Radioactive Waste Management

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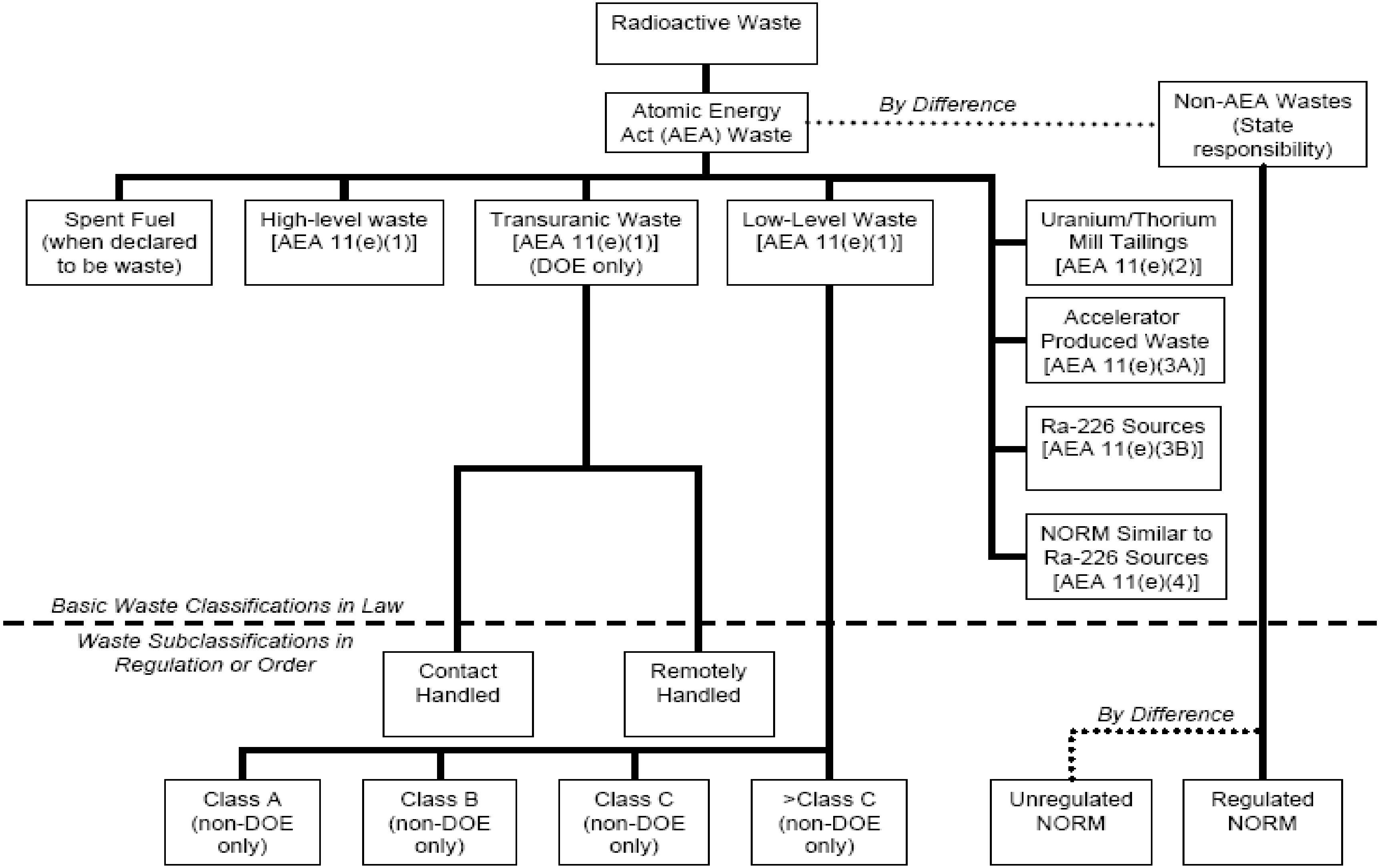
Outline

- Categorization of Waste
- Used (Spent) Nuclear Fuel
- High-Level Waste (HLW)
- Transuranic Waste (TRU)
- TRU & HLW [?] Disposal
- Low-Level Waste (LLW)
- Regulation

Categorization of Waste

U.S. Waste Classification



Definition of HLW (NWPA)

HLW is:

- highly radioactive material from fuel reprocessing, including:
  - liquid waste produced directly in reprocessing, and
  - any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and

- other highly radioactive material that NRC, consistent with existing law, determines by rule requires permanent isolation (e.g., used nuclear fuel)

Definition of TRU Waste (WIPPLWA)

- Transuranic waste is waste that contains more than 4 kBq/g of alpha-emitting transuranic isotopes, with half-lives greater than 20y, except for:
    - High-level radioactive waste
    - Waste that the Secretary of Energy has determined, with the concurrence of the Administrator of EPA, does not need the degree of isolation required by the disposal regulations in 40 CFR 191; or
    - Waste that NRC has approved for disposal on a case-by-case basis (in accordance with 10 CFR 61)

Low-Level Waste (NWPA)

- LLW is defined as radioactive waste that:
  - Is not high-level waste, spent fuel, transuranic waste, or byproduct material as defined in Section 11(e)(2) of the Atomic Energy Act; and
  - NRC, consistent with existing law, classifies as low-level radioactive waste

Definition of Byproduct Material

- Section 11(e) of the AEA
- The term "byproduct material" means–
  - any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;
  - the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content;
  - Certain other specific man-made and naturally-occurring materials defined--as of 8/8/05
- We won’t discuss further

Categorization Thoughts

- HLW/LLW seems simple, but…
  - Defined based on ‘source’ of material (instead of radioactivity, i.e., hazard)
  - Now also by a date (8/8/05)
  - And, often, on a case-by-case regulatory decision (e.g., there are a number of categories of LLW)
- IAEA scheme is different
  - Based on specific radioactivity (activity per gram)
  - Low level (LLW)
  - Intermediate level (ILW)
    - Sometimes combined – i.e., LILW
    - Further broken down:
      - Short-lived activity (<30 years)
      - Long-lived activity
  - High-level
- Perceived by some to be less arbitrary than U.S. system (i.e., hazard-based)

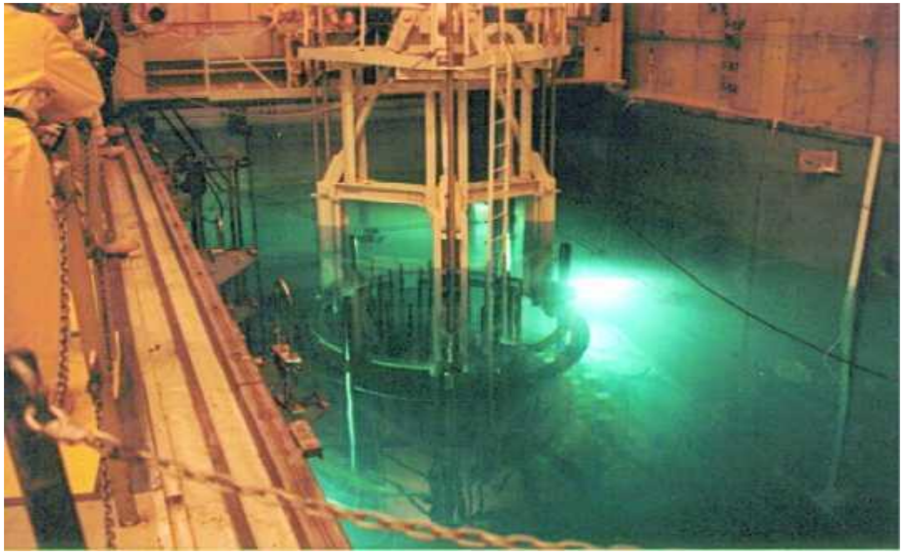
Used (Spent) Nuclear Fuel

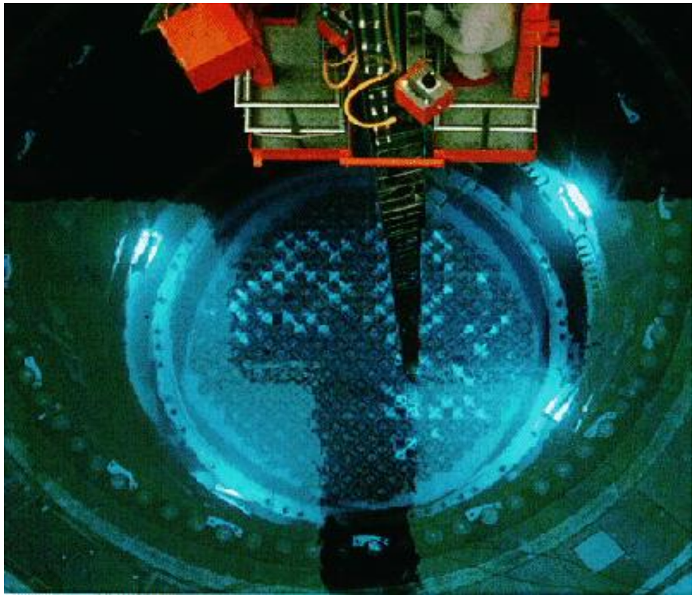
PWR Refueling-1

- Shutdown reactor
- Establish high concentrations of boron
- Let it cool and depressurize
- Remove head bolts
- Remove pressure vessel head and rods

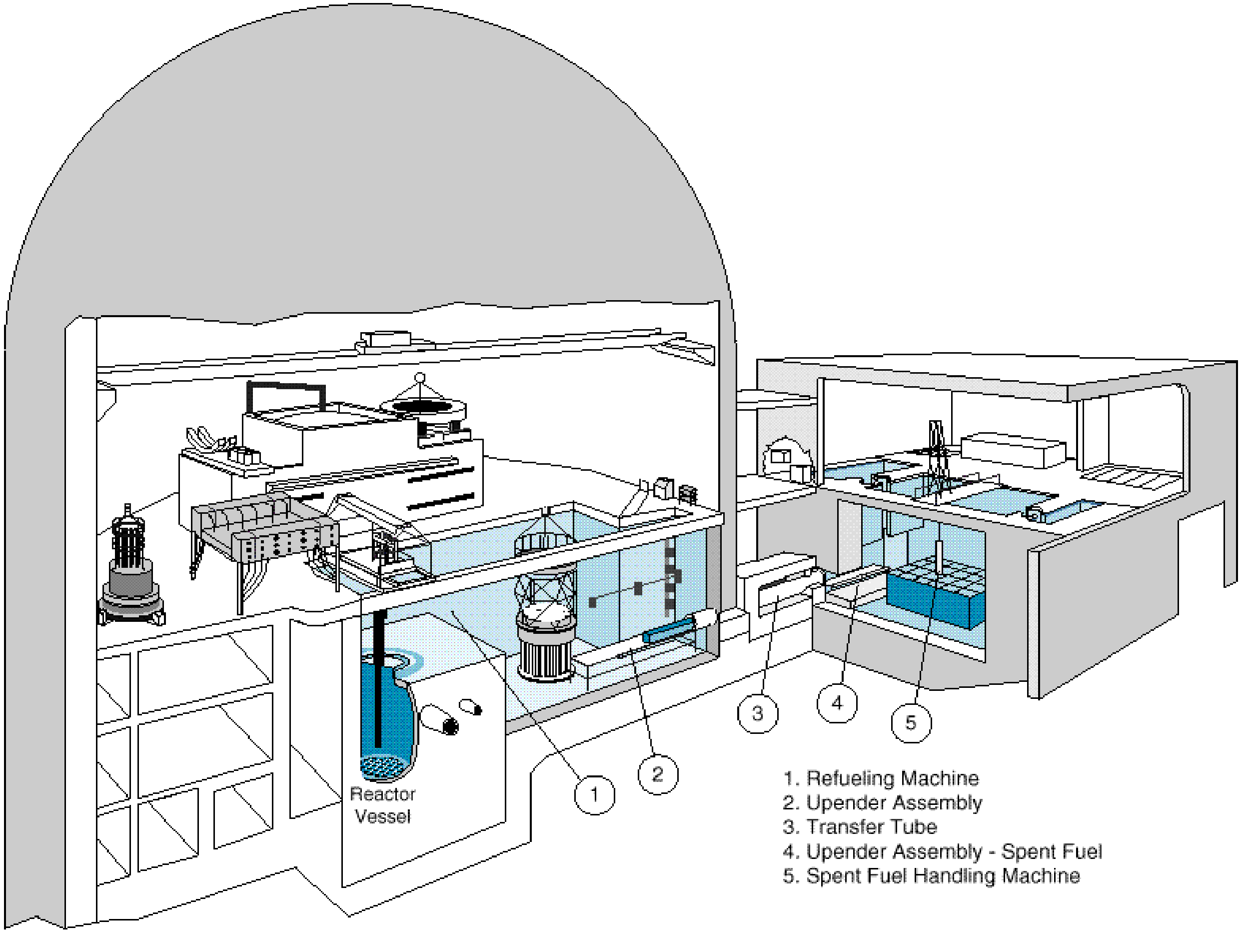
PWR Refueling [2]

- Remove the upper internals from the reactor
- Flood the refueling pool
- Begin removing spent fuel and inserting fresh fuel
- A wide spectrum of maintenance on the entire reactor system is done while refueling is ongoing





PWR Refueling-3



1. Refueling Machine
2. Upender Assembly
3. Transfer Tube
4. Upender Assembly - Spent Fuel
5. Spent Fuel Handling Machine

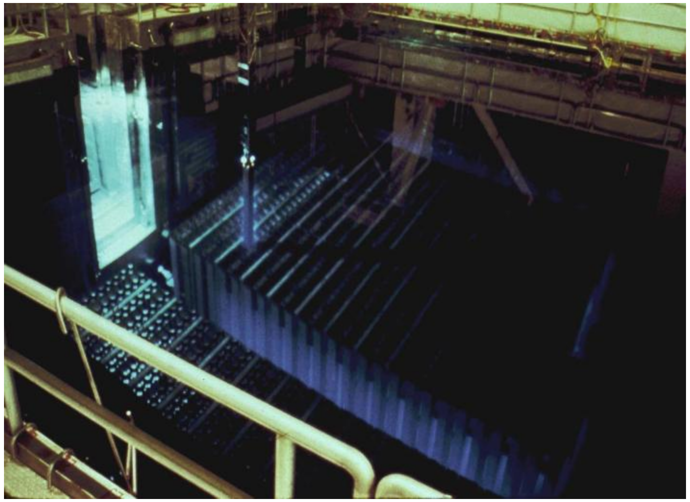
- After refueling the reactor is reassembled by reversing the previous sequence
- Average refueling outage is 38 to 42 days
- After initial load 20% to 33% of the core is replaced during each refueling outage

Interim Storage Concepts

- Reactors regularly discharge irradiated fuel
  - Spent nuclear fuel (SNF); AKA used nuclear fuel (UNF)
  - About 2000 MTHM/yr in the US
- The fuel generates considerable decay heat and may have criticality potential
- Interim storage is the next destination
  - Critically safe storage to reduce decay heat
  - Await disposition

