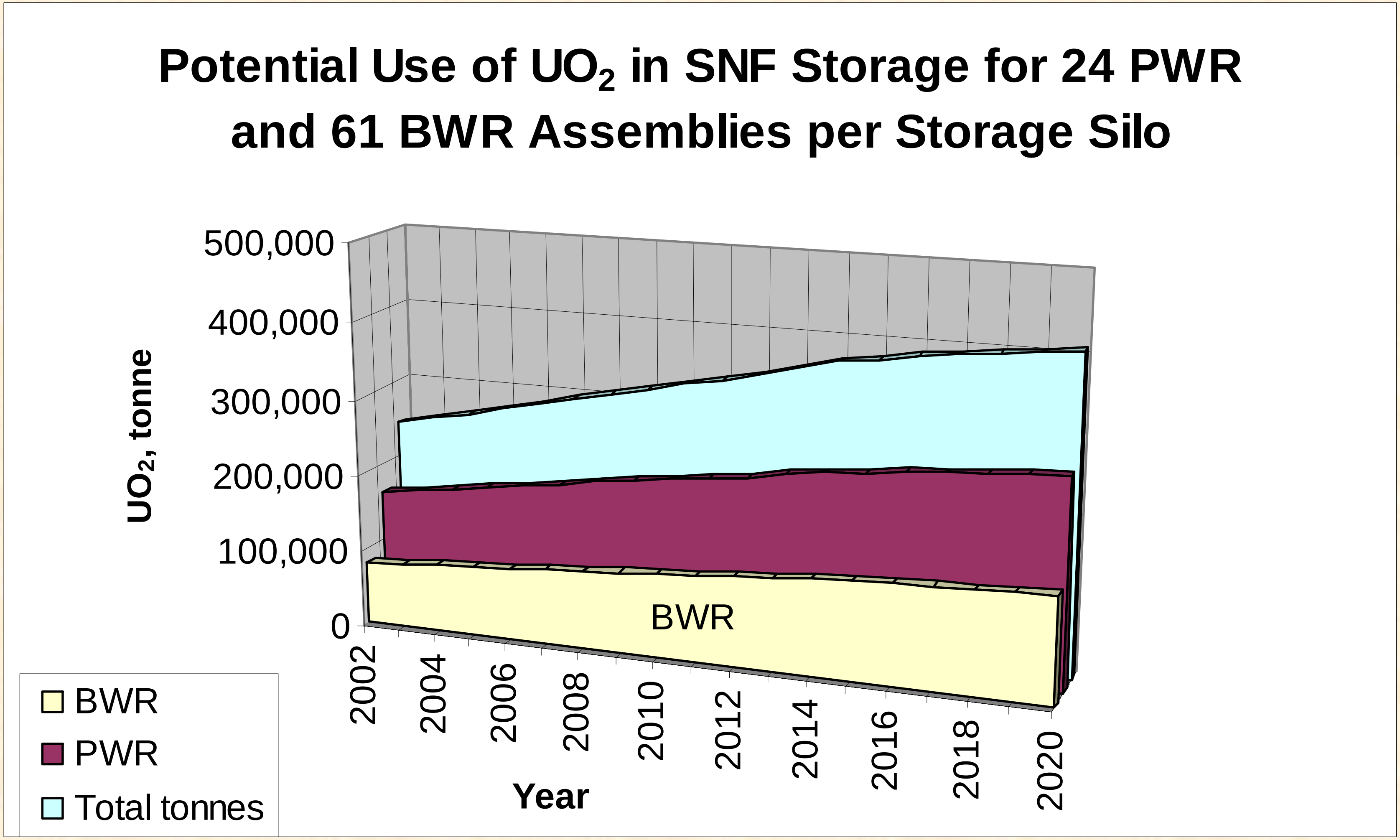
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Outline

- **Background of U.S. and DUCRETE Program**
- **Update laboratory DUAGG exposure testing**
- **Update preconceptual design and costing of DUCRETE cask fabrication**

