ELECTRIC POWER RESEARCH INSTITUTE

Waste Management for Decommissioning of Nuclear Power Plants – An EPRI Decommissioning Project Report

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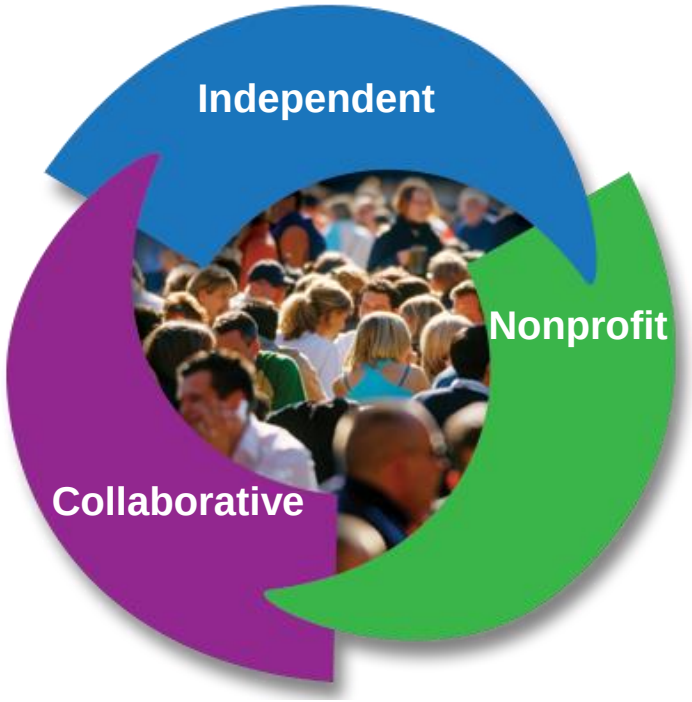
Symposium on Recycling of Metals Arising from Operation and Decommissioning of Nuclear Facilities