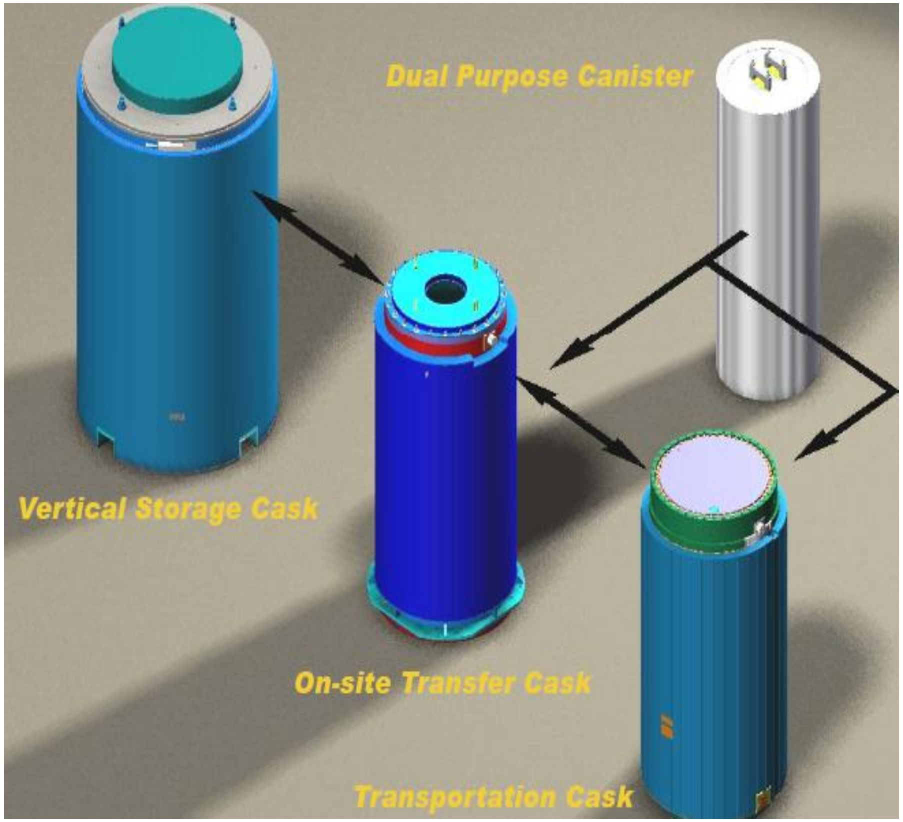
Interim Storage Concepts [2]

- Two types of interim storage
  - Water pool at reactor sites
    - For most recently discharged fuel
    - Have to maintain space for full core discharge
    - Ensure criticality control
      - Boron: dissolved, plates, or both
    - Can be an accident risk if pool is breached and drains
      - Breach caused by seismic activity or terrorism
      - Worst case scenario: dry out, overheating, Zr fire
  - Dry storage
    - Mostly at reactor sites, 2 configurations
    - Worst case hard to conceive (RPG and radionuclide dispersal??)
    - Key features passive (natural convection) cooling; stainless steel containers; concrete for most of shielding

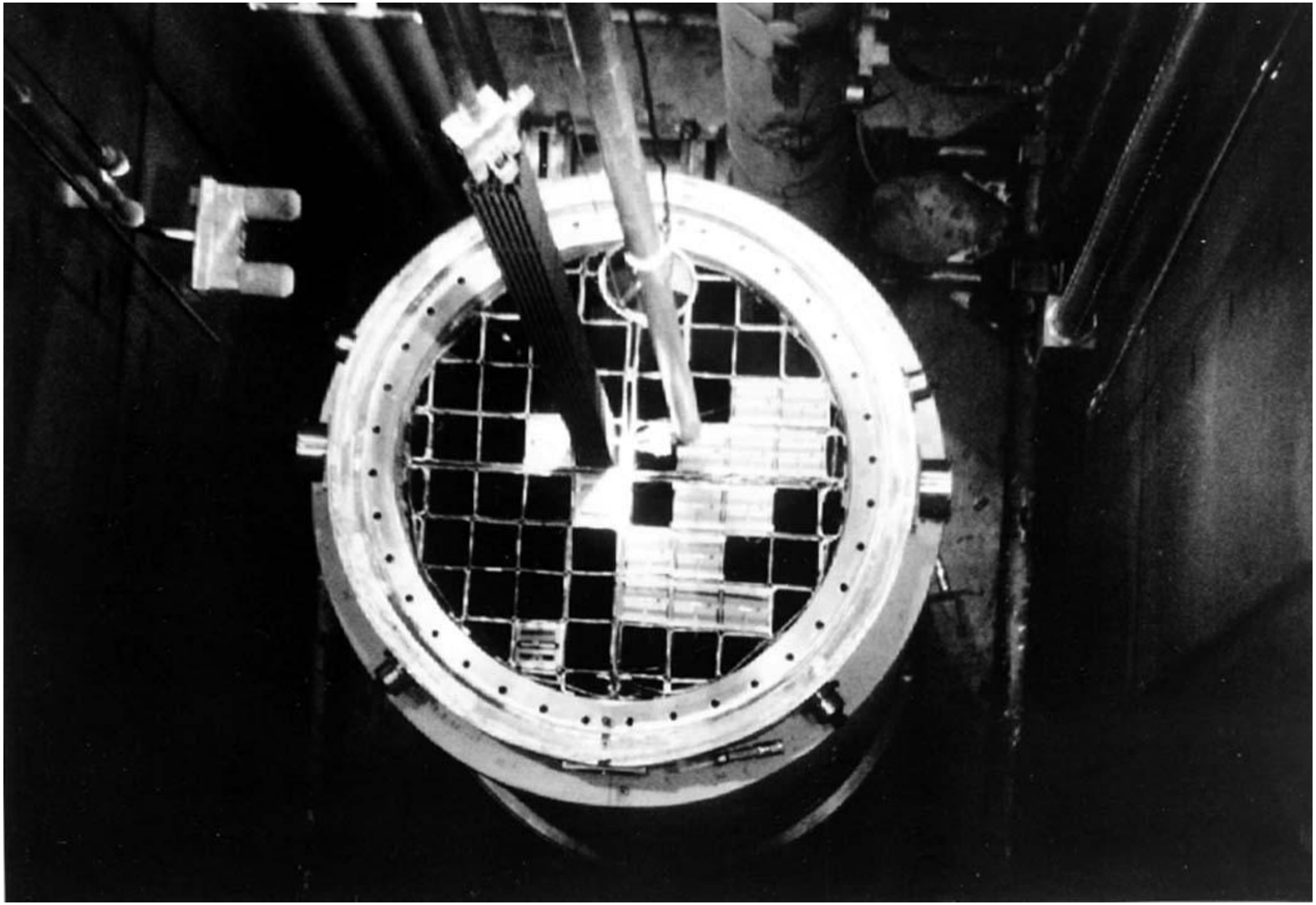


Multi-Purpose Casks?

- Concrete shielding contains a canister containing SNF
  - PWR: 21 to 37 assemblies
  - BWR: 44 to 87 assemblies
  - Generally load to the max; crane limits
- Multipurpose canister
  - Single: storage only
  - Dual: storage and transportation
  - Triple: storage, transportation, and disposal (unlikely)

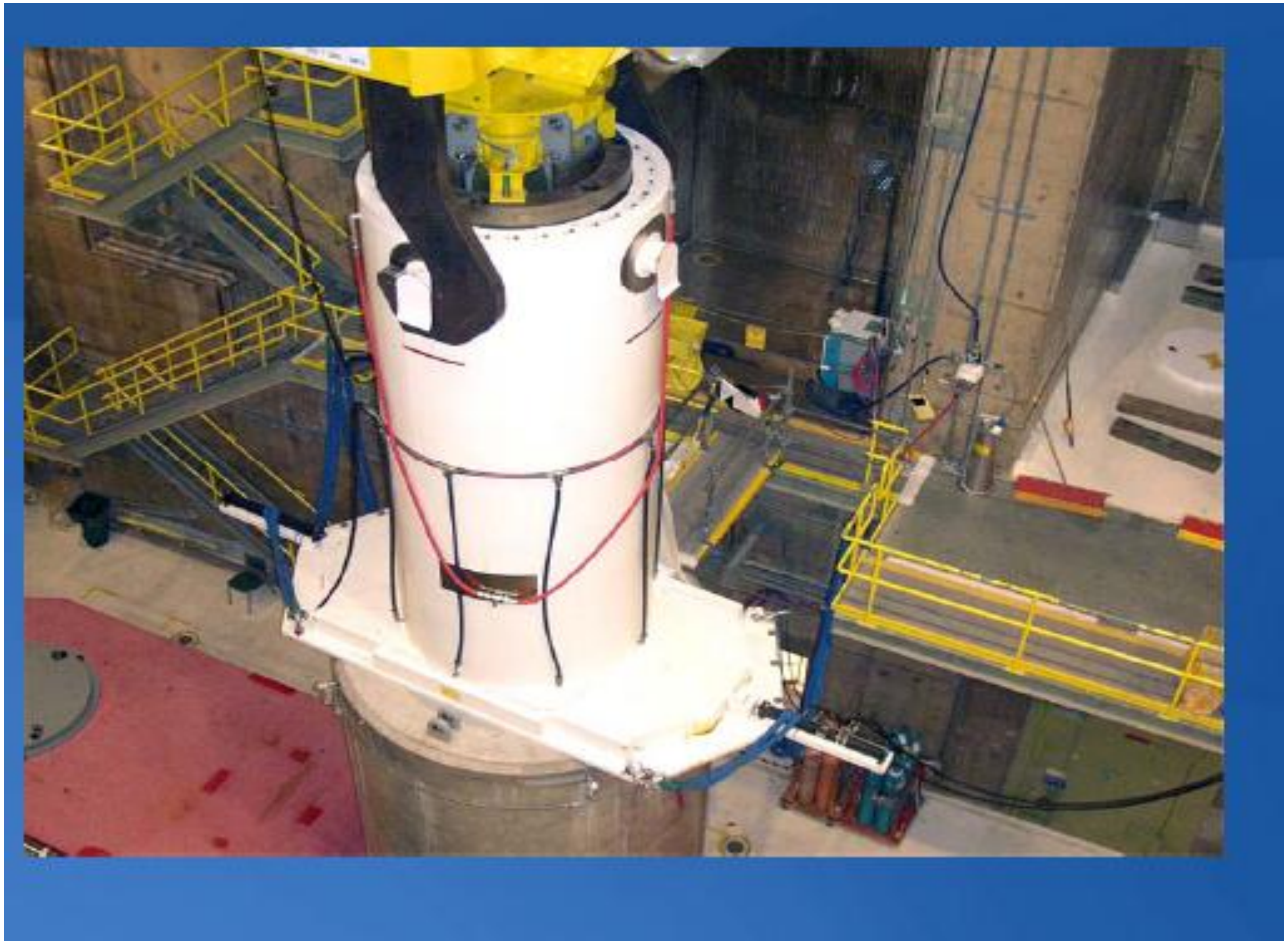


Spent Fuel Storage Cask Loading

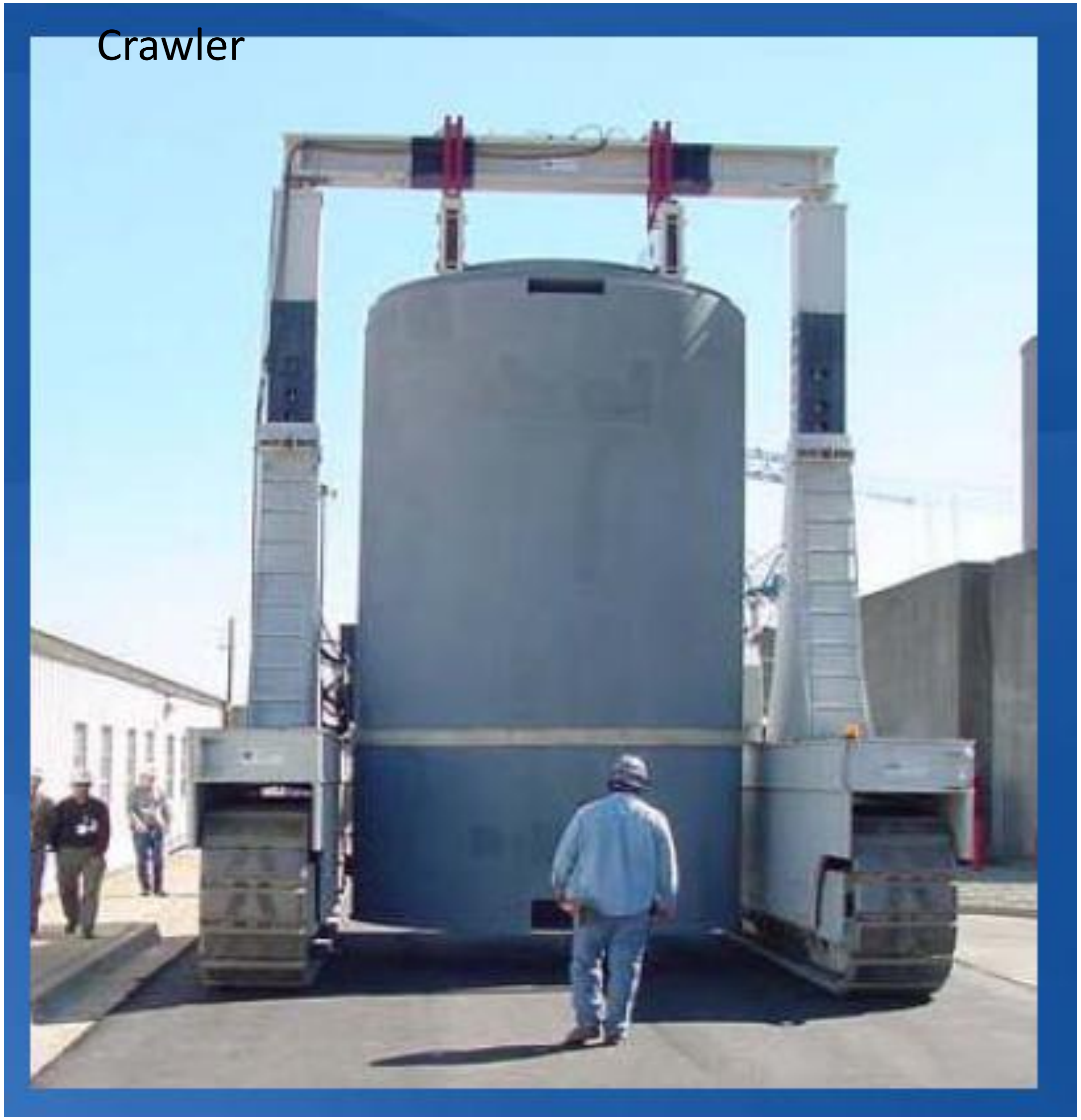


Performed Underwater

Transfer Cask Atop Storage Cask



Moving Vertical Storage Cask



Crawler

Aligning Cask with Storage Bay

Interim State

- Security: Double fences, razor wire, video, drive-by
- Monitoring
  - Temperatures in and out: vents are screened but critters will get in
  - Concrete durability
- Issues
  - Ongoing maintenance & security
  - “Orphan” sites
    - SNF in storage but reactor is gone
    - Several of these; local community issue
  - How long can dry storage keep fuel safe and ready to be retrieved, transported, and dispositoned?