Consumption in Storage/Transport Casks for projected Commercial SNF



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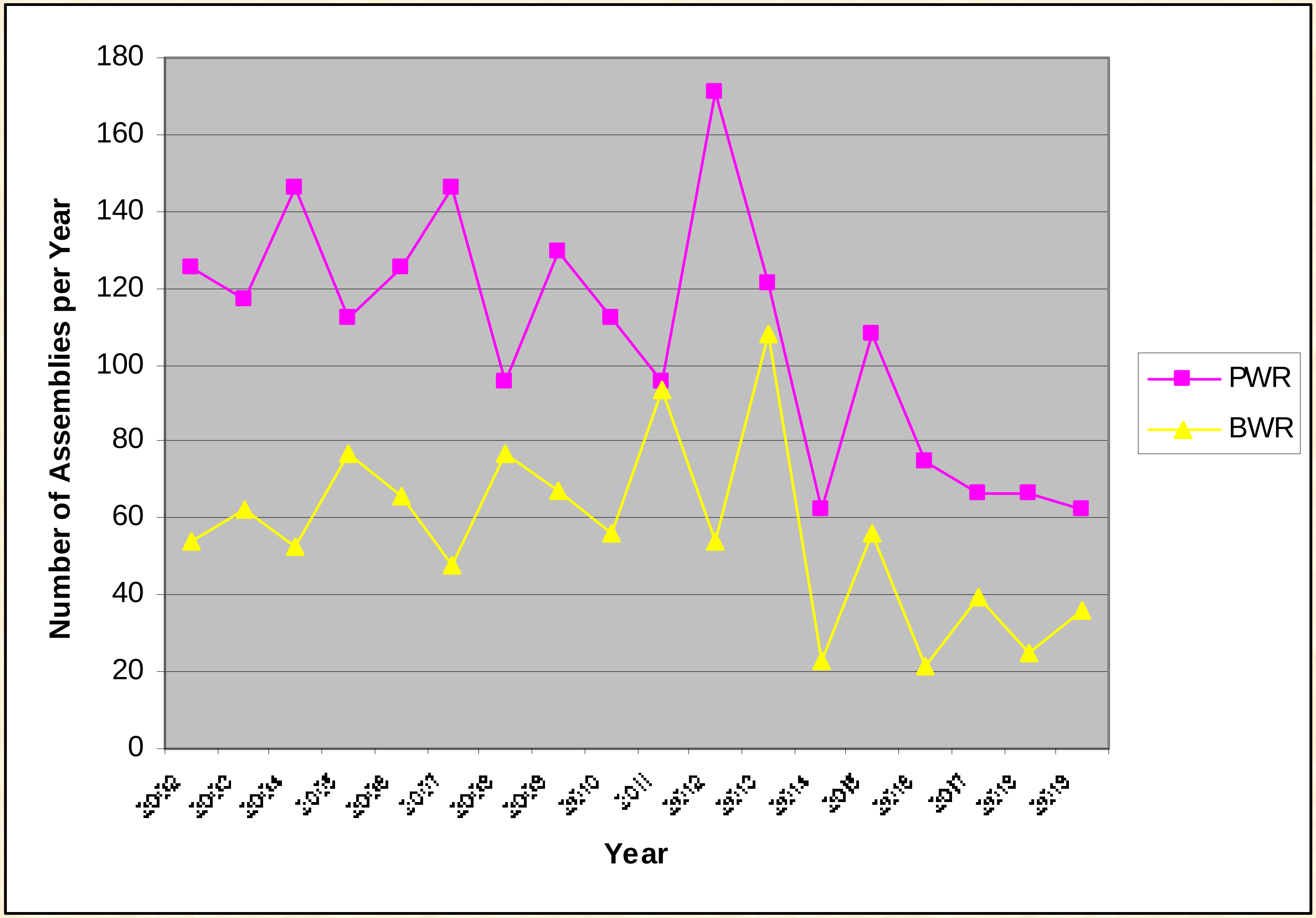
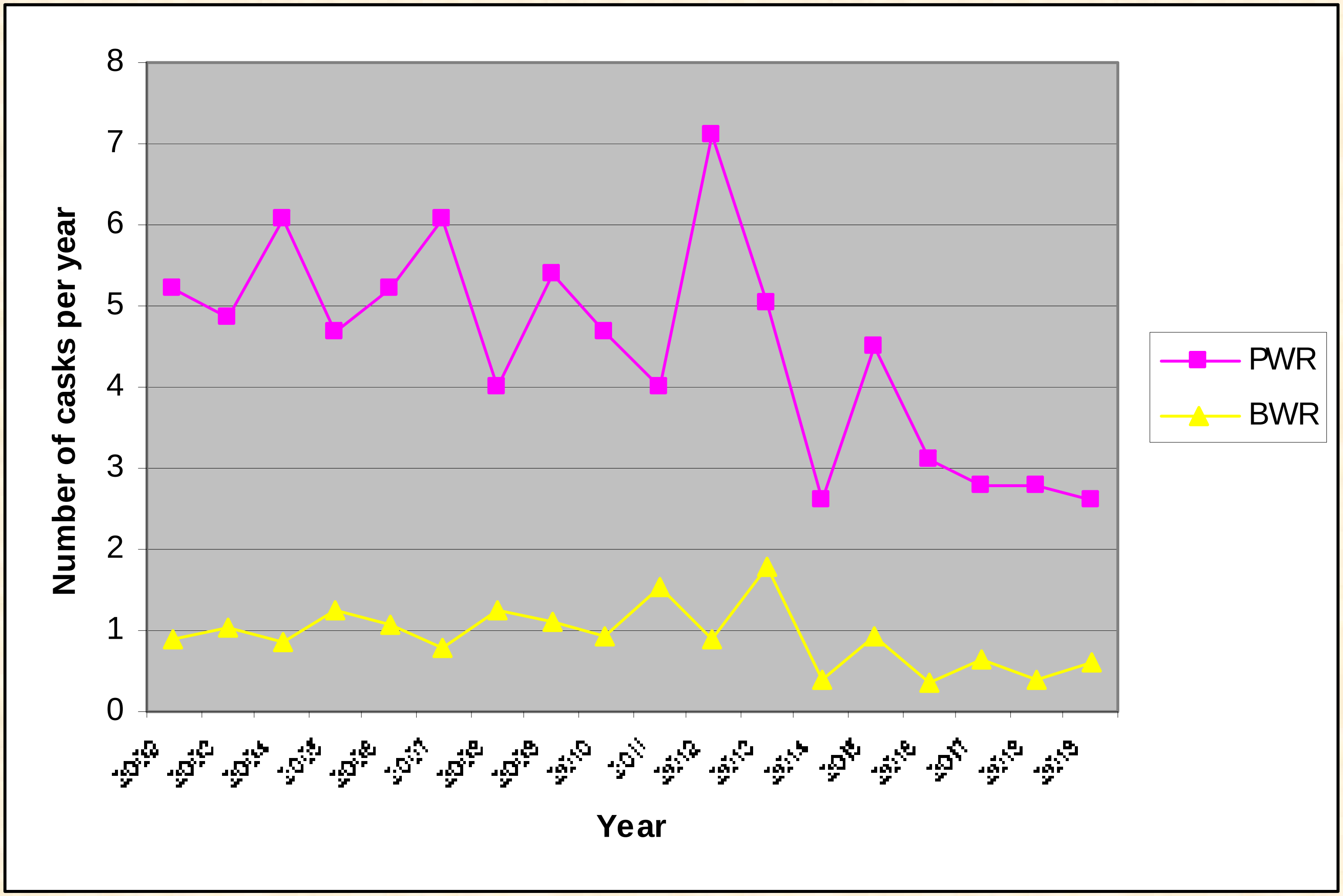
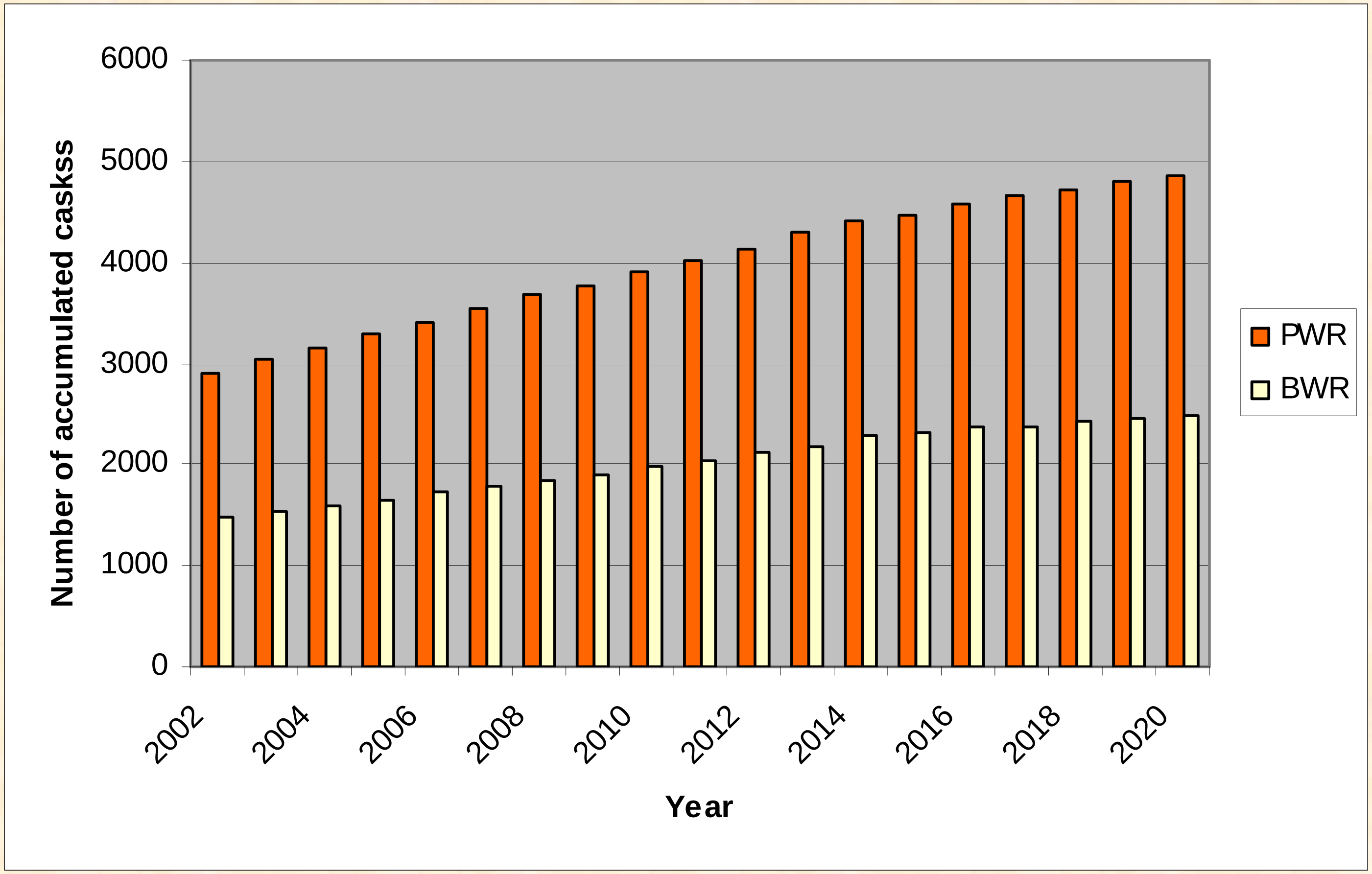
Yearly Rate of Spent Fuel Assemblies (no inventory included)