Studsvik, Sweden
8-10 April, 2014

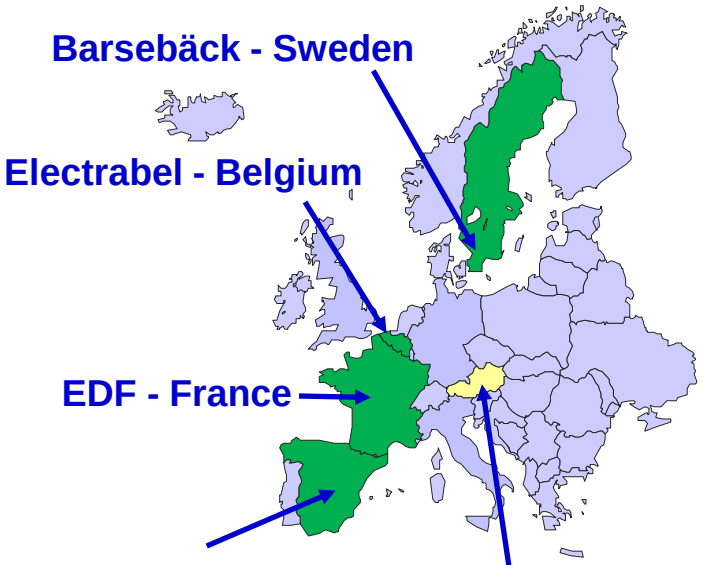
EPRI Decommissioning Technology Program

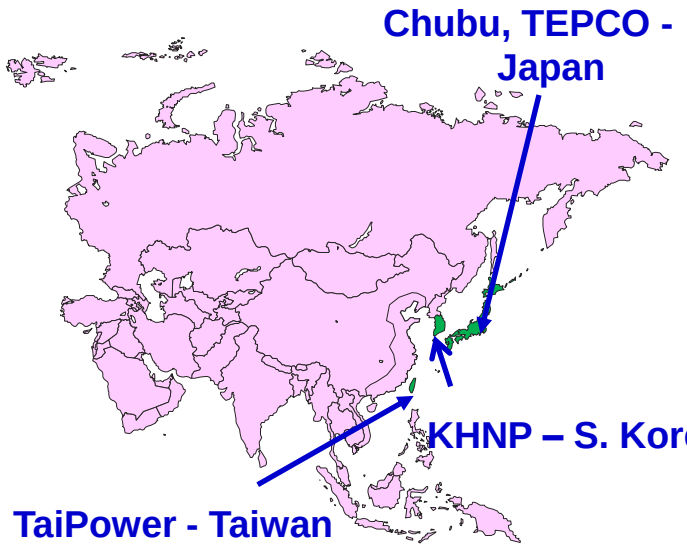


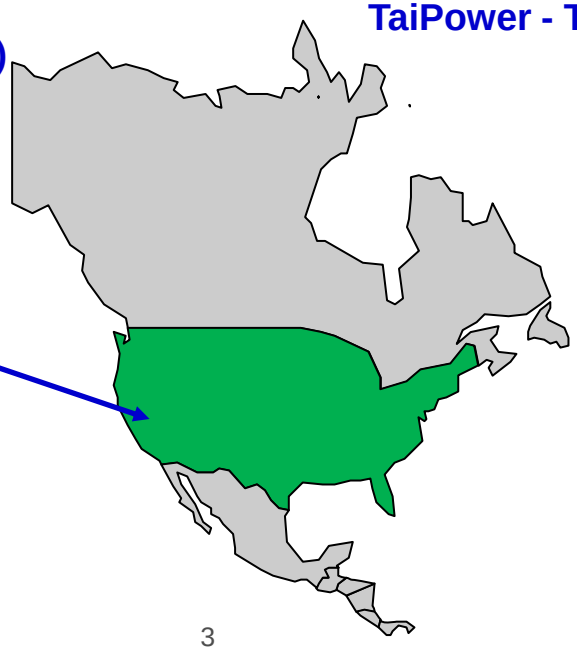
- Program Objective
  - To provide technical guidance for the planning and conduct of facility decommissioning
- Program Strengths
  - Documentation of more than 20 years experience in the successful decommissioning of commercial power plants (Over 100 EPRI Reports Published)
  - More than 20 years of R&D results covering all critical technical areas in plant decommissioning
  - Offers a forum for utilities to share current experiences and state-of-the-art technologies for plant decommissioning

Next EPRI Decommissioning Workshop, Brussels, Belgium, October 13-16, 2014

Decommissioning Technology Program Membership







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Discussion Topics

- Disposal Options in the U.S.
- Decommissioning Waste Volumes and Strategies
- Disposition of Large Components in the U.S.
- Metal Recycle Experiences in the U.S.

U.S. Radioactive Waste Disposal Requirements

- Disposal of radioactive waste in near surface disposal is classified in terms of disposal requirements such as;
  - Class A waste with minimal requirements, often unpackaged
  - Class B waste requires more rigorous requirements for waste stability
  - Class C waste also requires stability and additional intruder protection measures
- Greater than Class C (GTCC) Waste is not acceptable for near-surface disposal and requires disposal in a geologic repository.