High-Level Waste

High-Level Waste – Introductory Thoughts

Single-shell tanks under construction in 1944 at Hanford

Consistency and chemistry of tank contents varies greatly

Fluidized Bed Steam Reforming Treatment at Savannah River

- Storage: Tanks capacity is limited, and have exceeded their design life.
- Retrieval: Retrieval and monitoring operations are costly, inefficient, and limited by complicated tank design and previous leakage.
- Waste Pretreatment: Low- and high-level wastes must be effectively separated, which requires better understanding of contents chemistry.
- Waste Disposition: Waste is non-homogenous, requiring different processing:
- Tank Closure: Empty tanks filled with grout to stabilize contents and structure

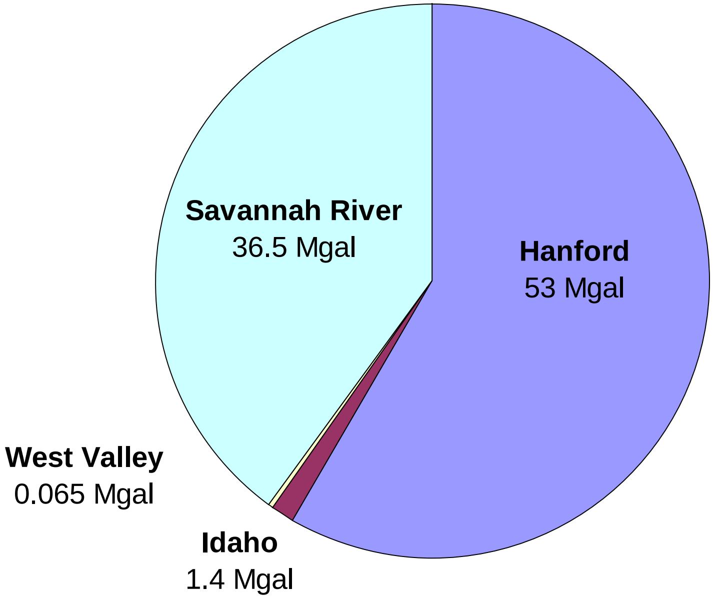
HLW Waste Management Overview

- Waste storage
  - HLW is highly radioactive and generates considerable heat
  - Typically stored in large, cooled underground tanks until short-lived radionuclides have decayed to innocuous levels
- Waste treatment
  - Converted to a form stable during transport and disposal
    - HLW typically is converted to glass
  - Other liquid wastes are immobilized with cement; solids are drummed
- Waste disposal
  - HLW, cladding, TRU wastes: deep beneath the surface in a geologic repository
  - Other wastes: typically in surface trenches

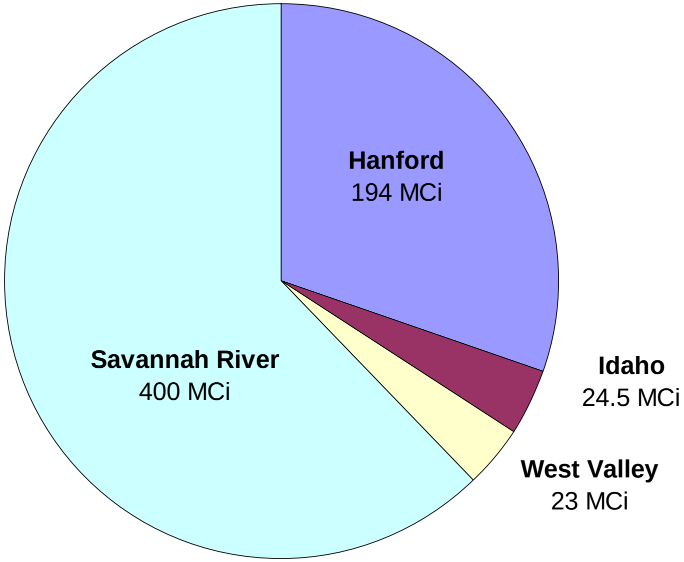
- The DOE-EM Waste Complex
  - Why discuss EM?
  - Site-specific reviews:
    - Waste origin
    - Processing plan
    - Waste disposition
    - Issues
  - For:
    - West Valley
    - Idaho
    - Savannah River
    - Hanford

Some HLW Basics

- High Level Waste (HLW) is derived from first cycle fuel reprocessing
  - Dissolved fuel assemblies
  - Radionuclides of interest recovered
  - Cladding and fission products stored in tanks
- Ultimate disposal of this waste must be in a Federal Repository



Volume



Radioactivity

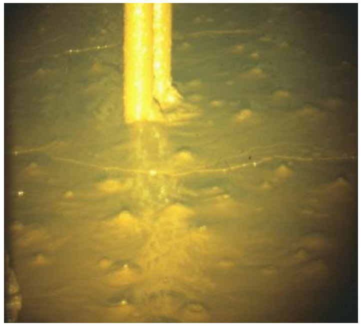
Some HLW Basics [2]

- HLW is typically stored on an interim basis in heavily shielded below grade tanks
- Most of the tanks are >30 years old and some are 60 years old
  - Many are carbon steel
  - Some are in or near the groundwater table
  - Some have no secondary containment
- The U.S. is not planning to reprocess additional used nuclear fuel (with one possible exception—Al clad fuel at Savannah River)
- Hence the need to remove this waste, treat it, place it in a stable waste from and dispose of it

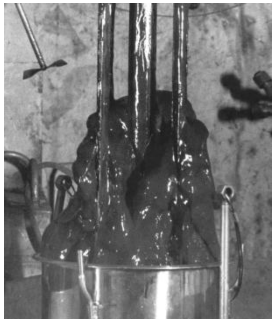
Site	Number of Tanks
Hanford	**177**
Savannah River	**51**
Idaho	**15/44***
West Valley	**4**

* Idaho also has 44 bins in 6 binsets

HLW: Stored in Several Different Forms



Sludge in the tank
Oxides and hydroxides of various cladding metals and most fission products

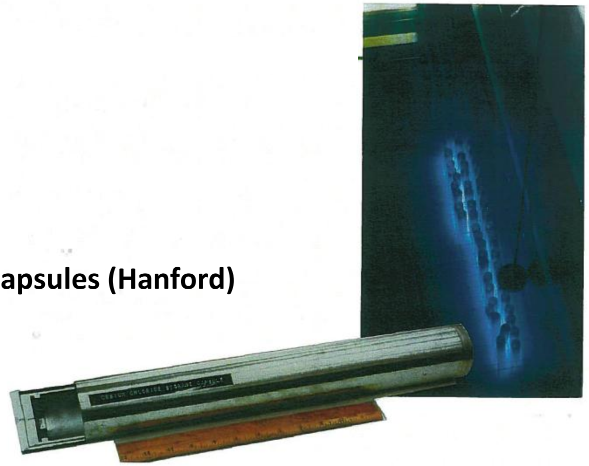


Sludge in the lab

Saltcake in the tank
Na salts (OH, NO_2, NO_3)

Supernate in the tank
NaOH liquor and most Cs-137

Calcine (Idaho)



Cs/Sr Capsules (Hanford)

“Other” HLW Hazards

- Criticality
  - In waste there is some moderator (e.g., water) and some remaining fissile materials
  - Preferred approach is to prevent criticality by design
    - Size and shape tanks and pipes so criticality cannot occur, or
    - Remove sufficient fissile materials to make criticality a remote possibility
  - Proof positive not always possible
    - Process monitored to measure fissile material concentrations
    - Administrative controls to avoid reactions that could concentrate fissile materials
  - There have been a number of criticality incidents in reprocessing plants, but none in waste applications; main causes:
    - Operators circumventing procedures
    - Leaks that let fissile material solutions get into a geometry that is not critically safe
- Chemical explosions and fires
  - Hydrogen
    - Hydrogen is produced by radiolysis: alpha, gamma
    - It can collect in pockets and, when oxygen is present, ignite and explode
    - Design to monitor, dilute and vent before it is a problem
  - “Red oil”
    - Degradation product of TBP from radiation/acid/heat
    - Large explosion in Russia believed to be from red oil
    - Keep solvent temperature below 130 C

West Valley (near Buffalo, NY)

Site History

- Demonstration Project
- Waste derived from reprocessing spent reactor fuel 1966 - 1972
  - 640 MT reprocessed
  - Solvent extraction to recover U and Pu
  - Generated 660 kgal HLW
- Stored in 4 tanks
  - 2 carbon steel 750 kgal tanks
  - 2 stainless steel 15 kgal tanks
  - ~23,000,000 Ci

West Valley (cont.)

Waste Processing

- This part of the site mission is virtually complete
- Cs-137 removed from dissolved salt and supernate via ion exchange with zeolite resin
  - Decontaminated salt solution mixed with grout in 19,877 drums (71 gal each) that were disposed at Nevada Test Site
- Sludge and zeolite vitrified similar to Savannah River
  - 275 canisters stored at West Valley awaiting Federal Repository
- Remaining issues associated with:
  - Closing the empty tanks
  - Decommissioning process buildings
  - Managing sub-surface contamination

Stored Canisters

Idaho National Laboratory (Idaho Falls, ID)

- Original site mission was Reactor Test Station
  - 52 different reactors
  - All but one decommissioned
- HLW generated and stored as a liquid
  - Acidic system
  - Stainless steel tanks
- Most was later calcined
  - Stored in binsets
- Remaining waste is called Na Bearing Waste
  - Stored in tanks
  - Tank closure in progress

Tanks being Grouted

Idaho (cont.)

- Calcine Waste
  - 8-9 Mgal of liquid waste was treated via a fluidized bed calcination process
  - Produced ~4,400 M^3 (1.17 Mgal) of dry calcine
  - Stored in 6 underground concrete-shielded binsets with 44 individual bins
- Treatment options under evaluation:
  - Direct dispose (need RCRA exemption)
  - Hot Isostatic Pressing (reduces volume, monolithic waste form)
  - Fluidized Bed Steam Reforming (via FBSR from Na Bearing Waste)
  - Direct Vitrification (expands volume, very stable waste form)

Binset Model

HIP Waste Form

Idaho (cont.)

- Na Bearing Waste
  - 900,000 gal
  - Maintained in acidic form
  - Primary rad is Cs-137
- 4 small tanks
  - 30 kgal
  - All emptied and closed
- 11 large tanks
  - 300 kgal stainless steel (acid waste)
  - 7 tanks closed, 4 tanks still in service
- Selected treatment is Fluidized Bed Steam Reforming (FBSR)
  - destroys Na salts and organics
  - produces harmless N, O and H_2O in the offgas and a solid carbonate product
    - Cs-137 remains with the solids
- Solid product will be stored until disposition is finalized

FBSR Test Facility

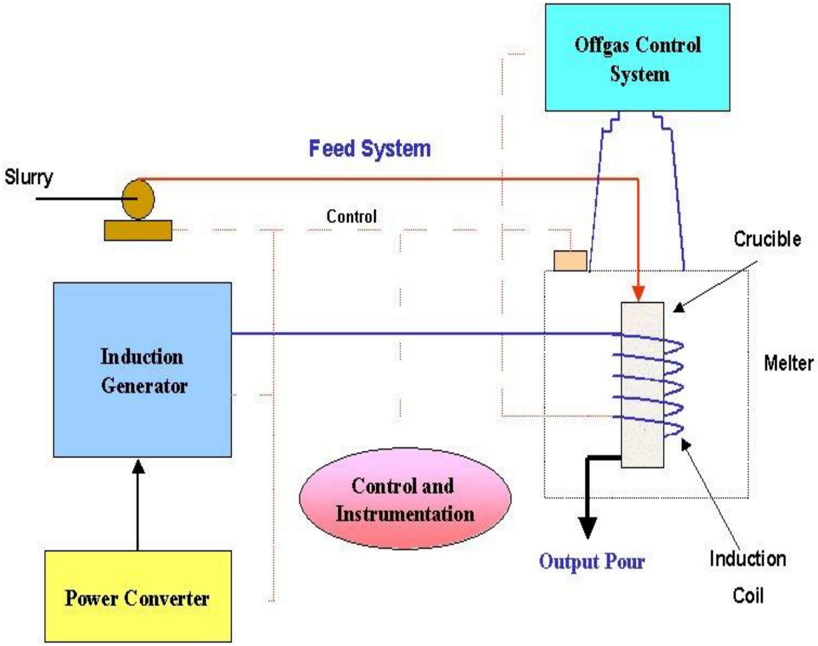
Idaho (cont.)

Issues:

- Na Bearing Waste
  - Disposal path for FBSR carbonate product not final
    - Originally intended to go to the national geological repository
    - With that project on hold, final disposition path in question
  - Must complete treatment by 12/31/2012 (regulatory milestone)
- Calcine Waste
  - Process selection
    - Hot isostatic pressing (HIP) in the EIS ROD
    - Cold Crucible Induction Melting (CCIM) also a possibility
    - Regulatory milestone to submit RCRA permit mod by 12/31/2012
  - Must be treated and ready to ship 12/31/2035

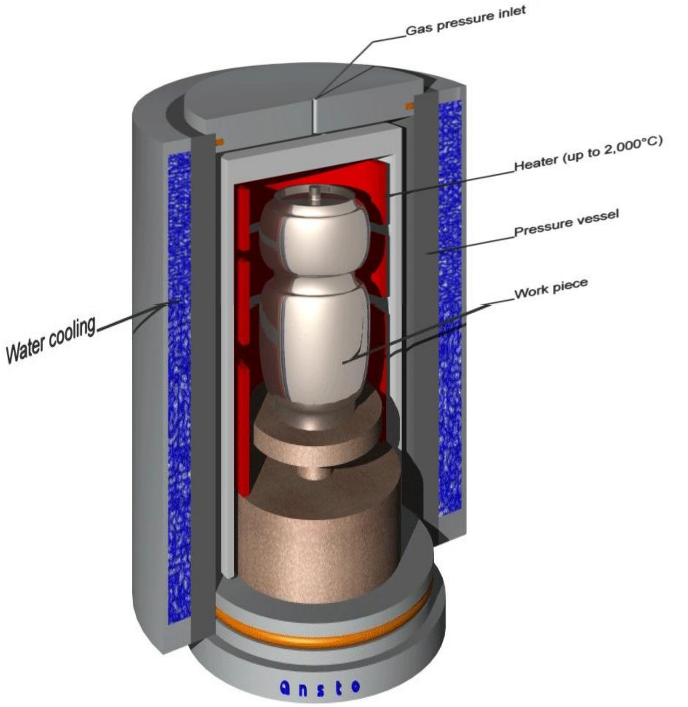
Idaho (cont.)

CCIM:



In commercial-scale operation: HLW at LaHague, France & LILW at Ulchin, South Korea

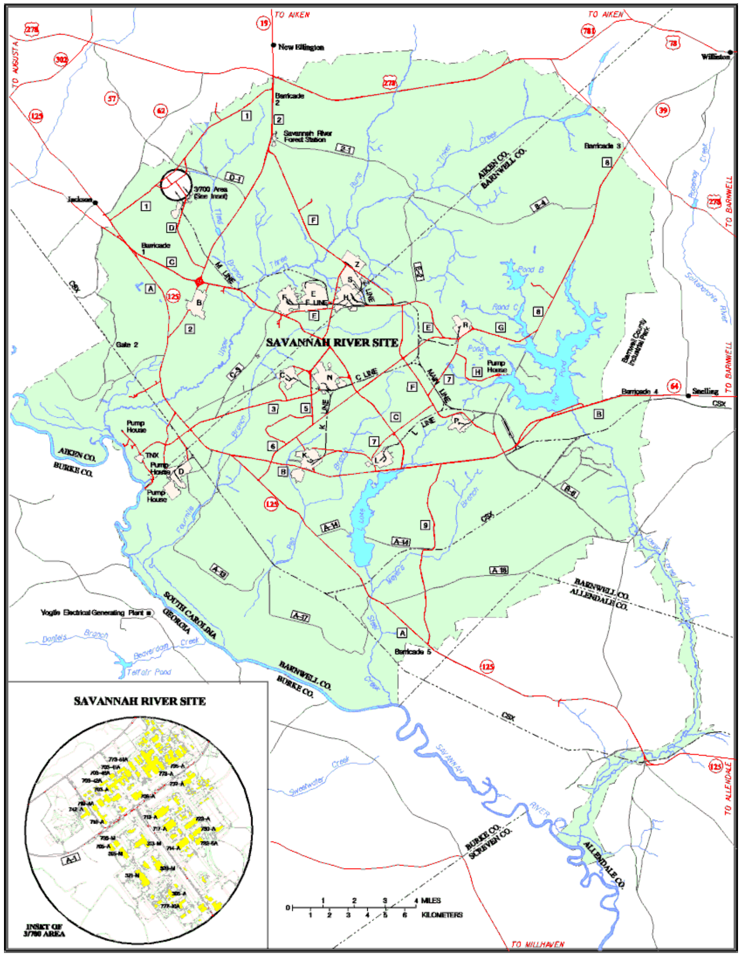
HIP: large commercial ops, one rad use



Savannah River Site (SRS)

Site History

- Site Construction begins Feb’51
- D-Area Heavy Water, operations begin Aug’52
- M-Area Fuel & Target fab, slugs produced Dec’52
- 100 Areas R-Reactor goes critical Dec’53
- 200 Areas Separations
  - F Canyon operations begin Nov’54
  - H Canyon operations begin Jul’55
- Tank Farms
  - F-Area Tanks 1-8 built 1951-1953, received first waste 1954
  - H-Area Tanks 9-12 built 1951-1953, received first waste 1955



SRS (cont.)