Yearly Rate of Spent Fuel Storage/Transport Casks (no inventory included)



Hypothetical Number of Casks for the Accumulated PWR and BWR Assemblies (including inventory)



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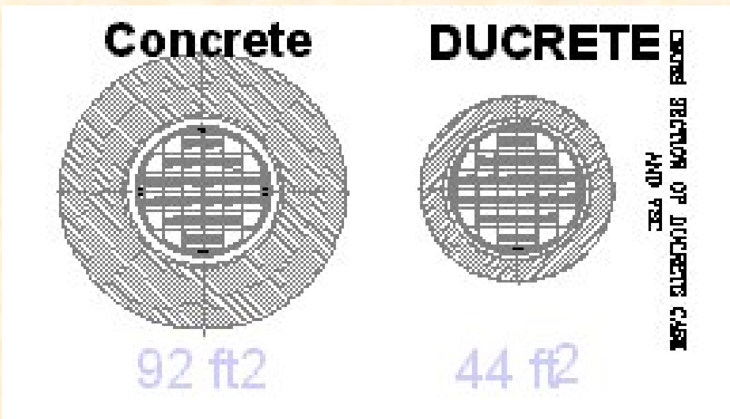
Design Capacity of the Plant

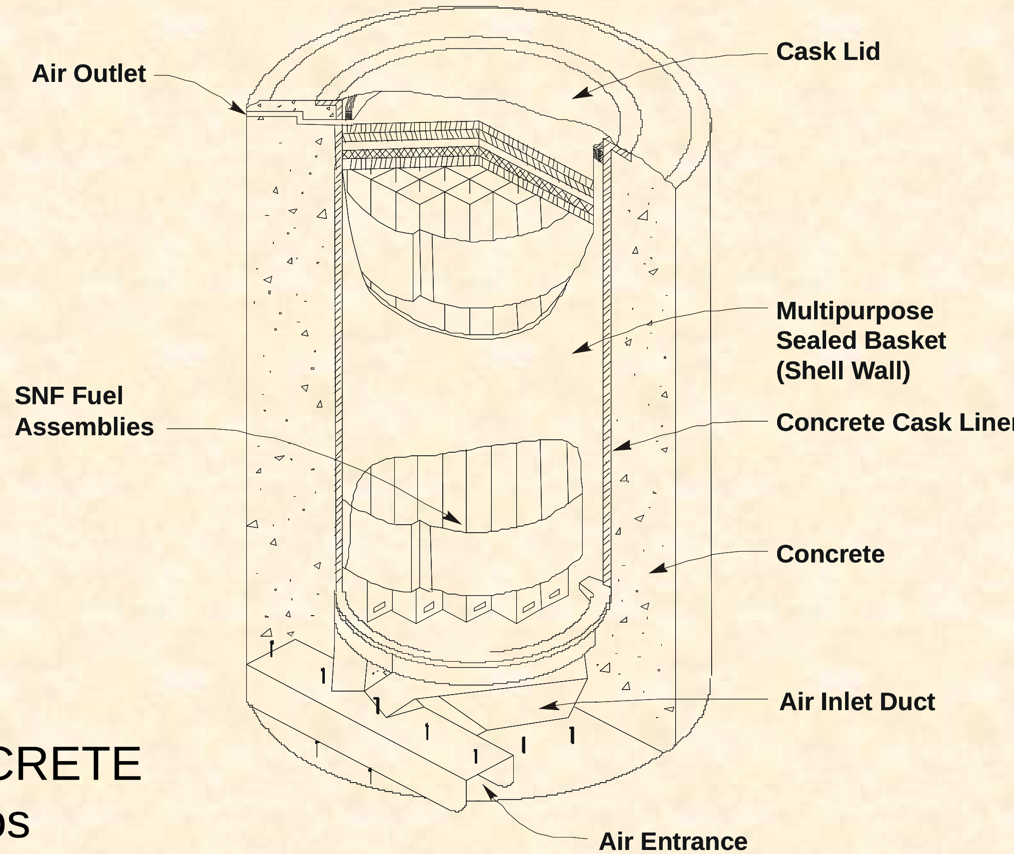
- **Plant produces 50 storage/transport casks per year, operating in one 8-hr shift**
- **Operates for 25 years**
- **Casks will store the equivalent to about 25% the inventory of PWR inventory or could store the equivalent to about 45% of BWR inventory**

DUCRETE Casks are Considerably Smaller and Lighter than Casks Constructed of Ordinary Concrete

The DUCRETE cask is 35 tons lighter and 100 cm smaller in diameter than casks made from ordinary concrete.



Comparison of conventional and DUCRETE spent-fuel dry storage casks/silos



Substitute DUCRETE in GNB CONSTOR Cask and Optimize Design

- Reduce size and weight
- Allow higher thermal loads
- Meet technical and economic performance criteria
- Comply with regulatory requirements and standards

Russian RBMK Spent Fuel Cask with Heavy Concrete

GNB CONSTOR test cask
for RBMK SNF

Heavy concrete with steel shot and barium sulfate

RMBK SNF Shipments in Russia

A train carrying a load of spent nuclear fuel from a Ukrainian nuclear power plant arrived at Zheleznogorsk, Krasnoyarsk County

http://www.bellona.no/en/international/russia/nuke_industry/siberia/zheleznogorsk/16331.html

DUAGG Briquettes are Stabilized DU Aggregates with Basalt Sintering Agent

Briquettes are pressed, solidified by liquid-phase sintering, crushed, and gap-graded for use in high-strength DUCRETE at 5000 to 6000 psi, (35–42 MPa)

Composition of DUAGG

Element	wt %
Aluminum	0.61
Copper	0.04
Iron	0.42
Potassium	0.14
Magnesium	0.15
Silicon	2.16
Strontium	0.01
Titanium	1.35
Uranium	93.71
Zirconium	0.85