Primary US Disposal Sites for Power Plant Radioactive Wastes

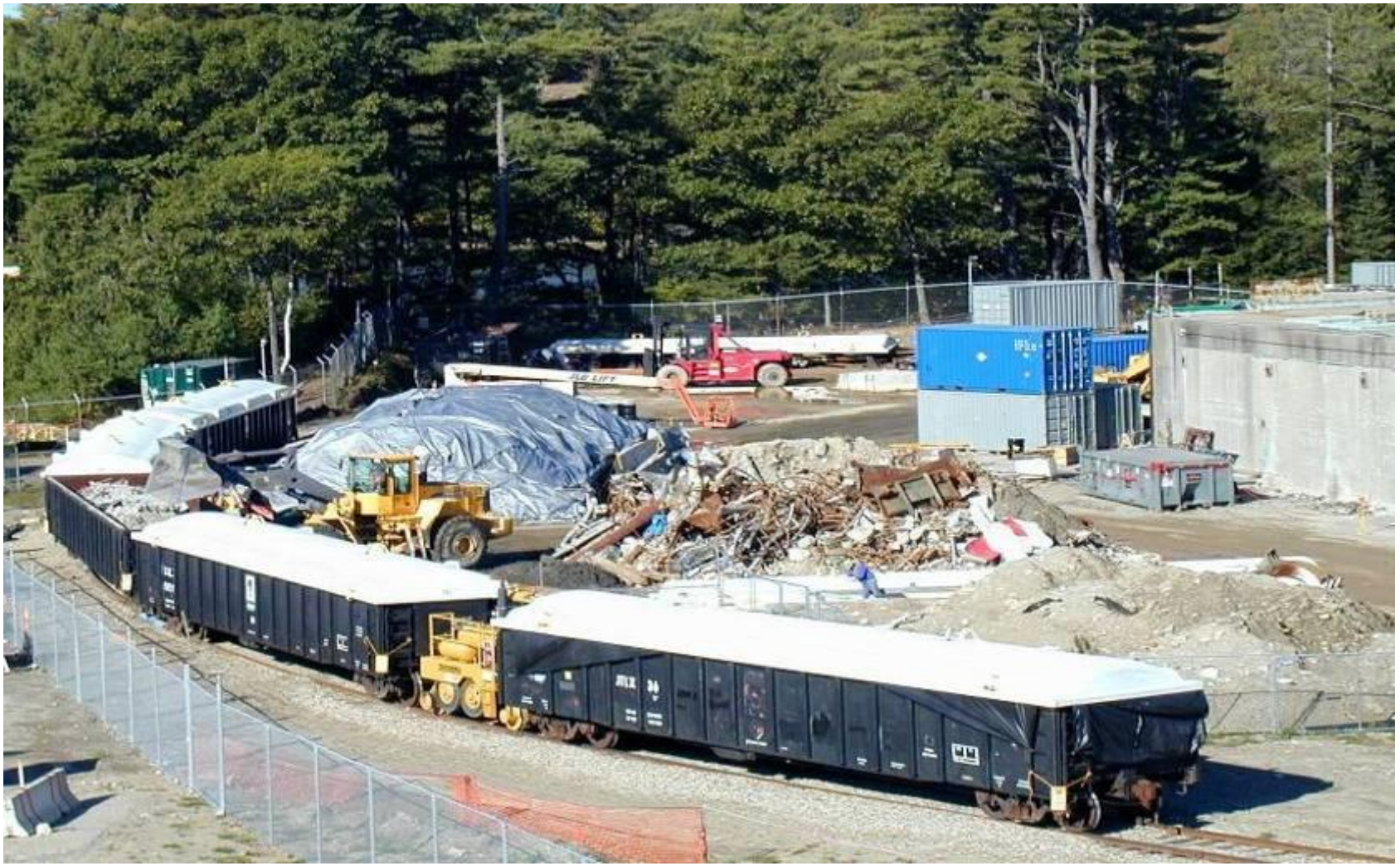
- **EnergySolutions - Clive, Utah site**
  - Can receive Class A waste from any state.
  - Waste disposal costs are in the range of 2,600 Euro/m^3.
- **State Licensed Facilities**
  - **Tennessee Licensed Landfills**
    - Can receive waste containing up to 0.5 Bq/g of gamma radionuclides.
    - Approximate disposal cost at these sites is 1,100 Euro/m^3.
  - **US Ecology Idaho Facility**
    - Can receive waste containing up to 0.6 Bq/g of gamma radionuclides which has been exempted by the NRC
    - Disposal cost is < 550 Euro/m^3.
- **Waste Control Specialists – Andrews, Texas Site**
  - Can receive Class A, B and C waste from Texas and Vermont (i.e., the Texas Compact) without special approval
  - Licensees from other states can request approval for limited access
  - Disposal costs approximately 133,000 Euros/m^3 for Class B/C Waste from out of compact licensees

Comparison of Radioactive Waste Volumes/Estimates

Waste Type (U.S. Classification)	Estimate for Selected European Plants (m^3)	Maine Yankee - US (860 MWe-PWR) (m^3)	Rancho Seco - US (913 MWe-PWR) (m^3)
Very Low Level and Low Level (Class A)	2,911	90,650	17,244
Intermediate Level (Class B and C)	2,459	570	93
Greater Than Intermediate Level (GTCC)	109	Not Available	11
Total	5,479	106,610	17,348
Decommissioning Strategy	Decontaminate Buildings and Equipment to Clearance Levels	Little Decontamination of Buildings and Equipment	Decontamination of Buildings, Little Decontamination of Equipment

Decontamination of Metal Typically Not Cost Justified in the U.S.