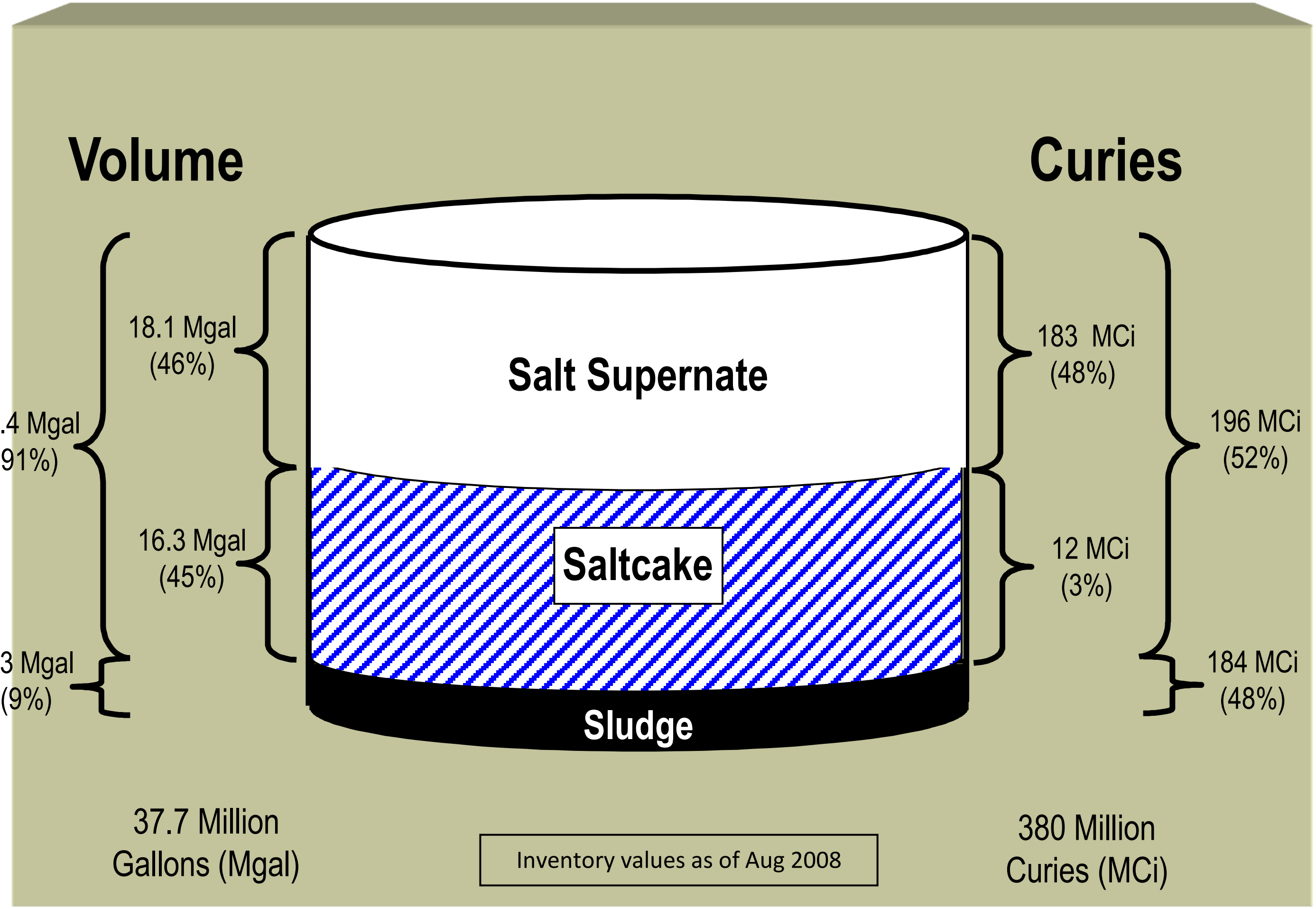
HLW originated from:

- Pu-239 recovery
  - Depleted uranium targets dissolved in nitric acid and processed through solvent extraction
- U-235 / Np-237 recovery
  - Uranium fuel dissolved in nitric acid and processed through solvent extraction
- Pu-238 recovery
  - Neptunium targets dissolved in nitric acid and processed through solvent extraction
- All 3 processes
  - Created an acidic waste that was evaporated and neutralized, and
  - generated significant fission products

SRS HLW Tank

SRS Tank Farm After Completion

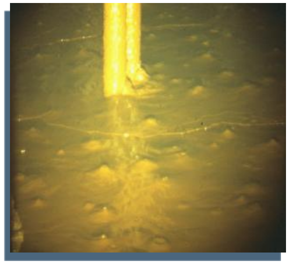
SRS HLW Tank Contents



Inventory values as of Aug 2008

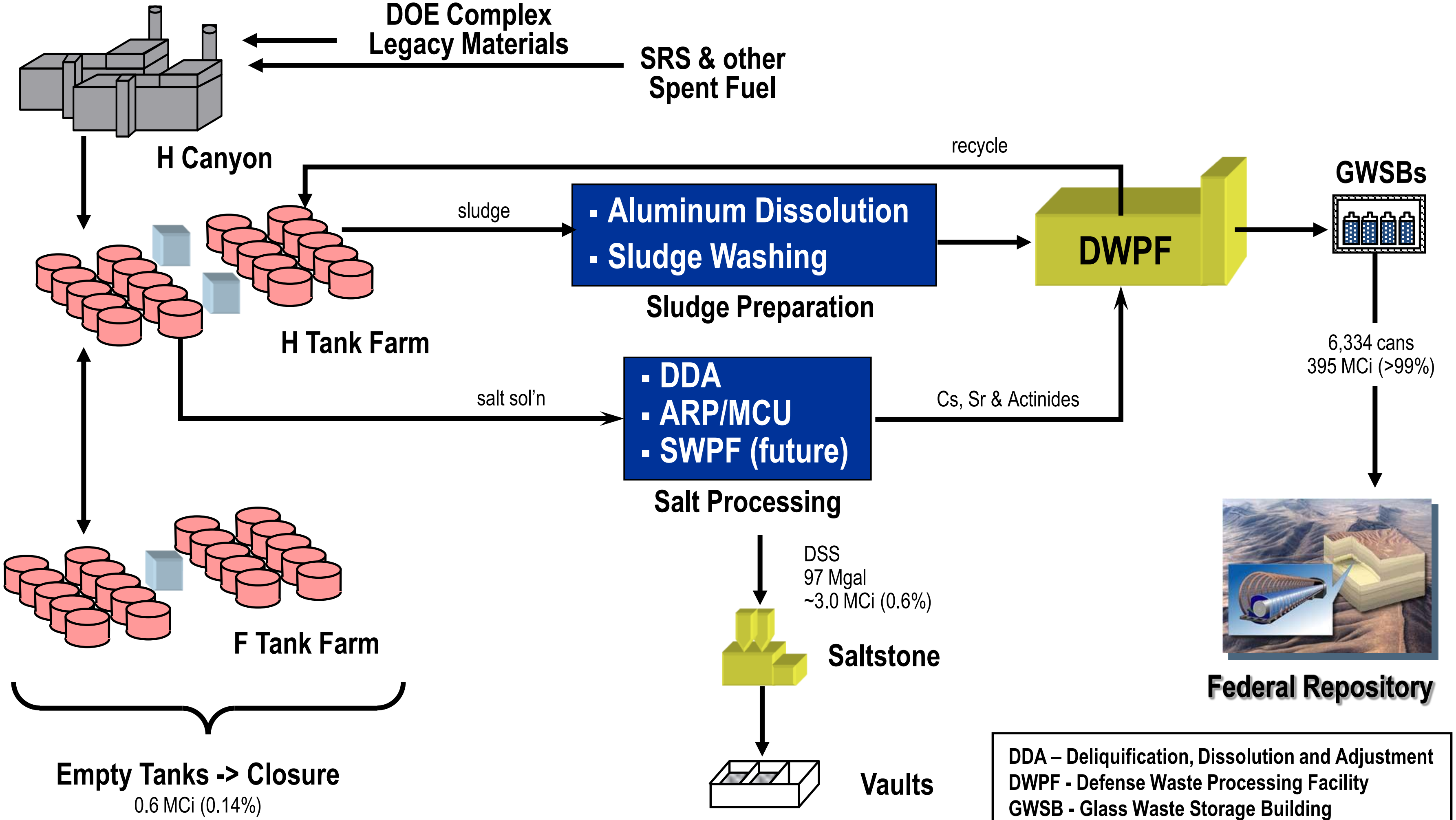
Salt Supernate

Saltcake



Sludge

SRS HLW Simplified Flowsheet



DOE Complex Legacy Materials

SRS & other Spent Fuel

H Canyon

recycle

sludge

- **Aluminum Dissolution**
- **Sludge Washing**

Sludge Preparation

DWPF

GWSBs

H Tank Farm

6,334 cans
395 MCi (>99%)

salt sol'n

- **DDA**
- **ARP/MCU**
- **SWPF (future)**

Cs, Sr & Actinides

Salt Processing

DSS
97 Mgal
~3.0 MCi (0.6%)

Saltstone

F Tank Farm

Federal Repository

Vaults

Empty Tanks -> Closure
0.6 MCi (0.14%)

DDA – Deliquification, Dissolution and Adjustment
DWPF - Defense Waste Processing Facility
GWSB - Glass Waste Storage Building
DSS – Decontaminated Salt Solution

SRS HLW Management

- ~120 Mgal HLW generated
- Volume reduced via evaporation to 36-37 Mgal
- Stored in 51 tanks
  - 2 closed (Tanks 17, 20)
  - 5 in closure process (Tanks 5,6,16,18,19)
  - 44 in active service
  - Underground
  - Heavily shielded
  - 43 of 51 have secondary containment

3H Evaporator

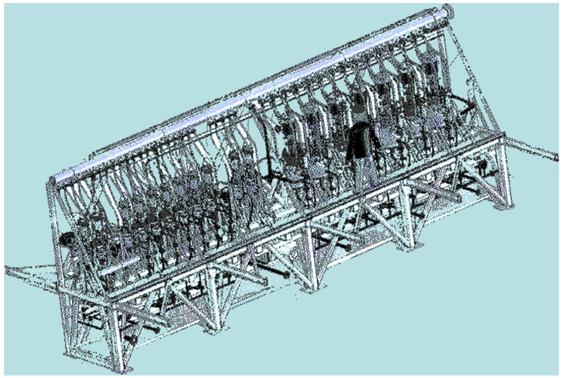
Tank under construction

SRS HLW Disposition

- Sludge - DWPF
  - –Pretreat to reduce Al and Na, then blend
  - –Treatment method is vitrification
  - –Waste form is borosilicate glass in a SS canister
  - –Disposition is in a Federal Repository
- Interim Salt Treatment– DDA
  - –Treat to reduce Cs-137 and actinides
  - –Low level fraction to grout, HLW fraction to glass
- Interim Salt Treatment – ARP/MCU
  - –Treatment methods:
    - adsorption/filtration to remove Sr-90 and actinides
    - Caustic Side Solvent Extraction to reduce Cs-137
  - –Low level fraction to grout
  - –HLW fraction to glass
- Long Term Salt – SWPF
  - –Same process as ARP/MCU
  - –3X throughput, 5X Cs-137 concentration in feed

DWPF

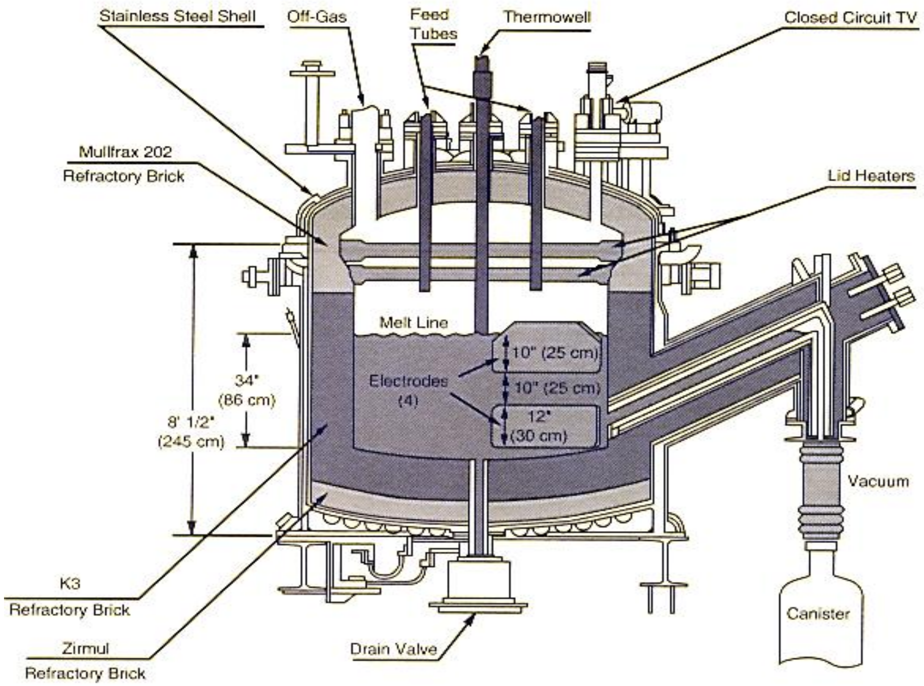
Canister

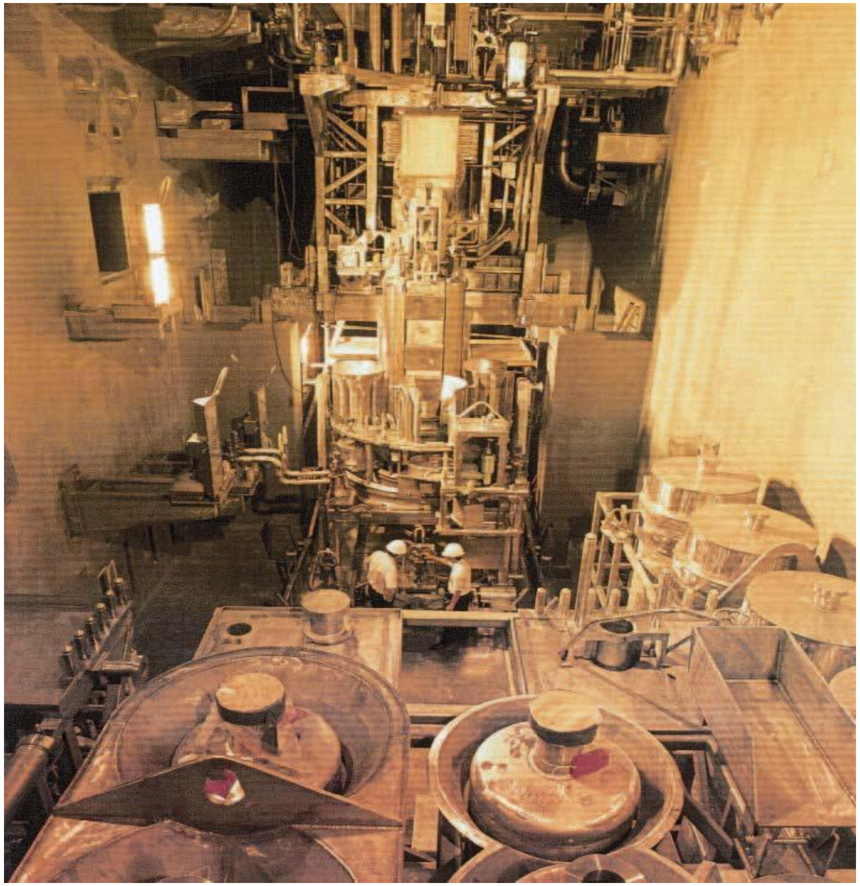


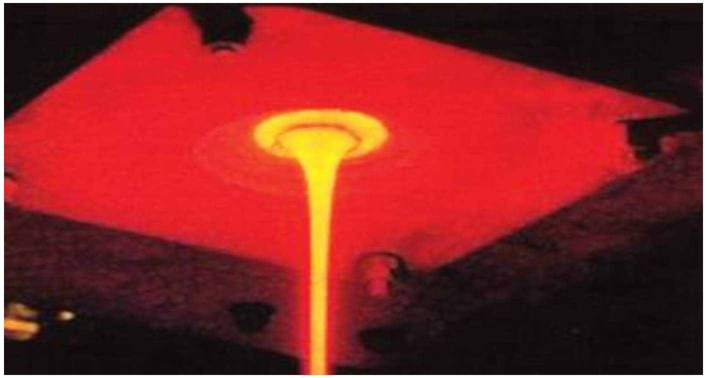
MCU Contactors

DWPF – Defense Waste Processing Facility
DDA - Deliquification, Dissolution and Adjustment
ARP – Actinide Removal Process
MCU – Modular Caustic Side Solvent Extraction
SWPF – Salt Waste Processing Facility