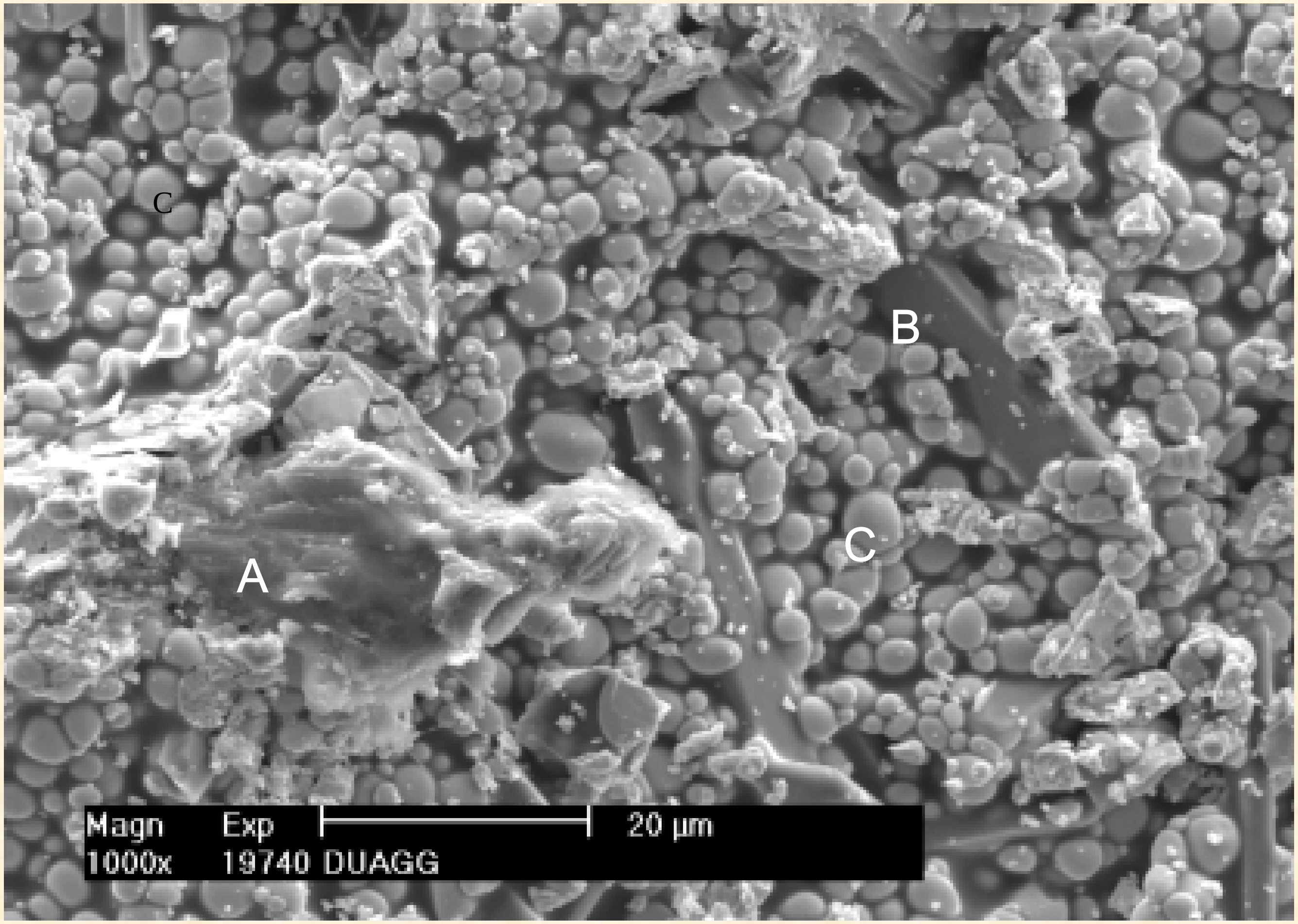
Current DUAGG Exposure Studies Using ASTM C289-94 Standard Test Method

At a consistent surface-to-liquid ratio of 1:10, the sintered DUAGG samples are exposed to:

(1) distilled water
(2) 1*N* sodium hydroxide standard solution
(3) saturated water extract of high-alkali cement

The three exposure temperatures and six times are as follows: 25, 66, and 150ºC at intervals of 30, 60, 90,180, 360, and 730 days

View of DUAGG Before Testing

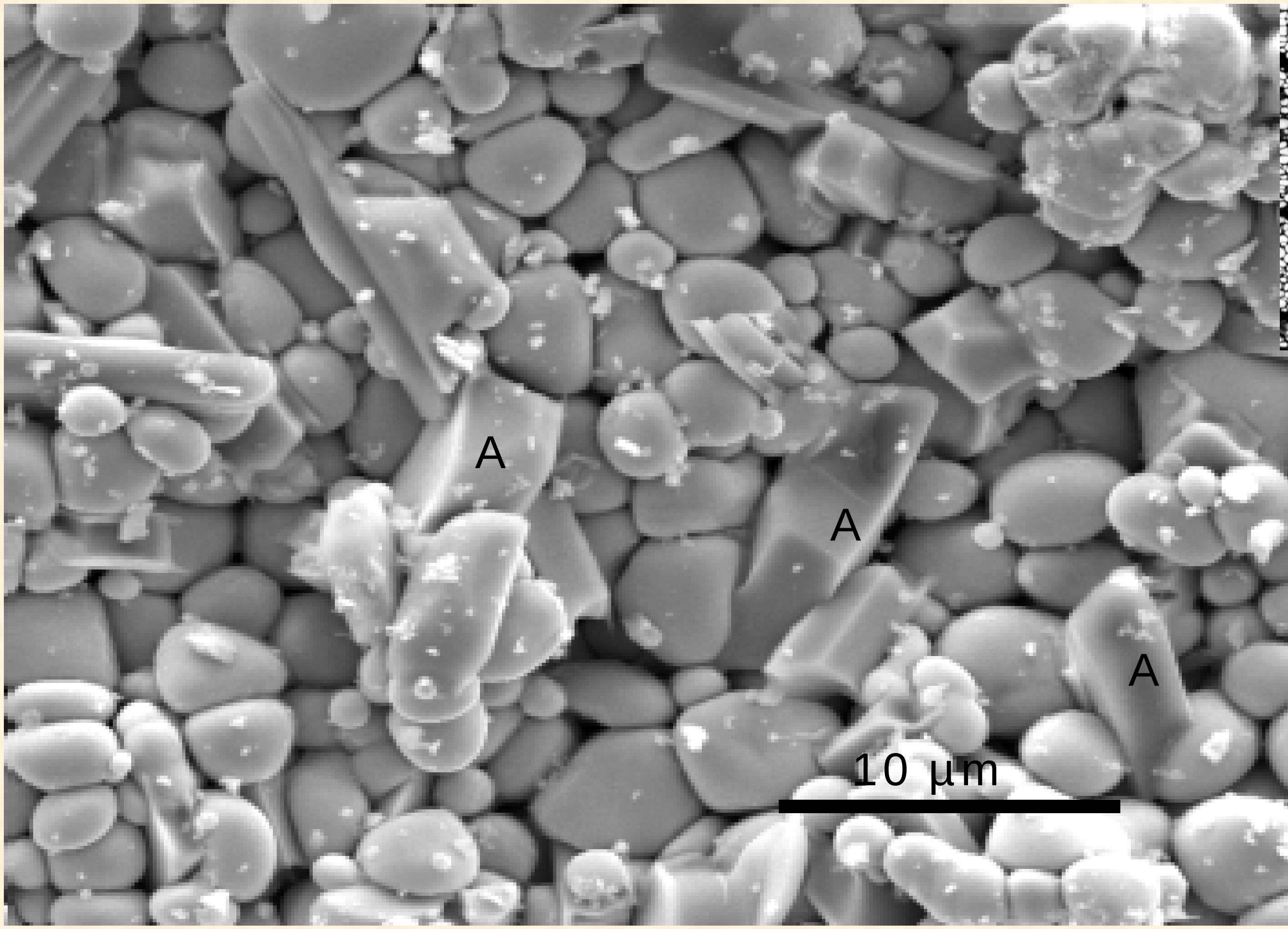


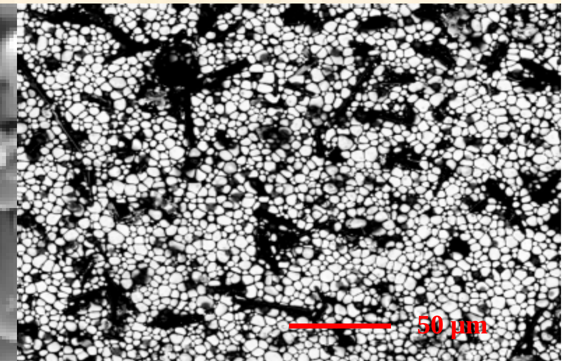
Detail of the surface (secondary electrons)