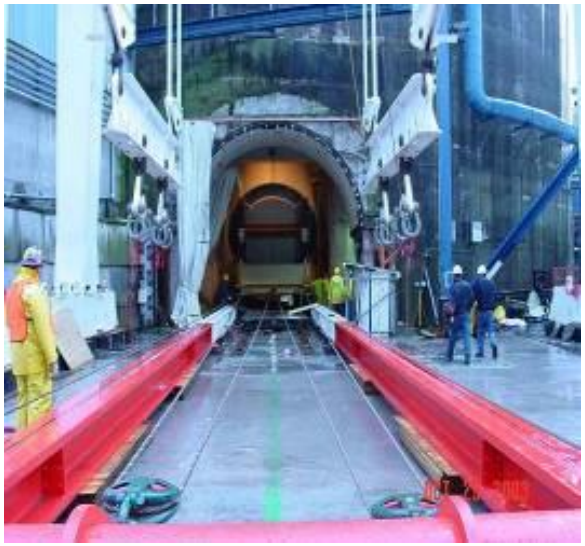
Shipment of Bulk Decommissioning Waste (Maine Yankee)



Large Component Processing in the U.S.

- Large components such as Reactor Vessels and Steam Generators (S/Gs) can be:
  - Qualified for shipping in one piece
  - Disposed at U.S. shallow land disposal facilities with little or no segmentation (other than the removal of GTCC Reactor Internals)
- Power plant licensees have successfully proposed that the robust construction of these large components:
  - Make them a suitable shipping package
  - Do not require the qualification testing normally required for other packaging for this category of waste
- Note that U.S. regulations allow the activity to be averaged over the entire weight of the large component – Has allowed S/G Lower Assemblies to qualify as Class A waste for disposal at Clive, Utah

Connecticut Yankee (CY) Reactor Vessel Packaging, Shipping and Disposal (Barnwell, SC)



Steam Generator (S/G) Processing in the U.S.

- Almost all of the activity in a S/G is located in the tube bundle and channel head (i.e., in the “Lower Assembly”)
- Due the ability to dispose of S/G in one or two pieces, typical disposition options for a S/G in the U.S. are:
  - Option 1: Dispose of in one piece if small enough to ship to disposal site
  - Option 2: Separate Steam Dome from Lower Assembly
    - Facilitates shipment to disposal site in two pieces ***and***
    - Allows Steam Drum to be segmented and disposed of at a lower overall cost
- Result: Decontamination and/or complete segmentation of S/Gs (and other large components) in the U.S. is typically not a cost effective option

CY Steam Generator Removal and Shipping

Steam Generator Dome – Shipped by Rail to Clive, Utah

Steam Generator Lower Assembly – Shipped by Barge and Rail to Barnwell, SC

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Need Effective Waste Management Planning Due to Simultaneous Activities (San Onofre Unit 1)

Important Lesson Learned for Decommissioning Waste Management

- Need Waste Management Plan to:
  - Define Appropriate Waste Disposal Methods
  - Determine Decontamination vs. Disposal Strategy Considering Waste Disposal Costs
  - Select Options for Packaging and Transport
  - Plan the On-Site Routing of Wastes
  - Decommissioning Project Sequence will Affect Waste Management
  - Decommissioning Waste often is Created Faster then it can be Shipped – May need Large Staging Areas

Metal Recycle Experience in the U.S.

- Metal Released for Unrestricted Use can be Sent to Recycler
- Metal Recyclers have Radiation Detectors at Facility Entrance
- Unrestricted Release Criteria in US: No Detectable Activity
  - Required Survey Instrument Sensitivity
    - Surface Contamination (Beta/Gamma Activity) – 0.83 Bq/cm^2
    - Final Aggregate Survey of Truck leaving Site for Recycler
      - Often Performed with Gamma Sensitive Truck Monitor
- Surface Contaminated Metals Released by
  - Health Physics Technicians at Power Plant Sites
  - At Centralized Processing Facility such:
    - EnergySolutions (Memphis and Oak Ridge, Tennessee)