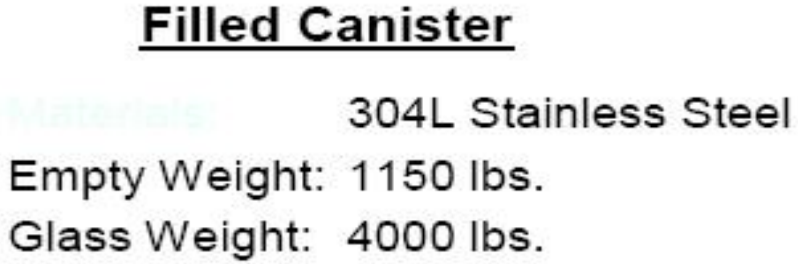
Defense Waste Processing Facility







Defense Waste Processing Facility



Filled Canister

Materials: 304L Stainless Steel
Empty Weight: 1150 lbs.
Glass Weight: 4000 lbs.

118 in tall x 24 in diameter

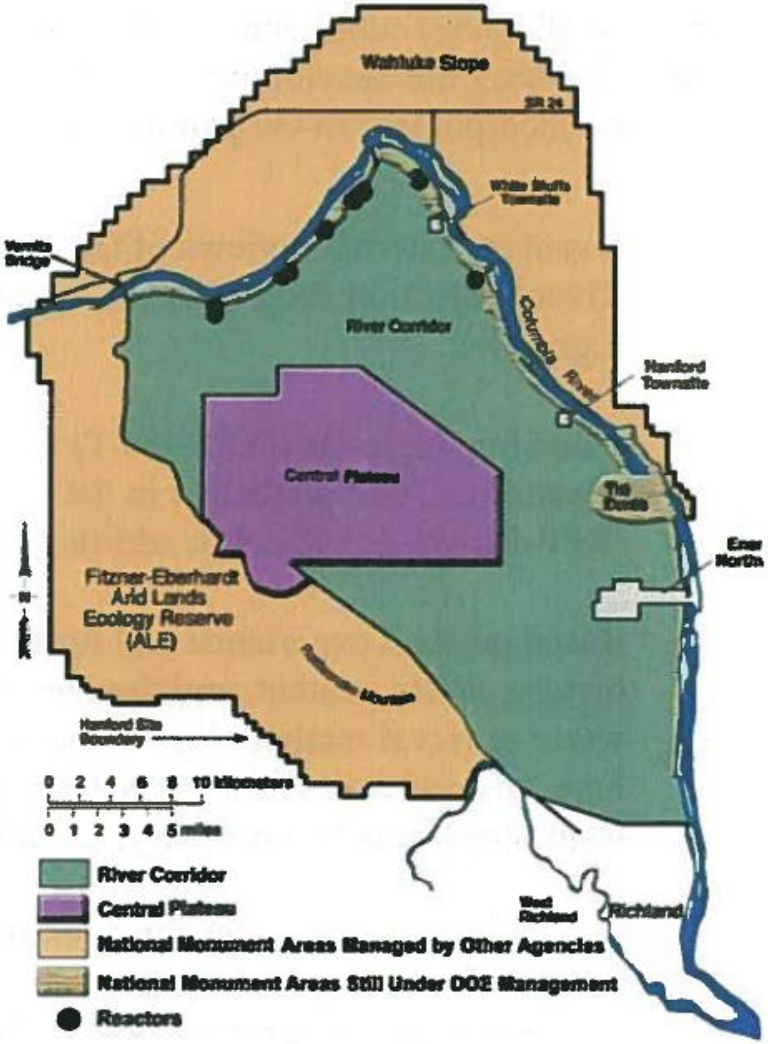
SRS HLW Challenges

- Flowsheet imbalance
  - All sludge can be vitrified before salt processing is complete
- Salt Processing schedule
  - Schedule uncertainty in this nearly first-of-a-kind facility
  - Delays increase the flowsheet mismatch
- Pu limit in glass
  - Limit in Yucca License Application reduces waste loading
  - Could extend life cycle
- Tank Closure
  - Uncertainty in Maximum Extent Practical evaluation

Hanford Site

<u>Site History</u>

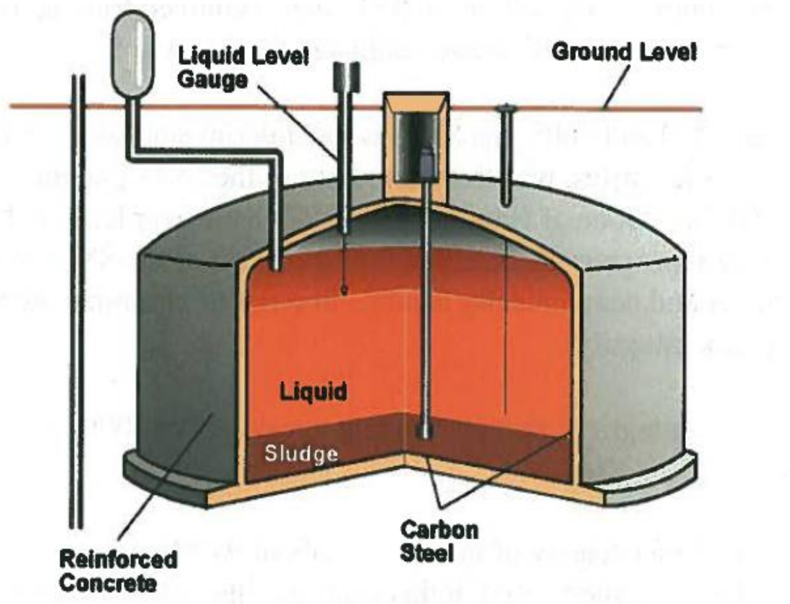
- Construction start 1943 as part of the Manhattan Project
- 9 reactors produced Pu and other rad materials mainly for national defense
- Irradiated fuel sent to 6 separations facilities from 1944-1989
- Special nuclear material recovered
- Waste neutralized and sent to tanks
- Significant fission product inventory in tanks
  - ~1/3 of original stored in a pool as capsules



Site Map

Hanford HLW Management

- Current ~57 Mgal and ~194 MCi
- Stored in 177 tanks
  - –all underground, shielded, carbon steel
  - –149 Single Shell Tanks built 1943-1964
    - 0.065 - 1 Mgal capacity
    - do not meet requirements
    - nearly all free liquids removed
    - focus of waste removal activities
  - –28 Double Shell Tanks built 1968-1986
    - 1 - 1.25 Mgal capacity
    - full secondary containment
    - meet current requirements
- Sludge, saltcake, salt supernate and capsules



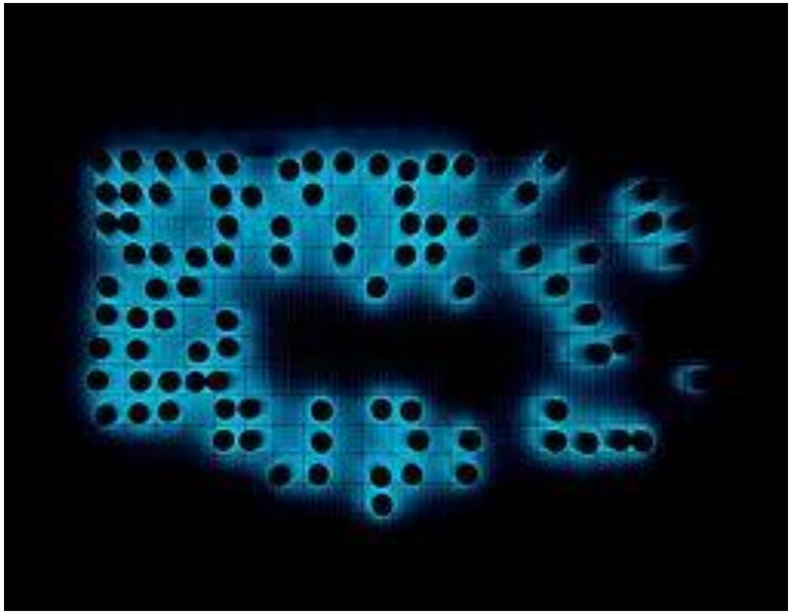
Single Shell Tank

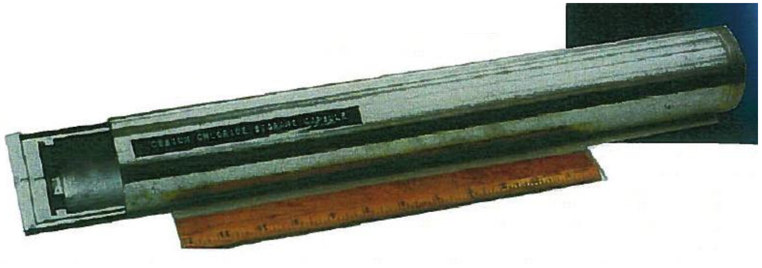
Hanford Tank Farm Under Construction

Hanford HLW Disposition

- Capsules produced from 1974-1985
  - 3” diameter, 21” long
  - double contained 316 SS
  - 130 MCi total
  - 1,335 Cs (as Cesium chloride)
  - 601 Sr (as Sr fluoride)
  - Produced as food irradiation sources
  - Plan to go to Federal Repository

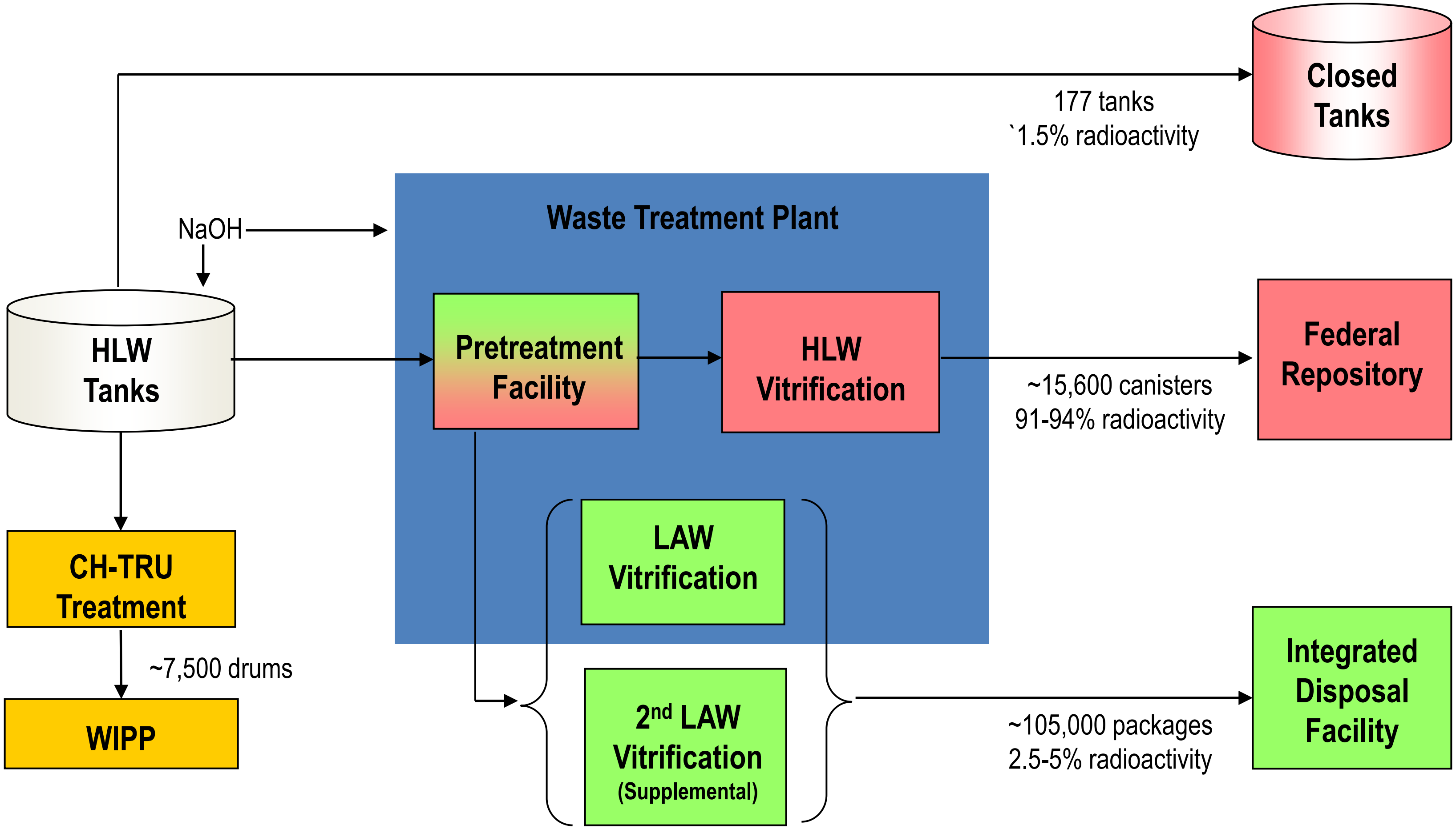
- TRU
  - 20 tanks have waste that could be classified as TRU
    - 11 Contact Handled, 9 Remote Handled
  - Could be dried, packaged and shipped to WIPP
  - Requires favorable EIS ROD and WIPP RCRA Part B permit change





Capsule

Hanford Tank Waste Disposition Flowsheet



Closed Tanks

177 tanks
`1.5% radioactivity

NaOH

Waste Treatment Plant

HLW Tanks

Pretreatment Facility

HLW Vitrification

Federal Repository

~15,600 canisters
91-94% radioactivity

CH-TRU Treatment

~7,500 drums

WIPP

LAW Vitrification

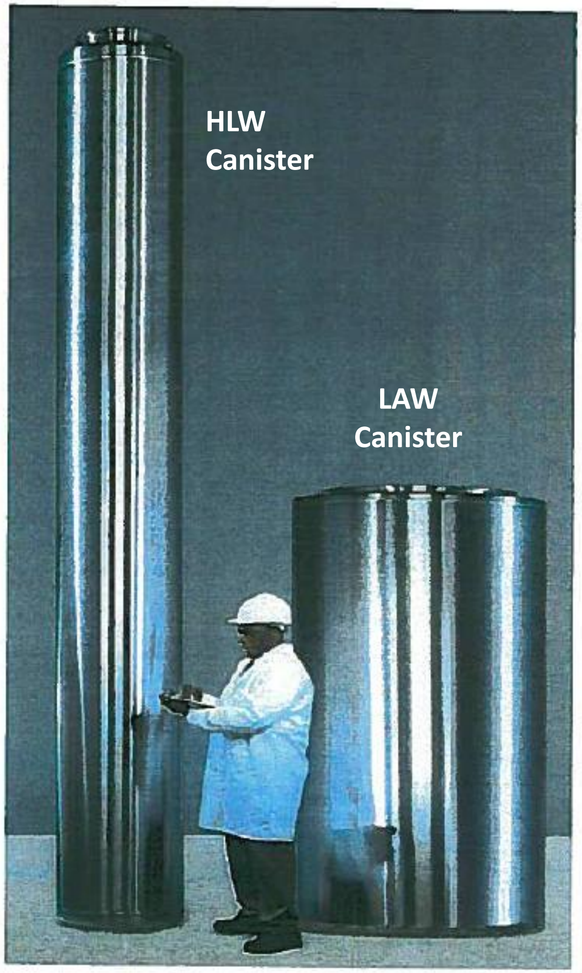
2nd LAW Vitrification (Supplemental)

Integrated Disposal Facility

~105,000 packages
2.5-5% radioactivity

Hanford HLW Disposition (cont.)