Particle A contains Al **Particle B contains Ti and some Mg**

Area C contains DUO_2 particles surrounded by dark basalt

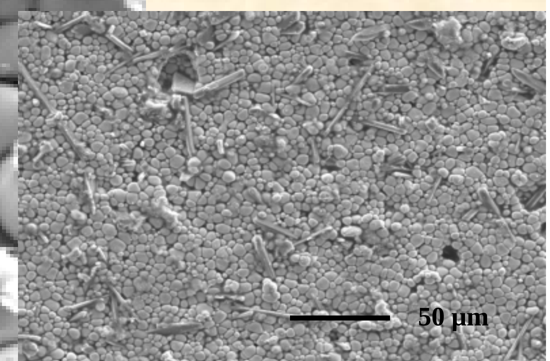
DUAGG After 6 Months in DI Water





Backscattered electrons

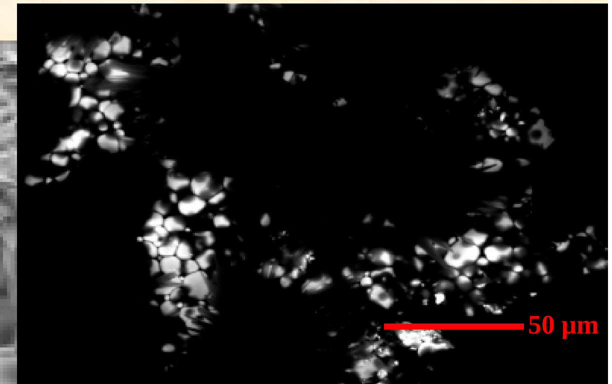
Secondary electrons



150°C — secondary electrons

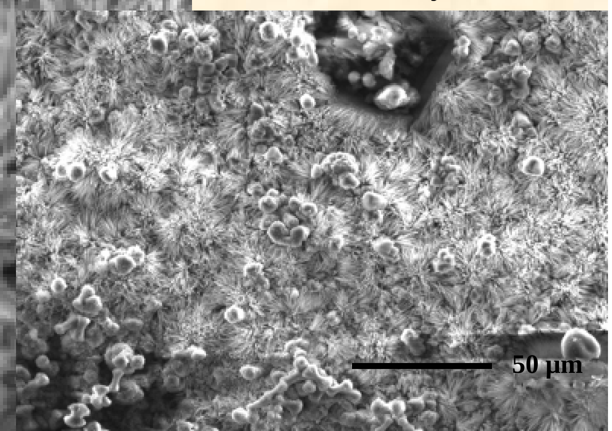
Particles A contain Ti and some Mg

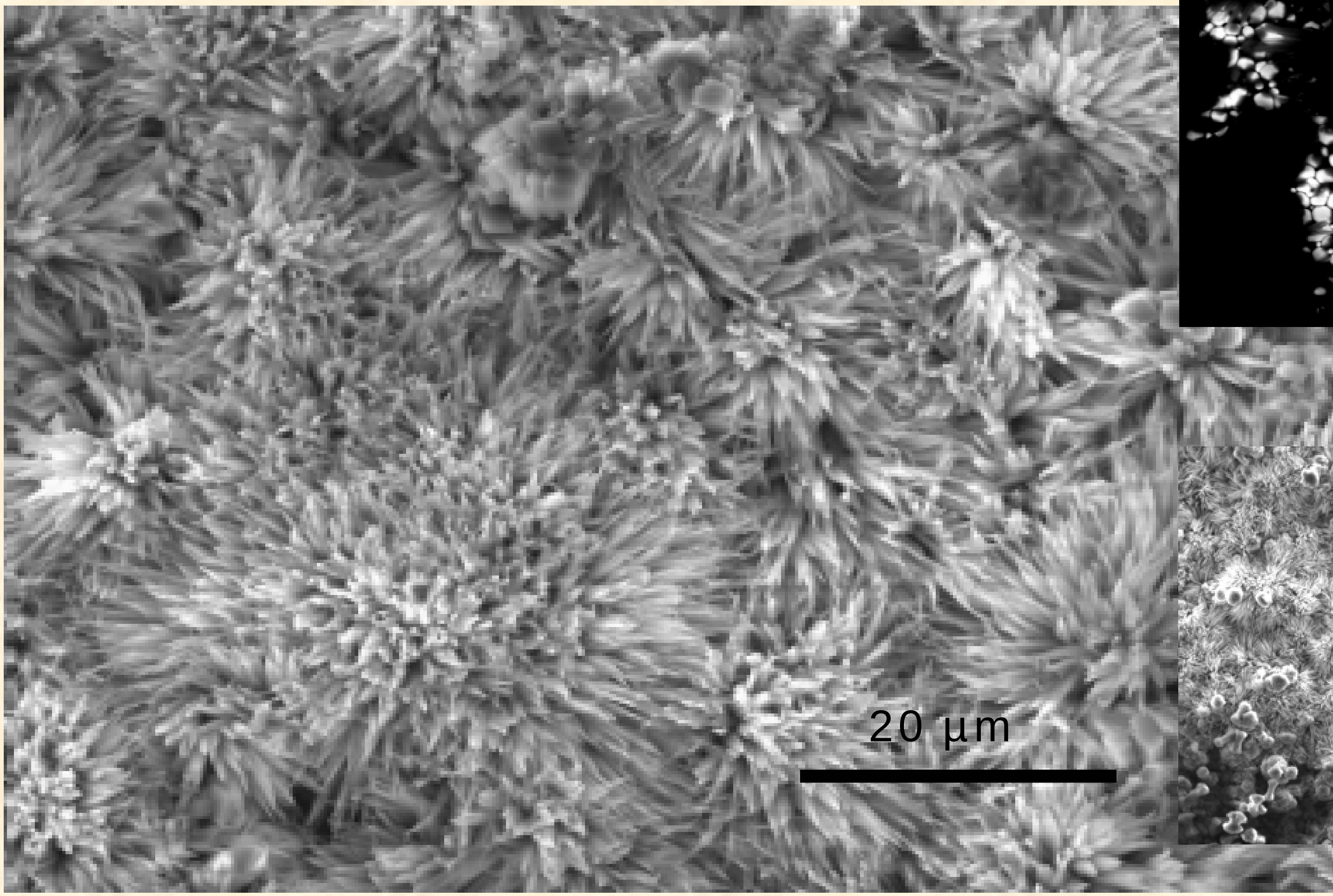
DUAGG After 6 Months in Cement Pore Solution