Metals That Have Recycle Potential

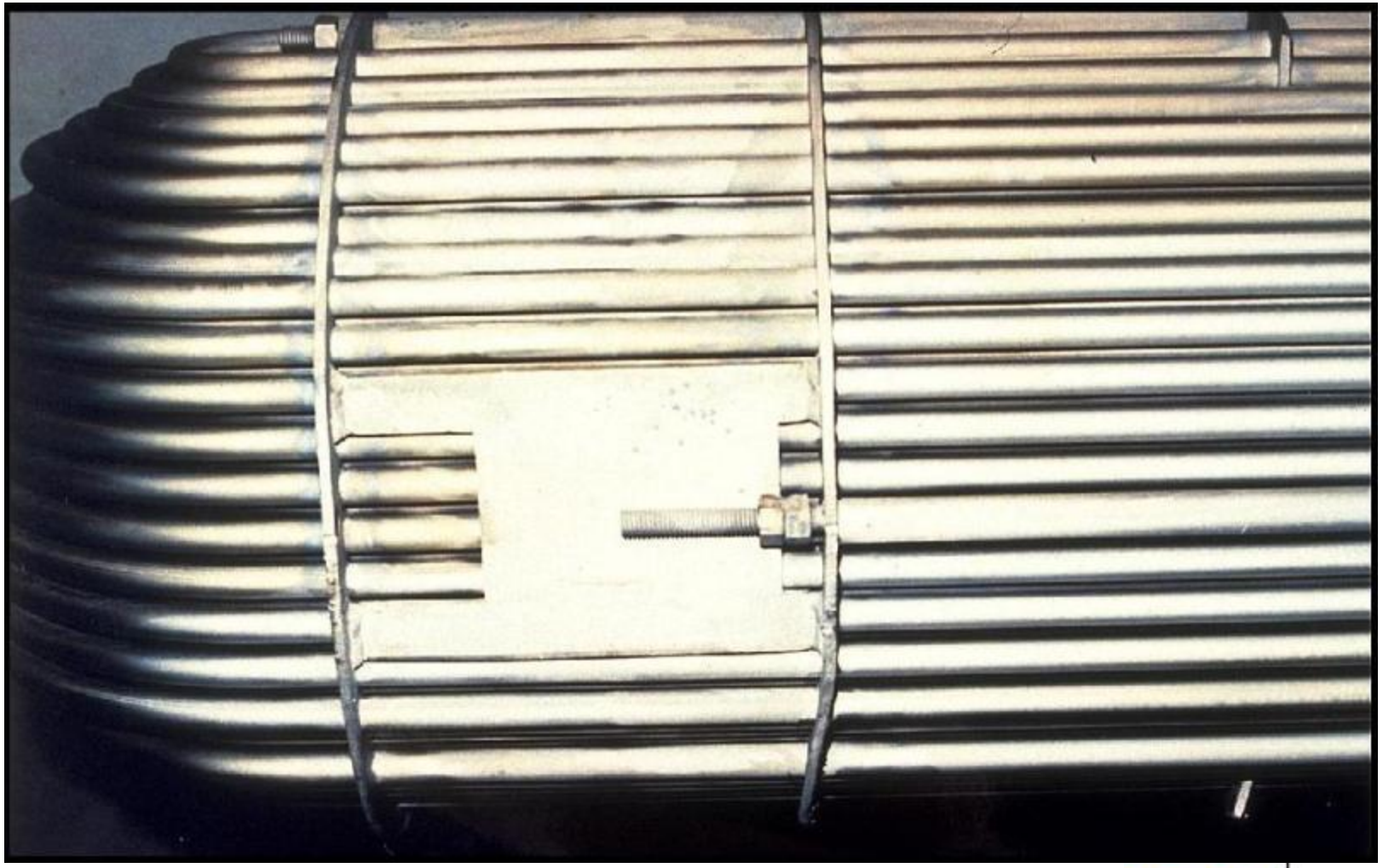
- Lead (Shielding, Waste Packages)
- Nickel (Steam Generator Tubing)
- Steel (Carbon and Stainless)
  - US Department Of Energy Road Barriers
  - Waste Packages
- Metals with PCB Paint >50 ppm Released from Connecticut Yankee Site to Recycler (Avoided Special Disposal)
- Neutron Activated Metals Generally not Candidates due to Volumetric vs. Surface Contamination