- Salt Waste
  - ultrafiltration to reduce suspended solids prior to ion exchange
  - ion exchange using Spherical Resorcinol Formaldehyde resin to reduce Cs-137 concentration
  - Solids and Cs-137 to HLW vitrification
  - Decontaminated salt solution to LAW Vitrification
- Sludge
  - Pretreatment to reduce Na, Cr and Al content via caustic and oxidative leaching
  - Treated sludge solids to HLW vitrification similar to DWPF but larger canisters
  - LAW fraction to LAW vitrification



Hanford HLW Challenges

- LAW Vitrification
  - Estimate of NaOH required to leach Al and keep it in solution has increased
  - Drives need for more LAW pretreatment and vitrification capacity
  - Critical decision as to how best to provide the extra capacity
- DST tank space
  - Limits rate of SST retrieval in near term
- WTP schedule
  - Additional discovery in first-of-a-kind processes could cause further delays
  - Presently scheduled to go on line ~2019
- Path forward on Cs/Sr Capsules

Transuranic Wastes

Definition

- Not HLW
- More than 100 nCi/g from alpha-emitting, TRU isotopes
- Half-lives greater than 20 years
- International consensus on the need for deep geological repositories

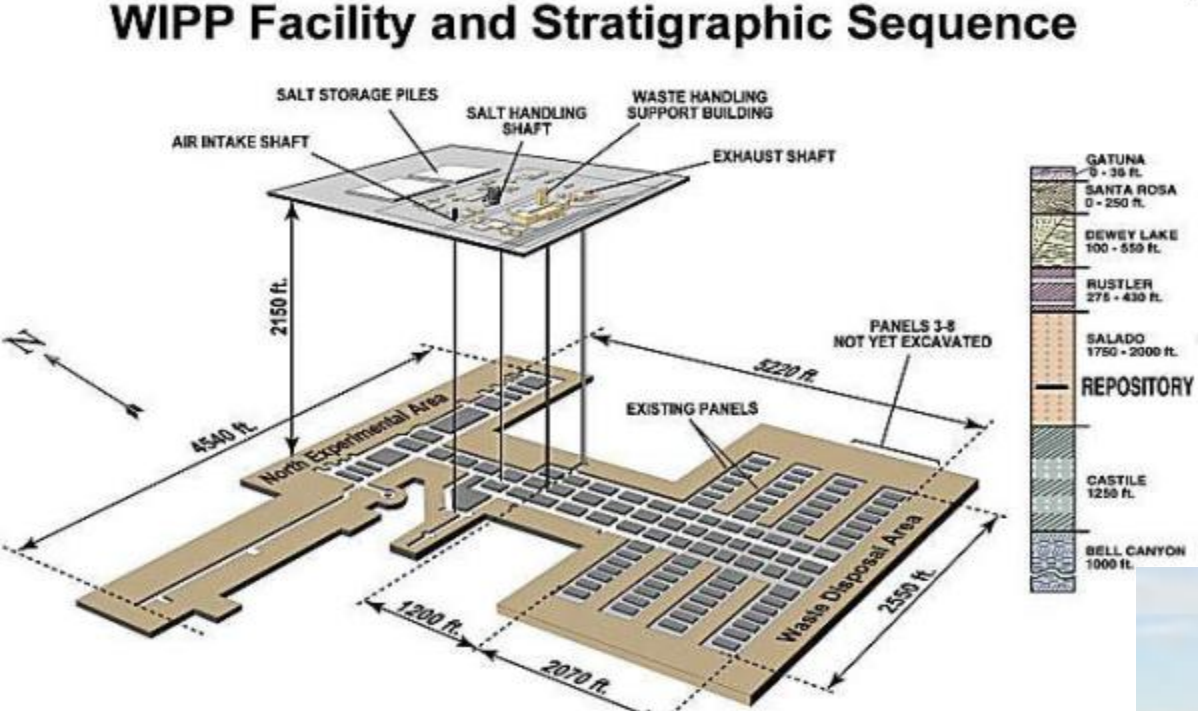
Sources and Nature

- Three major types of facilities:
  - Used fuel reprocessing plants (that separate Pu from U, i.e., PUREX)
  - Mixed-oxide fuel fabrication facilities
  - Pu weapons production facilities
- Nature of the waste: waste materials, protective clothing, equipment, cleaning materials, etc.
- Much of the material has the potential for RCRA constituents

Waste Acceptance Criteria (WAC)

- Containers
  - Types
  - Weights
  - Allowable surface contamination (very low)
  - Markings
  - Filters
- Radiologic properties of the waste
  - Radionuclides that are present
  - Concentration of Pu-239 (fissile isotopes)
  - Radiation dose rates
- Physical properties
  - Amount of free liquid
  - Size and nature of sealed containers
- Chemical properties
  - Pyrophoricity
  - Other hazardous constituents
  - No explosives, corrosives, or compressed gases
  - Organics
  - Asbestos (declared)
- Gas generation
  - Decay heat limits
  - Estimated hydrogen gas generation rates
  - Flammability
  - Venting requirements
- Record keeping
  - Waste characterization documented
  - Shipper records reviewed before shipment
  - Shipper certification by WIPP

WIPP Repository


WIPP Facility and Stratigraphic Sequence

High-Level Waste Disposal [?]

U.S. Waste Disposal System

- There are only three classes of disposal destinations:
  - Release to the environment
  - Near-surface disposal: normal activities such as building basement or digging a water well would hit wastes
  - Deep geologic disposal: normal activities would not get near wastes
- Rules say what can be released
- Near-surface disposal: mill tailings, LLW
- Deep geologic disposal: TRU, HLW, UNF…GTCC[?]

Disposal of HLW and UNF

- The situation
  - The U.S. currently has about 60,000 MTHM of LWR fuel growing at about 2,000 MTHM/yr
  - The U.S. has a large volume of defense wastes in tanks that will be converted to 15,000 to 20,000 logs containing HLW glass
  - These wastes require DGR disposal

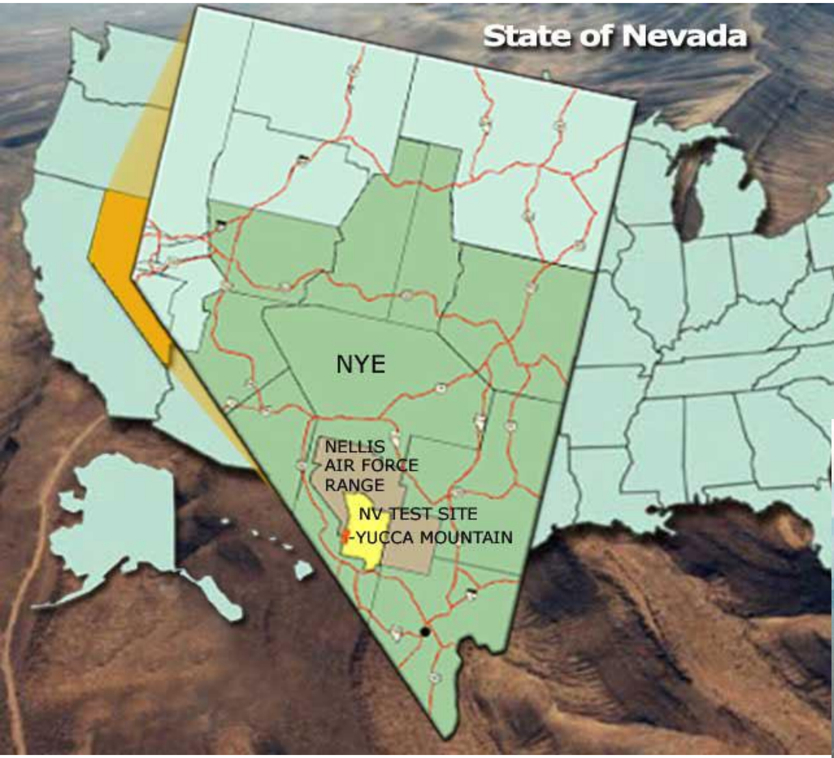
DOE’s Program

- Beginning in 1982 Congress passed the Nuclear Waste Policy Act (NWPA) directing DOE to evaluate repository sites and select one to be developed
- DOE was in the process of doing so when, in 1987, Congress terminated the process and directed DOE to characterize a site at Yucca Mountain, NV (YM) and, if suitable, submit a license application (LA) to the NRC.
- Also in 1987, the WIPP Land Withdrawl Act stipulated that the facility should not be used for Used Nuclear Fuel
- After a lengthy and difficult process, DOE submitted the LA for Yucca Mountain in 2008.

DOE’s Program (cont.)

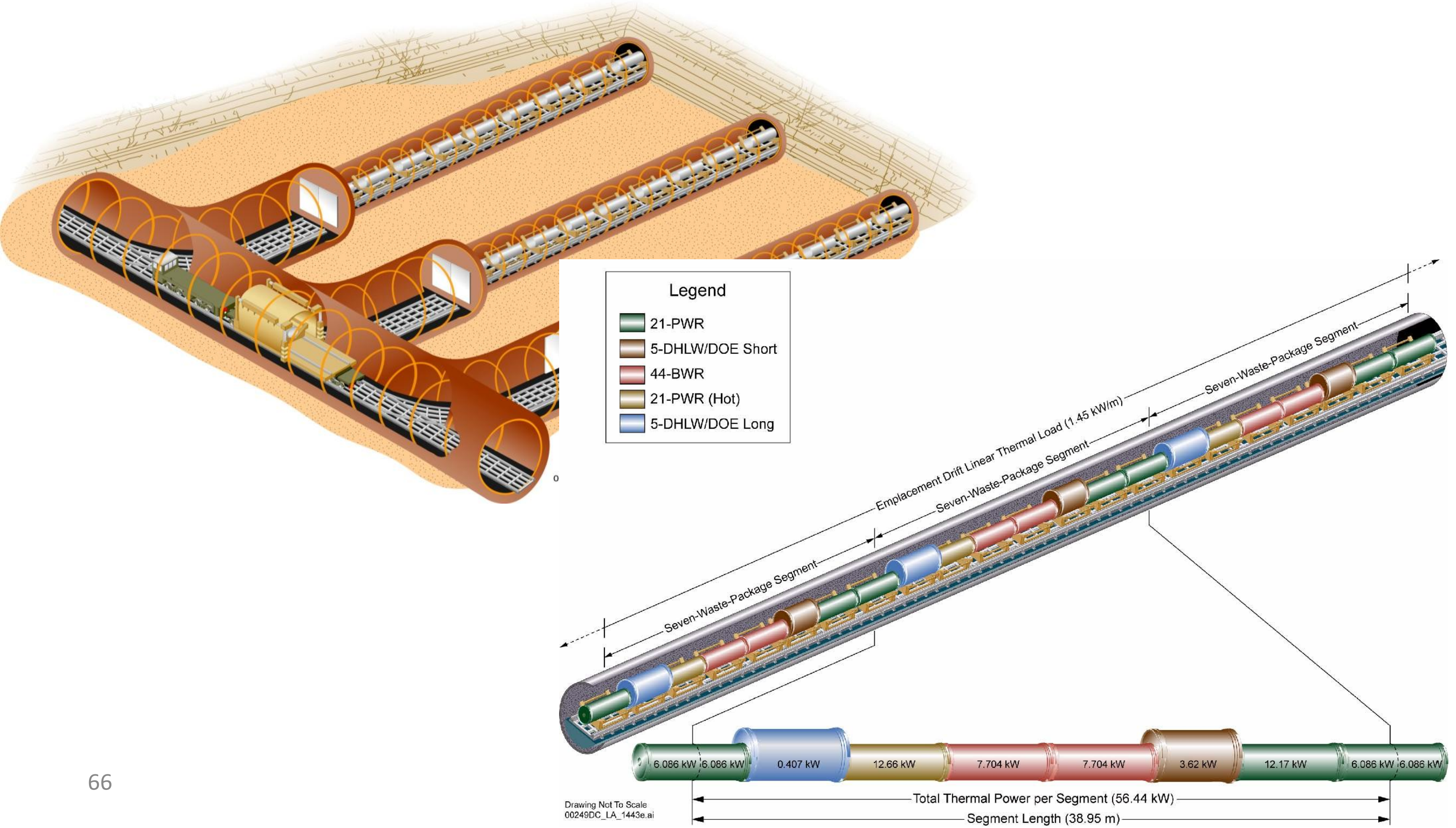
- Licensing activities began in earnest in the Fall of 2008, with the submittal of a License Application (LA)
- In the Fall of 2009 the DOE announced it was withdrawing the LA
- The withdrawal action is now in court (2 separate suits) and the NRC has not formally accepted the DOE withdrawl
  - ASLB
  - Commission
  - Blue Ribbon Commission
- Stay tuned

Yucca Mountain Site



YM Tunnel Boring Machine

YM Waste Emplacement Concept



Low-Level Waste

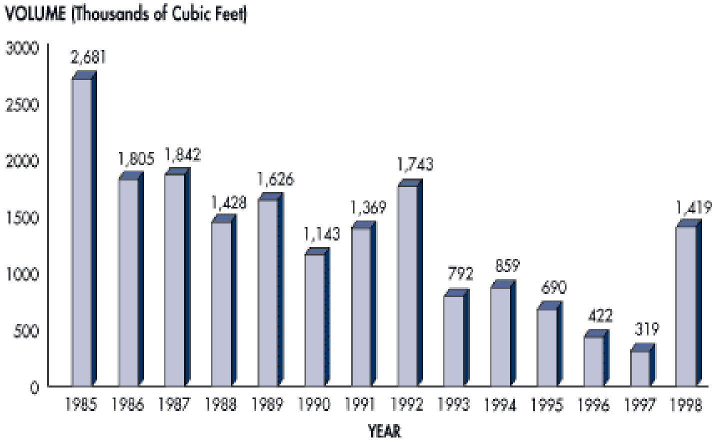
Low-Level Waste (NWPA)

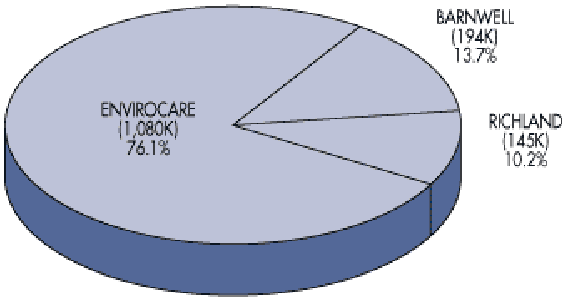
- LLW is defined as radioactive waste that:
  - Is not high-level waste, spent fuel, transuranic waste, or byproduct material as defined in Section 11(e)(2) of the Atomic Energy Act; and
  - NRC, consistent with existing law, classifies as low-level radioactive waste

What Comes from Where

- DOE
  - On-going operation of facilities yields:
    - Protective clothing
    - Cleaning materials
    - Monitoring samples
    - Tools, etc.
  - D&D and Environmental Restoration:
    - “Spike” in volumes of mostly very LLW
    - Soils
    - Rubble
    - Materials similar to ops
- Commercial Nuclear Plants: similar to DOE operations materials, also numerous resins from liquid waste processing
- Medical facilities:
  - Diagnostic material production
  - Wastes from administration
- Industrial Uses: sources for gages and radiography, sterilization of medical supplies and equipment

How Much is LLW There?