67°C—Backscattered electrons

67°C — secondary electrons





67°C — secondary electrons

Covered by $CaCO_3$ and needle-like crystals containing Ca, Si, and some Al

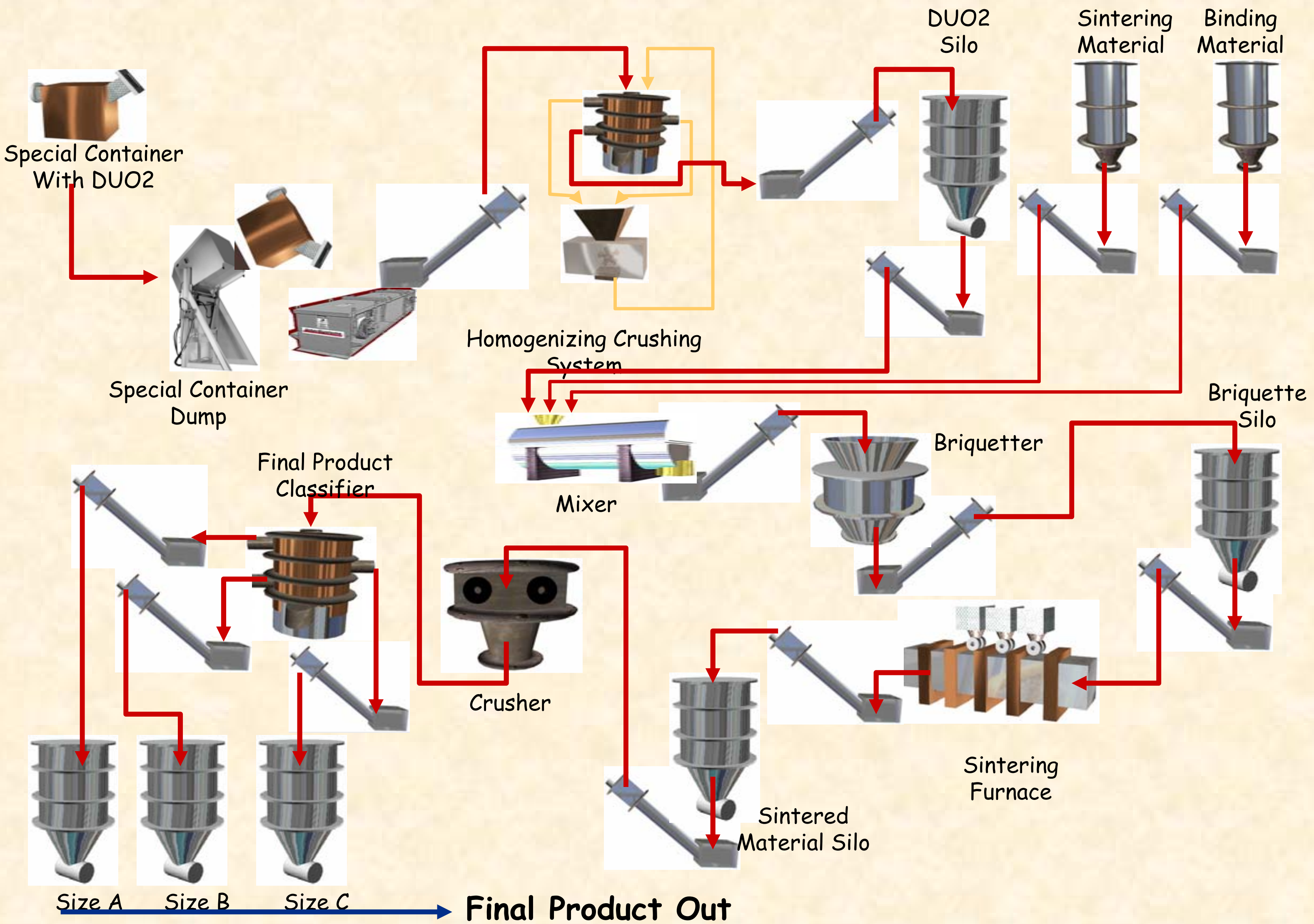
Conclusions on DUAGG Testing

- After >24 months of exposure, the release rate of uranium in a cement pore solution is low and shows that DUAGG is superior to pure UO_2
- A protective layer of recrystallization products from the basalt phase of DUAGG cover the surface, slowing the release of uranium
- In the cement pore solution, after >24 months of exposure, no deleterious products from the alkali-aggregate reaction were seen

Conclusions on DUAGG Testing (continued)

- **Results show that DUAGG can be expected to be stable under the casks' service conditions**
- **We are continuing laboratory experiments to characterize DUAGG/DUCRETE materials and their behavior in SNF cask applications**
- **We are pursuing a collaboration with the Russians to design and demonstrate the next generation of SNF transport and storage casks**