Techniques for Decontamination of Metals

- Decon Useful Precursor to Recycling
- Mostly Performed in Decon Enclosures with:
  - Water Wash (Hot and Cold)
  - Grit Blast
    - Not effective for convoluted surfaces, Lead
  - Dry Ice Blasting
- Chemical Decon (i.e., EPRI DfD and DfDX Processes)
- Wiping
- Planing (Mechanical Removal of Surface Layer of Lead)
- Secondary Waste Minimization Important

Skid Mounted DfDX Equipment

DfD Decontaminated Steel – (Part of a BWR Heat Exchanger)



Recycle of Contaminated Metals in US

- Metal Melting in Foundry-like Process
- Non-metal Radionuclides (i.e., Cs, Pu) Rise to the Surface of the Melt and are Separated as Slag
- Radionuclides like Cobalt and Nickel stay in the Melt
- At the Peak of Recycling in 1995, 13,600 tones/yr of Carbon and Stainless Steel Recycled (Total US Radioactive Scrap Inventory in 1999: 1.8 M tones)
- Public Concern that some Radioactivity was left in Metal to be Recycled into Commercial Products
- In 2000 DOE Suspended Unrestricted Release of all Scrap Metal from Radiological Areas
- Use of Metal Melt for DOE Restricted to Items going for Reuse at a “Controlled” Nuclear Location

Recycle of Lead from Radiologically Controlled Areas

- As of 2004, DOE had Recycled 710 tones of Lead at a Savings of Approximately 2.5 Million Euros
- Lead Used in Shielding Products
- U.S. Disposal Costs for Lead in 2004 was 6 Euros/kg (Encapsulation in Plastic Required)
- Recycling Costs approximately 3 Euros/kg
- Limits on Contamination Levels in Metals to be Recycled through “Controlled” Release Procedure
- Type of items formed from Recycled Lead
  - Radwaste Drums
  - Shipping Casks

Recycled Lead Bricks Sent to NASA

Recycled Lead Integrated as Shielding in Shipping Container

Potential Recycle of Nickel

- Price of Nickel Currently Approximately 10,000 Euros/ton
- Inventories of highly pure (low elemental Cobalt content) Nickel have existed (Decommissioning of DOE Enrichment Facilities)
- Each new PWR Steam Generator requires approximately 75 tones of Nickel for the Inconel 690 used for the tubing
- Process:
  - Decontaminate the Contaminated Nickel
  - Melt with appropriate alloying constituents to form Alloy 690
- Not Done in US for non-technical reasons

EnergySolutions Metal Recycle Facility – Oak Ridge, Tennessee

- U.S. Nuclear Industry needs which can use slightly contaminated metal:
  - Shield blocks
  - Waste containers
  - Security barriers
  - Shipping casks (can also utilize contaminated lead)
- From 1994 to 2007 over 54 million kg of metal has been processed for recycle by Energy Solutions

Induction Furnace at EnergySolutions Facility

Shield Blocks for High Energy Test Facilities

Summary

- In the U.S.:
  - No Clearance Levels
  - Due to Low Disposal Costs, Contaminated Metal not usually Recycled
  - Decontamination is Primary Metal Volume Reduction Method
  - Where Reuse in a “Nuclear” Application is Available, Cost Savings have been Substantial (i.e., DOE Lead Recycle)
- Related EPRI Reports
  - ***#1013512 “Program on Technology Innovation: Controlled Recycling of Contaminated Materials for Nuclear Industry Uses” 2006***
  - ***#1013280 “The EPRI DFDX Process- Final Report” 2006***

Other Related EPRI Reports

- ***Connecticut Yankee Decommissioning Experience Report (1013511, 2006)***
- ***Maine Yankee Decommissioning – Experience Report. (1011734, 2005)***
- ***WasteLogic™ Decommissioning Waste Manager, 2.1 and Solid Waste Manager 2.1. (1007632, 2003)***
- ***Decommissioning Waste Reduction Guide (TR- 110234, 1999)***
- ***Decommissioning Waste Management Workshop Proceedings. (1000006, 2000)***

New EPRI report to be Published in 2014***, Waste Management for Decommissioning***, will discuss all aspects of Decommissioning Waste Management

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