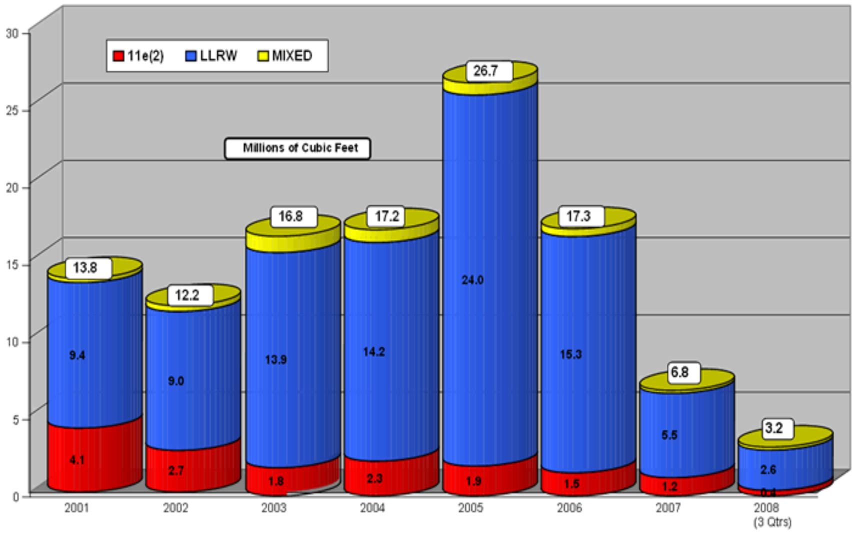


1998 VOLUME BY DISPOSAL FACILITY

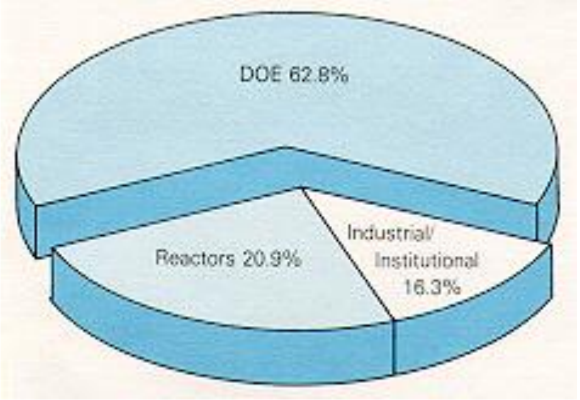
Note: Volumes are rounded to the nearest thousand cubic feet and percentages are rounded to the nearest tenth of a percent.

Source: DOE 1998 State-by-State Assessment of Low-Level Radioactive Washes Received at Commercial Disposal Sites [DOE/LLW–252], pages A2 and A3.

Radioactive Waste Disposal Volumes 2001-2008



1998 'Split'



Classes of LLW

- Class A: least hazardous; short & long-lived waste that will not endanger an inadvertent human intruder beyond 100 years
  - Trash
  - Low-level water treatment resins
  - Some biomedical waste
- Sturdy container (55-gallon drum, waste boxes)
- No further stability requirements (over & above general requirements)

Classes of LLW (cont.)

- Class B: more hazardous; short-lived wastes that will not endanger an inadvertent intruder beyond 300 years
  - Evaporator concentrates
  - Filter sludges
  - Spent resins
  - Must be solidified in a stable matrix (grout, polymer)
- Class C – most hazardous; will not endanger inadvertent intruder beyond 500 yrs
  - Some spent resins
  - Some sealed sources
  - Stability, greater burial depth, 500 yr intruder barrier

LLW Disposal in Trench

Barnwell

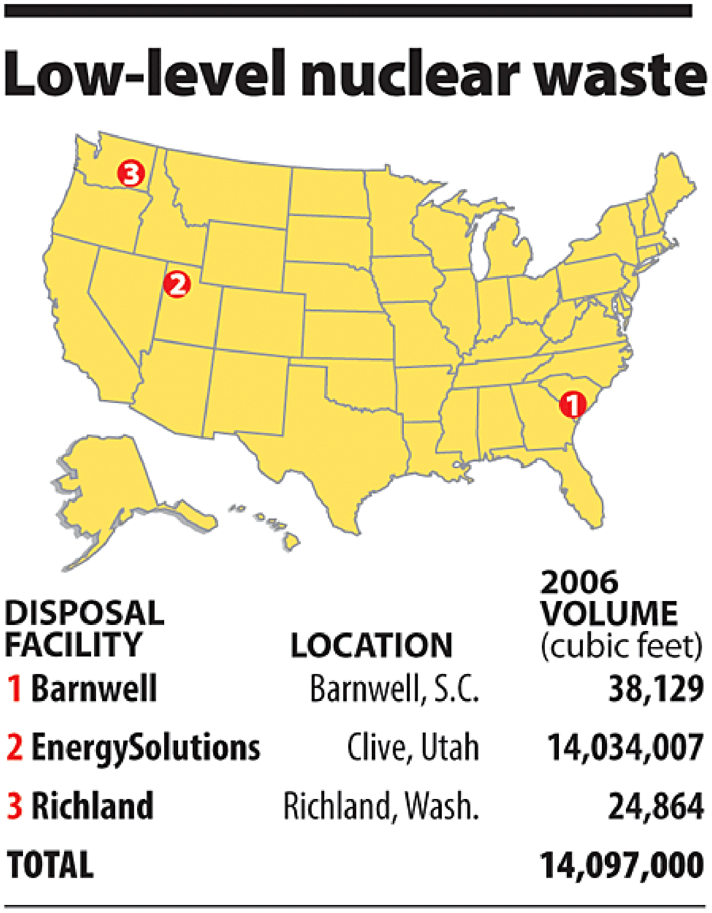
Envirocare

NTS

General Disposal Requirements

- All waste classes must meet the following requirements for disposal (10CFR61):
  - Waste form & packaging meet DOE & NRC requirements for transportation
  - Cannot be packaged in cardboard/fiberboard
  - Liquids must have 2X absorptive material
  - No explosive decomposition at normal temperature/pressure nor energetic reactions with water
  - Not capable of generating toxic off-gases
  - Non-pyrophoric
  - No pathogens
  - Gases: <1.5 atm, <100 Ci/container

LLW Disposal Sites



Low-level nuclear waste

DISPOSAL FACILITY	LOCATION	2006 VOLUME (cubic feet)
1 Barnwell	Barnwell, S.C.	38,129
2 EnergySolutions	Clive, Utah	14,034,007
3 Richland	Richland, Wash.	24,864
TOTAL		14,097,000

- Three operating LLW commercial disposal sites in the U.S.
- One newly licensed and getting ready to go operational in Texas
- Note: important imbalance – most nuclear power plants are in the East

The Slowdown of 1979

- In 1979 the 2 western sites were temporarily closed
  - Initially in response to shoddy shipping
  - Then to make a statement
- Barnwell, in SC, imposed volume restrictions (had been receiving ~80% of commercial waste)
- Add-in general public apprehension regarding nuclear waste, and you get: the Low Level Radioactive Waste Policy Act
- LLWPA of 1980: defined LLW as a state vice national issue and urged the states to form "compacts" to address LLW disposal requirements & set a deadline of 1986
- By 1985 very slow (or no) progress indicated that the deadline would not be met
  - Introduced a plan for inter-regional disposal thru 1993 and authorized surcharges
- No new disposal sites have been sited
- Why no problems???

Progress in Treatment of LLW

- Treatment Technologies
  - *Transfer technologies* (filtration, IX)
  - *Concentration technologies* (evaporation, dewatering, compaction)
  - *Transformation technologies* (incineration, calcining)
- Waste minimization

- Type of technology to use depends on the nature of the waste:
  - Liquid (IX, evaporation)
  - Wet solids (dewatering)
  - Dry Solids (compaction, volume reduction)
- And ‘other factors’
  - Economics (capital vs. operating expenses)
  - Permitting

The Demise of Incineration

- Permits became hard to come by in the mid-1990’s
  - Spill-over from problems with commercial non-radioactive applications
  - Inherent control issues, including off-gas, carry-over & output quality
  - Now a “niche” player, numbers have plummeted; no new U.S. licenses since mid-90’s.
- Concern: giving up the *90-95% reduction* in volume produced

- Fluidized-Bed Steam Reforming*
  - Hi temperature
  - Catalyzed/additives
  - Breakdown of organics and/or transformation (oxidation)
  - Stable mineralized waste form
- Wet Air Oxidation**
  - Zimpro process
  - Mostly off-gases (CO2, water vapor, short-chain organics)
  - Waste needs further stabilization
- Vitrification?

*Fluidized Bed Steam Reforming of INEEL SBW…”, INEEL/EXT-04-02564 (2004)
**Destruction of Tetraphenylborate in Tank 48H Using Wet Air Oxidation…”, SRNL-STI-2009-00200 (2009)

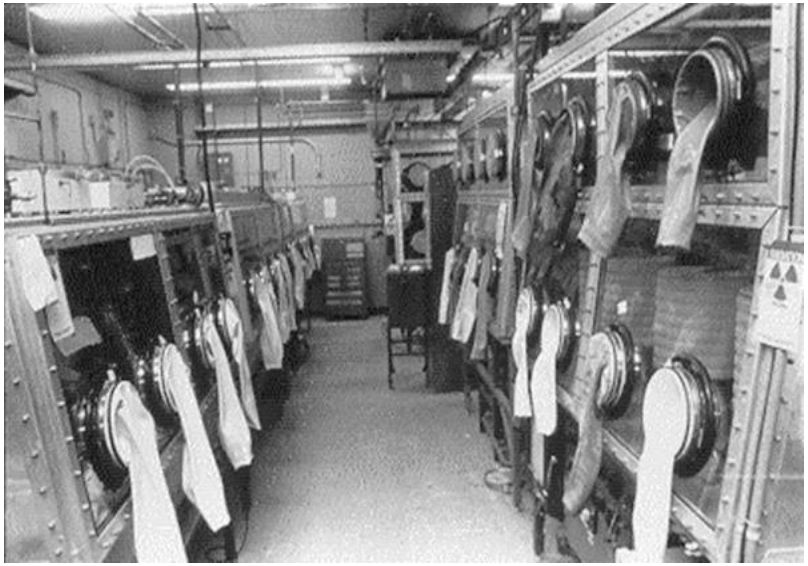
And now, to Even Bigger Challenges

- Greater than Class C (GTCC) – higher radiation and half-lives, but <u>not</u> HLW
  - Sealed radioactive sources

  - Activated components

The challenge (cont.)

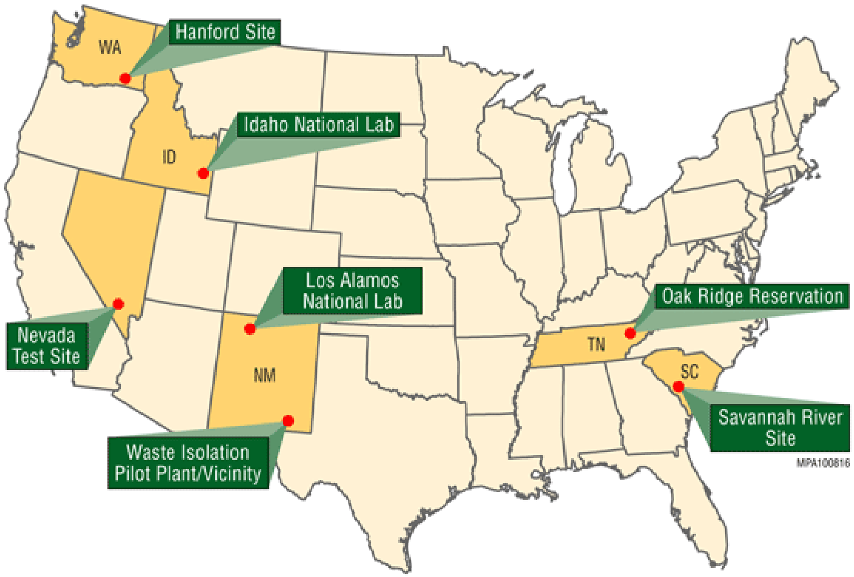
- Other wastes, including:
  - Contaminated equipment
  - D&D wastes
  - Radionuclides that normally predominate include: Co-60, Cs-137 and Am-241
  - Non-defense TRU



GTCC EIS

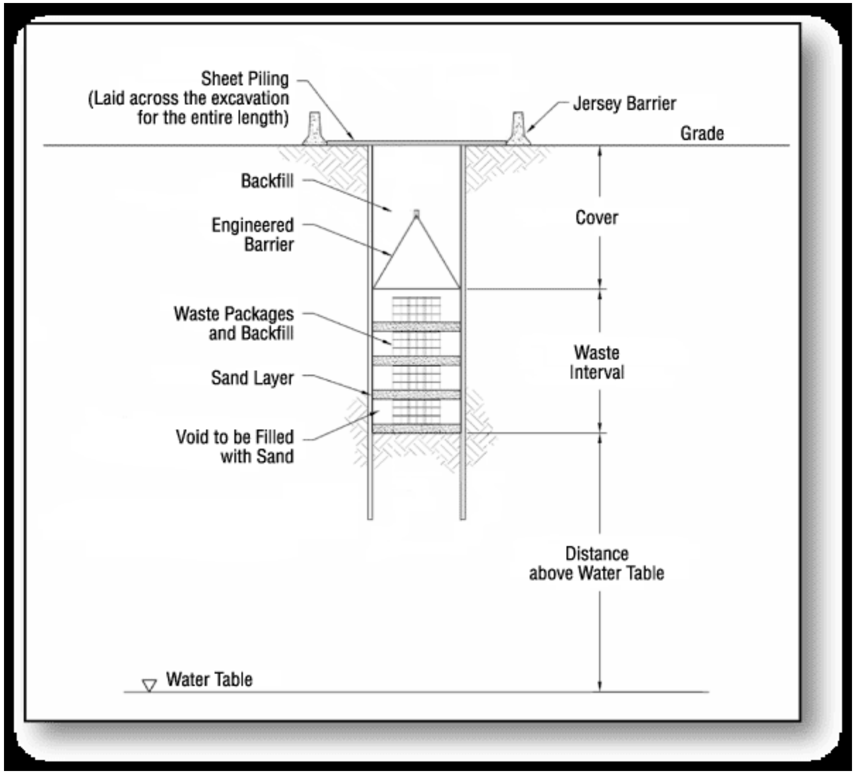
- Responsibility assigned to DOE to deal with
- Subject of on-going NEPA activity
- Seven (7) DOE sites under review for potential GTCC disposal
- Geologic burial one option (e.g., WIPP)
- Draft EIS issued