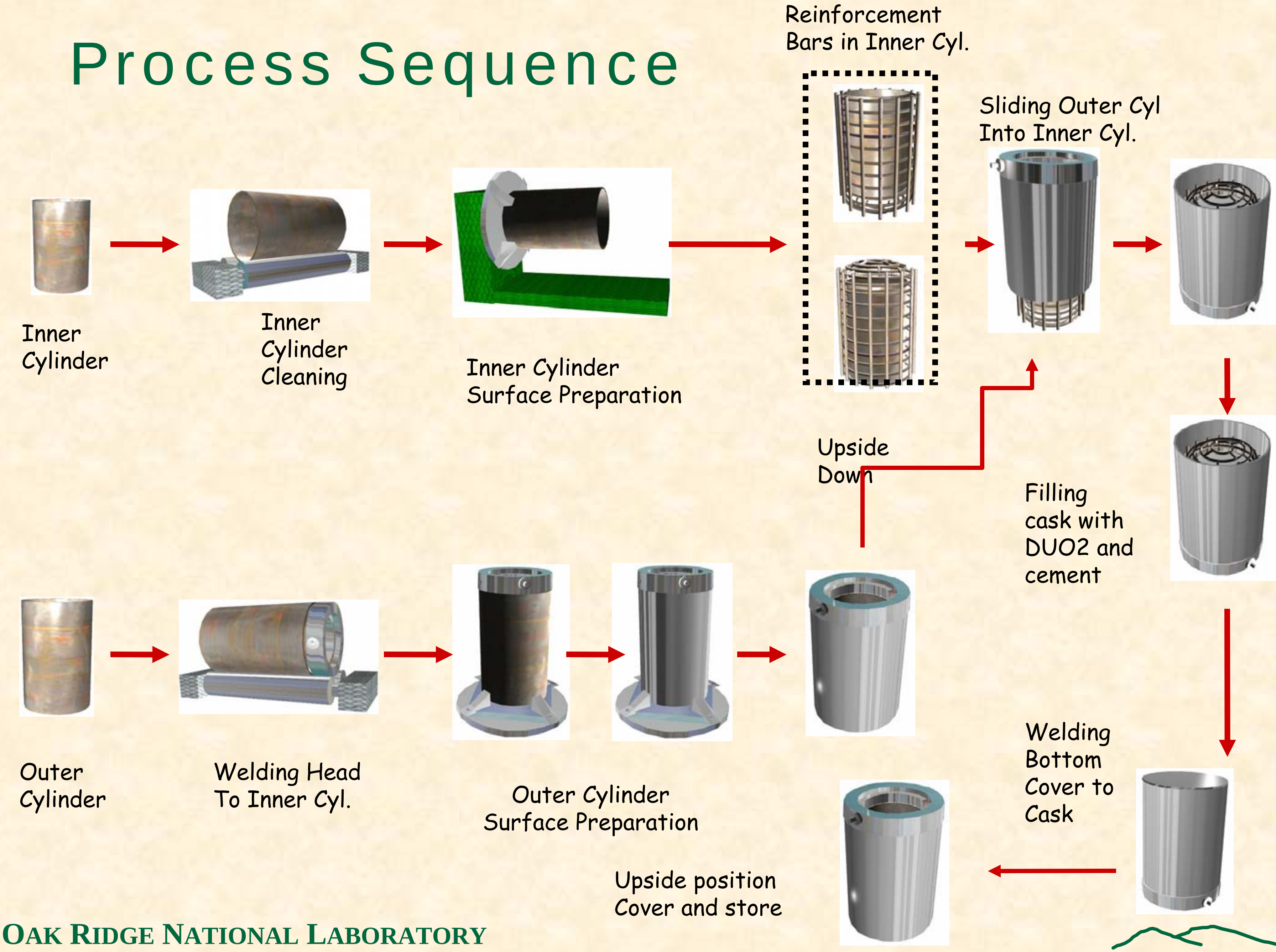
Conceptual Fabrication of DUAGG



Conclusions of DUAGG Price Study

- **Labor is primary cost**
  - **Reduce by privatization**
  - **Reduce by integrating with DUF6 conversion**
  - **Reduce labor intensive processing steps**
- **Cost of Producing DUAGG, $138,000 per cask (62 tons DUAGG per cask)**

Process Sequence

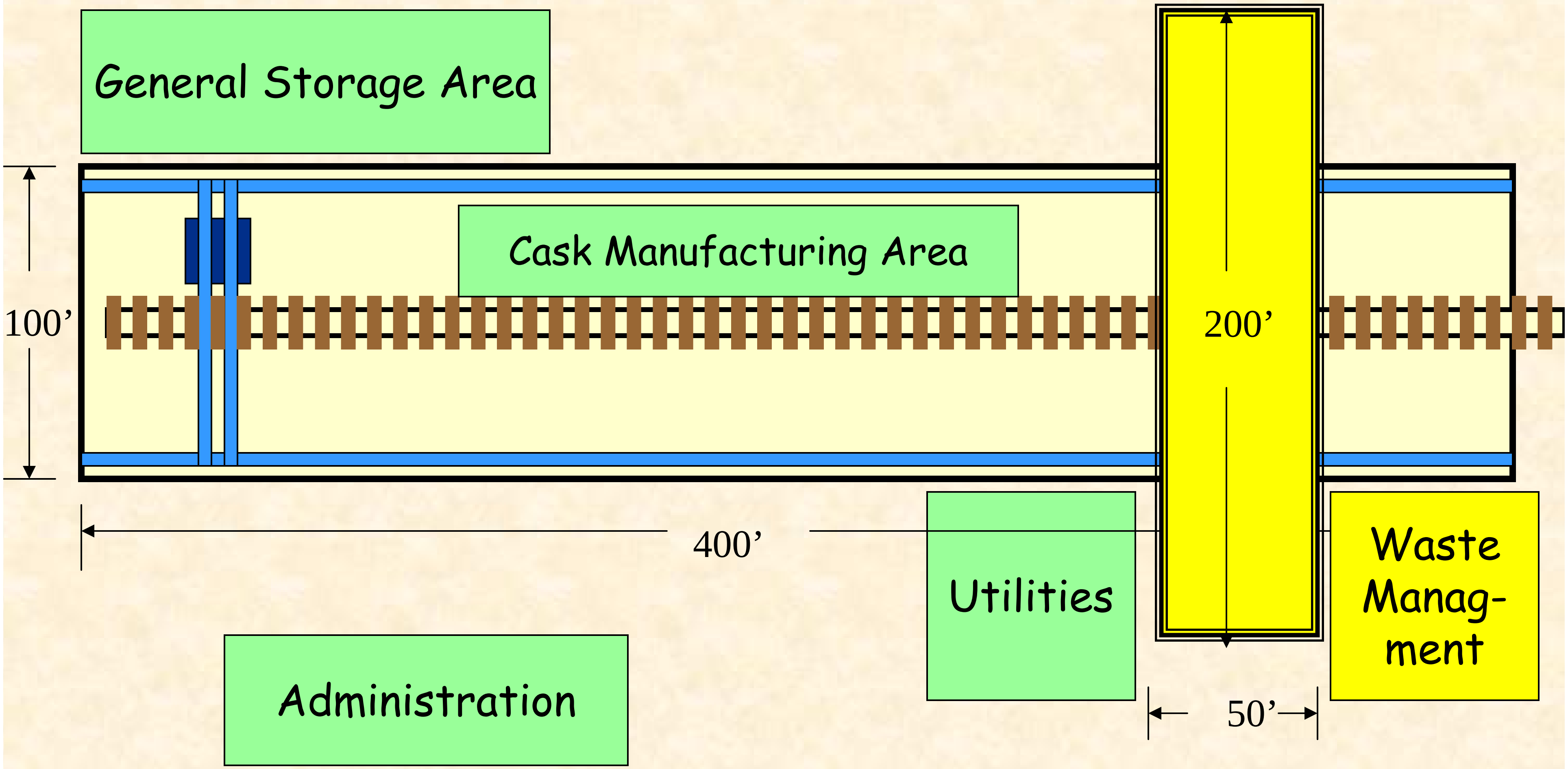


Some Fabrication Steps

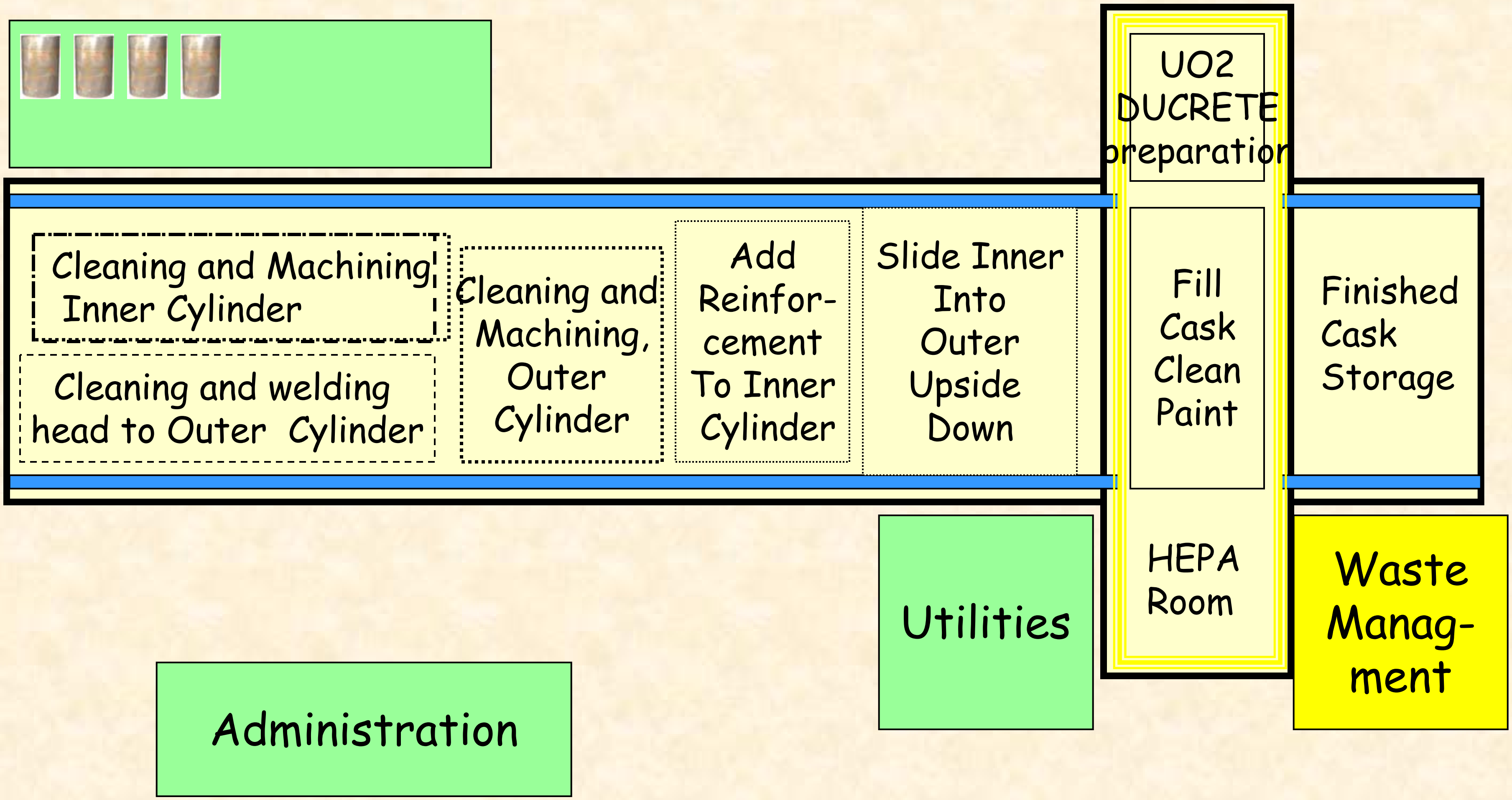
Assumptions

- Plant can manufacture 50 casks per year working one shift per day
- The manufacturing plant receives DUAGG, cement, and steel pre-fabricated parts to make the casks
- It takes three days (1 shift) to make a cask
- The plant will work 5 days a week

Surface Area Required



Process Stage Distribution



Capital Cost Components

- Civil/site preparation
- Utilities building services
- Process equipment
- Land and buildings
- Special process services
- Engineering
- Piping
- Electrical
- Spare parts
- Management
- Shipping
- Safety system
- Installation labor

Capital Cost

- Capital cost has been estimated for a plant capable of manufacturing 50 casks per year (in one 8-hr shift)

- The estimated capital cost for this plant is $17.1M

Operation Cost Calculation

- Labor
- Cement
- DUAGG
- Utilities
- Waste Management
- Administration
- Inner cylinders
- Outer cylinders
- Bottom covers
- Cask primary lid
- Cask secondary lid
- Paint

Labor Cost for the Baseline Case of 50 Casks Per Year

- Operators

  Labor cost for operators : $70/hr

  For production of 50 casks : 13 * 2080 hr/yr * $70/hr
  : $1,900K/yr

- Administration

  Secretary : 1*2080 hr/yr*$30/hr = $ 62.4K/yr

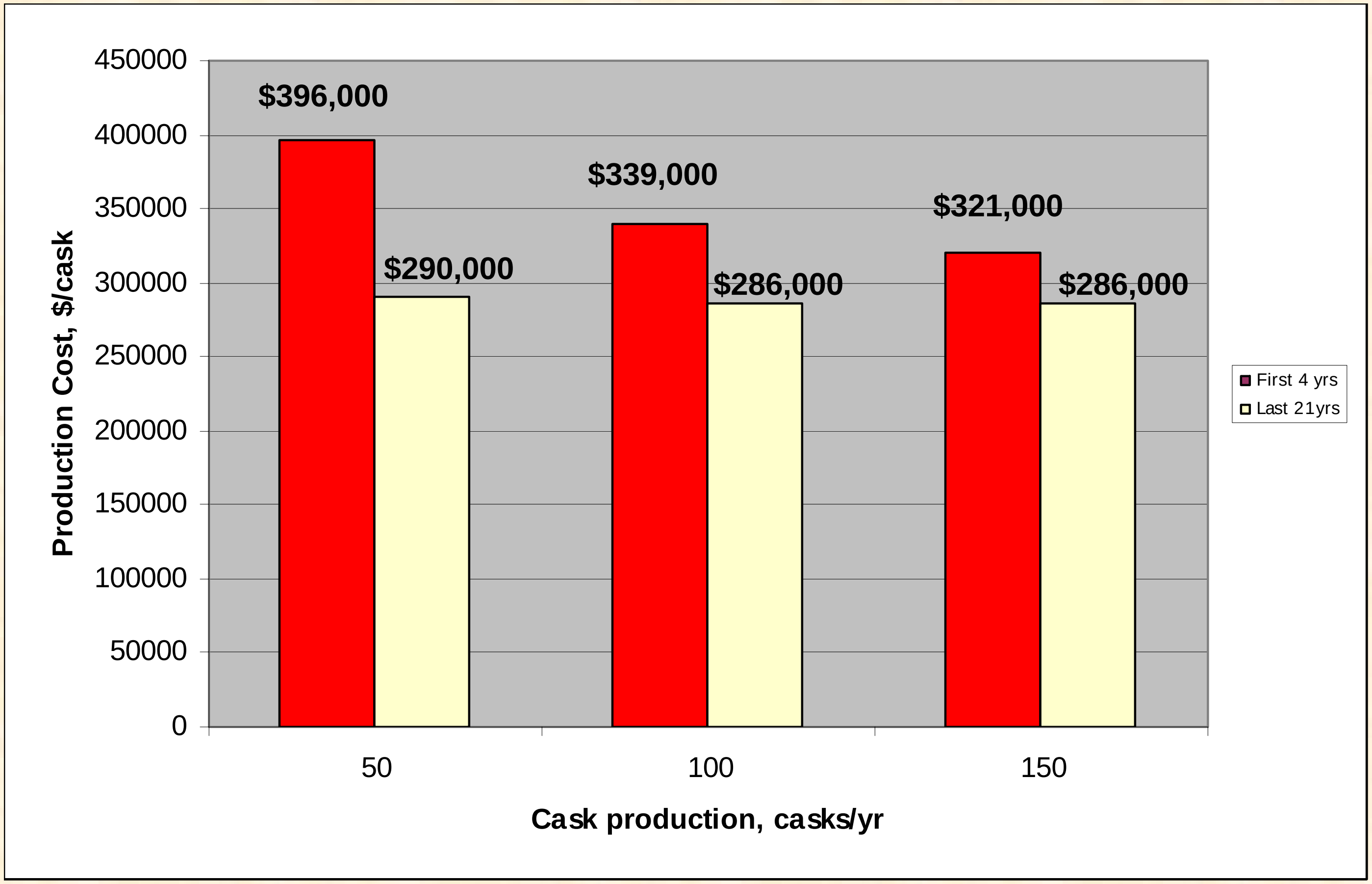
  Shift superintendent : 1*2080 hr/yr *$80/hr = $166.4K/yr

  General Manager : 1*2080 hr/yr*$90/hr = $187.2K/yr

Total Annual Labor Cost: $2,316K/yr

Production Cost per Storage/Transport Cask

Analysis was made for three cases:
50, 100, and 150 casks per year



Assumes:
Capital Recovery Factor: 25%