Potential GTCC Repository Sites

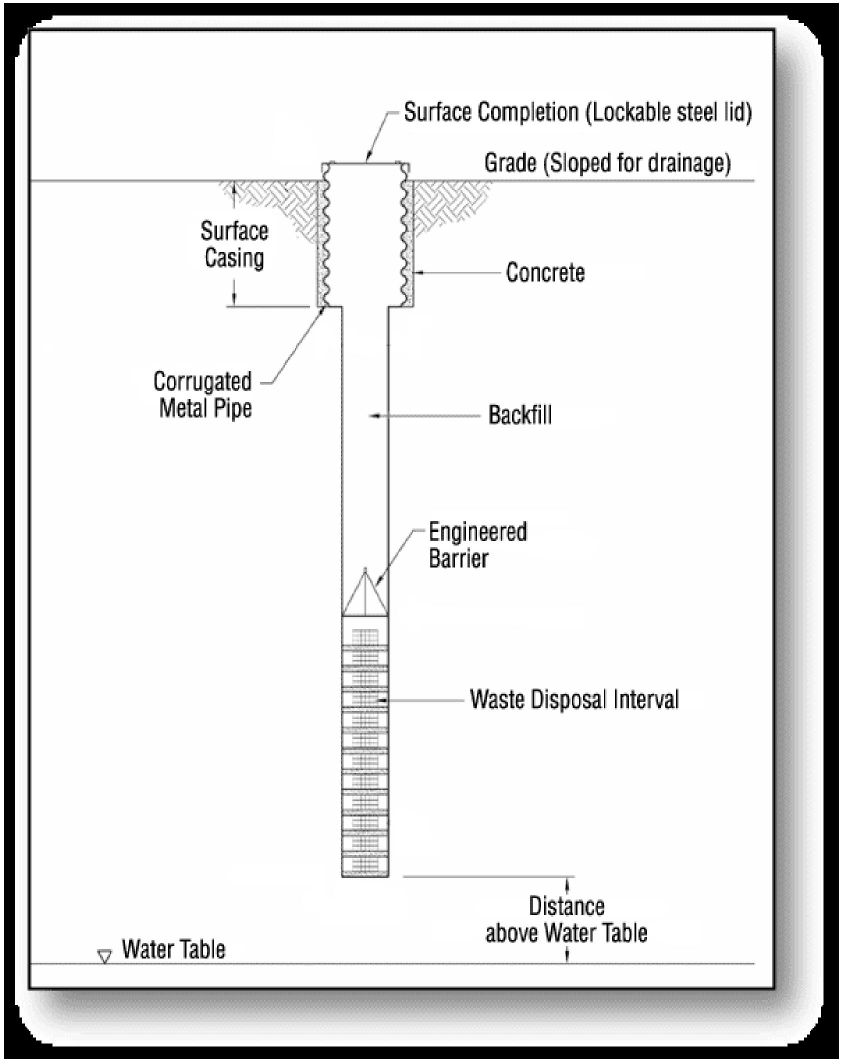


Other GTCC Options Under Review

Enhance Shallow Burial



Deep Bore Hole Emplacement



Waste Incidental to Reprocessing (WIR)

- Or…when is HLW <u>not</u> HLW??
- New Law: "Ronald W. Reagan NDAA of 2004" revised the Atomic Energy Act
  - Applies to only the states of SC & ID, in fact, "not binding" on the states of WA and OR (i.e., Hanford)
  - Sets up a process for waste to be 'determined' to be 'incidental to reprocessing' and therefore, not HLW
  - Provides for NRC "Technical Review" of the DOE Performance Assessment* that demonstrates compliance with:
    - "does not require isolation in a deep geological repository"
    - "has had highly radioactive radionuclides removed to the maximum extent practical"
    - May or may not be GTCC
- NRC to act in concert with the respective state regulators
- Consistent with DOE Order 435.1
- Remains *controversial*
- <u>Does not</u> apply to Hanford
- Requires determination of satisfactory processing to be tied to an evaluation of the performance of waste form in a disposal site

*e.g., DOE SRS HLW-SDT-2001-00281, "Waste Incidental to Reprocessing Evaluation for Disposing Saltcake to Saltstone" (2002)

Concluding LLW Thoughts

- Time has not stood still since 1985
- Continued refinement of waste classification
  - More rules
  - Less clarity?
  - In a SC or ID ‘state’ of mind?
- Incineration out…FBSR in, WAO in (to a limited degree), vitrification in for South Korea
- What is OK is a combination of specific activity, waste form, site-specific characteristics and…..

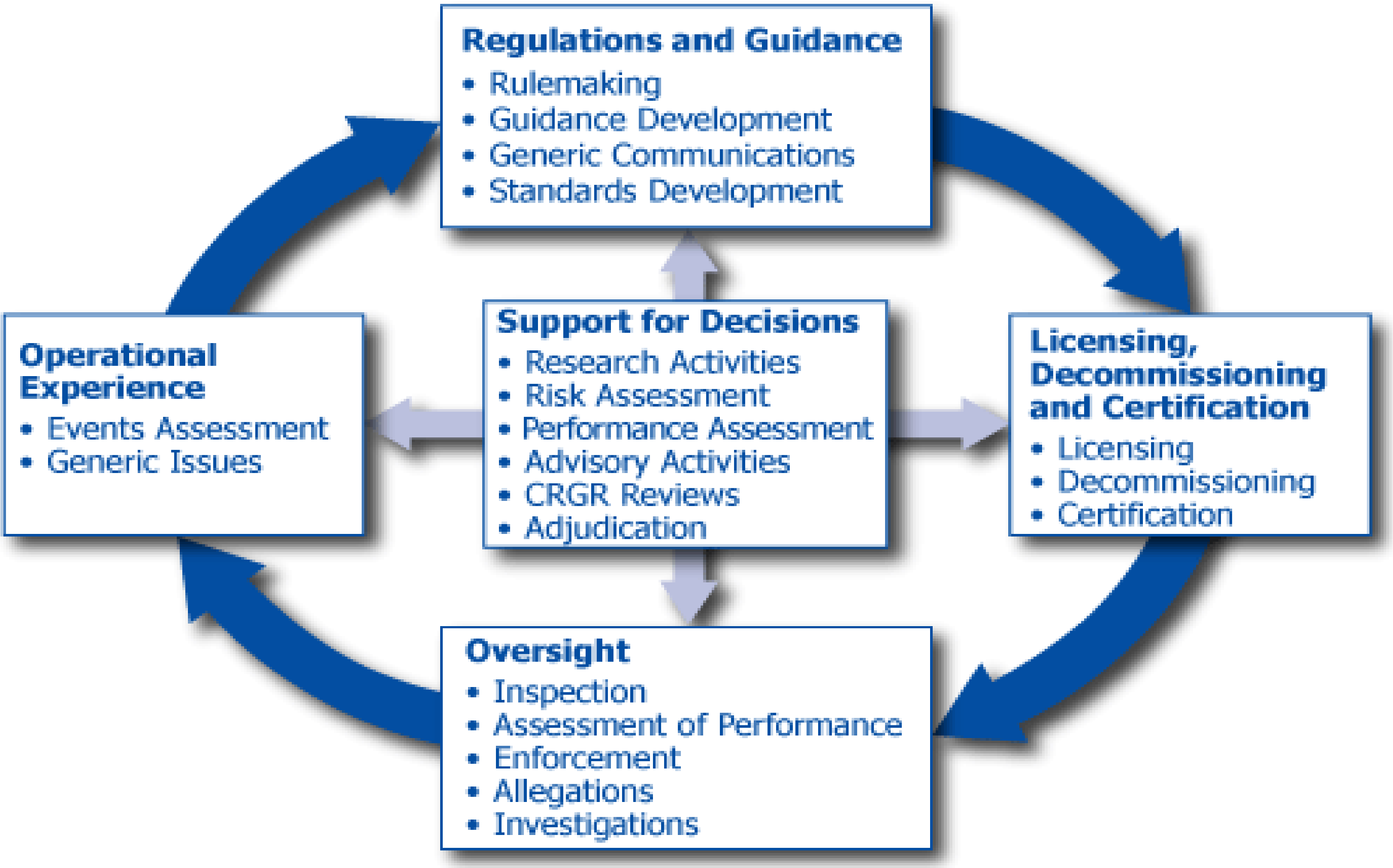
Regulation

The Players*

- Environmental Protection Agency (EPA)
  - Develops generally applicable standards for nuclear and many other kind of facilities for effluents (RADNESHAPS) and potential effluents (RCRA, CERCLA)
  - Direct role at WIPP
- Nuclear Regulatory Commission (NRC)
  - Regulator for
    - Civilian nuclear facilities and uses
    - DOE activities as directed by Congress or at DOE request (e.g., MOX, WIR)
- Department of Energy (DOE)
  - Nuclear Safety
    - 10 CFR 830, Parts A (QA, USQ) & B (DSA)
  - Radiation Protection
    - 10 CFR 835
  - Radioactive Waste Management
    - DOE Order 435.1
  - Administered for the Secretary of Energy by the Office of Health, Safety & Security (DOE-HS)
    - Independent Oversight
    - Enforcement
    - Rule & Standards Development
    - Integrated Safety Management

*An excellent overall summary of the regulation of radioactive waste can be found in NUREG-1853, “History and Framework of Commercial Low-Level Waste Management in the United States: ACNW White Paper,” NRC (2007)

How the NRC Regulates (DOE similar)



Regulations and Guidance
- Rulemaking
- Guidance Development
- Generic Communications
- Standards Development

Operational Experience
- Events Assessment
- Generic Issues

Support for Decisions
- Research Activities
- Risk Assessment
- Performance Assessment
- Advisory Activities
- CRGR Reviews
- Adjudication

Licensing, Decommissioning and Certification
- Licensing
- Decommissioning
- Certification

Oversight
- Inspection
- Assessment of Performance
- Enforcement
- Allegations
- Investigations

Reactor Licensing [1]

- Old process: 10 CFR 50
  - Construction Permit
    - Applicant: Safety Analysis Report (SAR) plus other documents
    - NRC staff review
    - Public hearings and written comments
    - NRC staff: Safety Evaluation Report (SER), Environmental Impact statement (EIS)
    - If all goes well, the applicant gets a construction permit
  - Operating License
    - Application
    - Final SAR and SER are issued here if not before
    - May or may not be hearings
    - If all goes well, the applicant gets an operating license

Reactor Licensing [2]

- New process: 10 CFR 52
  - The two-step process was a concern; applicant could invest billions with no assurance of an operating license
  - NRC created a one-step licensing process in

    10 CFR 52
    - Construction-Operating License (COL)
    - Early site permit
    - Design certification
  - Based on 10 CFR 50 technical reqts
- COL
  - In essence, the applicant must submit the documents for both a construction permit and operating license
  - The process proceeds much like the two-step process
  - At the end the NRC verifies that all requirements have been met (hearing a possibility)
- Early Site Permit
  - Pre-approval of the safety, emergency response, and environmental aspects of a site without consideration of reactor-related issues.
  - NRC issues SER and EIS
  - Mandatory public hearing
  - Good for 10 to 20 years with renewal rights
- Design Certification
  - A reactor vendor can get pre-approval of a standardized reactor design
  - May or may not be hearings
  - Certification can be incorporated by reference into a COL or Early Site Permit application
  - Good for 15 years

Reactor Licensing Status

- **Early Site Permits (~3.5 years):**
  - 4 issued (Clinton, Grand Gulf, North Anna, Vogtle)
  - 2 under review (Hope Creek; Victoria County)
  - 2 additional permits expected
- **COLs (~4 years)**
  - 17 companies have submitted applications for 26 new reactors for NRC review (20 are for PWRs)
  - 13 applications under review; 4 suspended
  - 7 additional (10 new reactors) expected by 2012
- **Reactor Design Certifications (~5 years):**
  - Three completed: ABWR, ESBWR, Westinghouse AP 1000
  - Three under review: AP 1000 Amdt, Areva US-EPR, and Mitsubishi US-APWR

Fuel Cycle Facility Licensing [1]

- Fuel cycle and waste facilities are licensed under numerous regulations
  - Mill tailings: 40 CFR 192 and 10 CFR 40
  - Uranium conversion and enrichment: 10 CFR 40
  - Fuel fabrication: 10 CFR 70
  - Spent fuel storage: 10 CFR 72
  - Reprocessing: 10 CFR 50
  - LLW disposal: 10 CFR 61
  - HLW/SNF disposal except YM: 40 CFR 191 and 10 CFR 60
  - HLW/SNF disposal at YM: 40 CFR 197 and 10 CFR 63

Fuel Cycle Facility Licensing [2]

- Transportation: 10 CFR 71
- Physical protection: 10 CFR 73
- Material control and accountability: 10 CFR 74
- Environmental protection: 10 CFR 51
- Radiation protection: 10 CFR 20
- Operator’s license: 10 CFR 55
- Decommissioning: 10 CFR 50, 51
- Note that a single facility may and likely will have components licensed under multiple regulations

Fuel Cycle Facility Licensing [3]

- 10 CFR 70 allows for a one-step licensing process applicable to fabrication plants
- For reprocessing, 10 CFR 50 presents problems
  - This regulation has evolved over the years to be very reactor specific
  - It would involve a two-step licensing process
  - The NRC has determined this regulation is not adequate for reprocessing plants and is in the process of creating a regulation appropriate for reprocessing

Operator Licensing

- Operators are licensed to operate a specific facility
  - Years of related experience
  - Extensive classroom and simulator training
  - Application for license
  - Written examination administered by NRC
  - Operating test on a simulator administered by NRC
- Training programs are accredited by an arm of the Institute for Nuclear Power Operations

Regulatory Approaches

- Technology based
  - Best available technology, etc.
  - Seldom used by NRC, EPA for HLW (BDAT)
- Performance based
  - Usually used by NRC, e.g., specify a dose limit and the applicant shows how it will be met
    - Can be deterministic or probabilistic
      - Reactor licensing is increasingly probabilistic and Yucca Mountain licensing was fully probabilistic
      - Most other facilities are not probabilistic -- yet
    - Limits can be expressed as dose or risk but NRC usually regulates dose

Oversight

- NRC has inspectors that oversee nuclear facility operations
  - Large facilities: resident inspectors
  - Smaller facilities: periodic inspections
- NRC also uses performance indicators to measure the safety performance of a facility
- The “plant assessment” is a combination of inspection results and performance indicators
  - Results are on NRC web site
  - Poor performance→ more NRC scrutiny

Sources

- Croff, A., “Short Course on Reactors and Fuels”, CRESP, delivered October 2010
- Gilbertson, M. and Krahn S., “20 Years of Progress in Processing Nuclear Waste”, CRESP Short Course: *Introduction to Nuclear Fuel Cycle Chemistry*, August 2009
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- Saling, J. & Fentiman, A., Radioactive Waste Management, Taylor & Francis, New York, NY, 2001