NUCL 402 Engineering of Nuclear Power Systems

Lecture 18: Waste Management

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Radioactive Waste

Milling: ^{230}Th (α,γ)76000y, ^{226}Ra (α,γ)1620y, ^{222}Rn-, (α,γ)3.823d

Radition level < few mrem/hr

Mill Liquid Waste: 2500 Metric ton/day of liquid waste
U-natural=800 (pCi/l)=0.01 g/ml, ^{226}Ra=350(pCi/l), ^{230Th}=22000(pCi/l)

Conversion Facility: 10,000 Metric Ton of U/yr produces 1000 metric tons of solid waste while making UF_6
U-natural=0.6Ci, Th-natural=4.0Ci, ^{234}U=0.5Ci, ^{234}Th=0.6Ci, Protactinium234=0.6Ci, ^{226}Ra=0.5Ci : Total *6.7Ci*

Enrichment Facility :Daughter nuclide of ^{234}U –basicallysolid waste

Fuel Fabrication: Process gaseous radwaste, liquid radwaste

Reactor Core: Volatile radio-nuclides, treatment of moderator, coolant

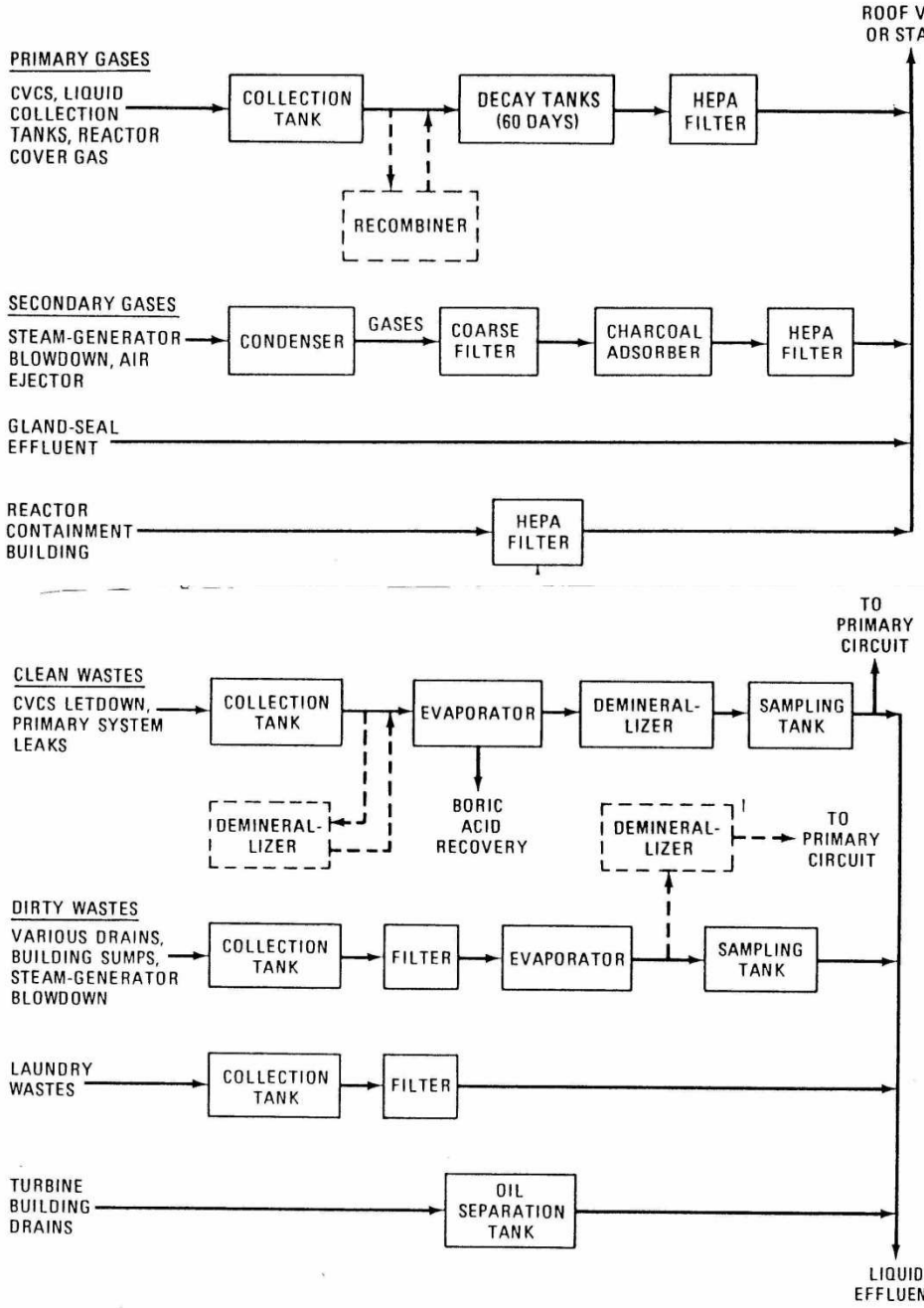

Fig. 9.5. Liquid radwaste system of a PWR.

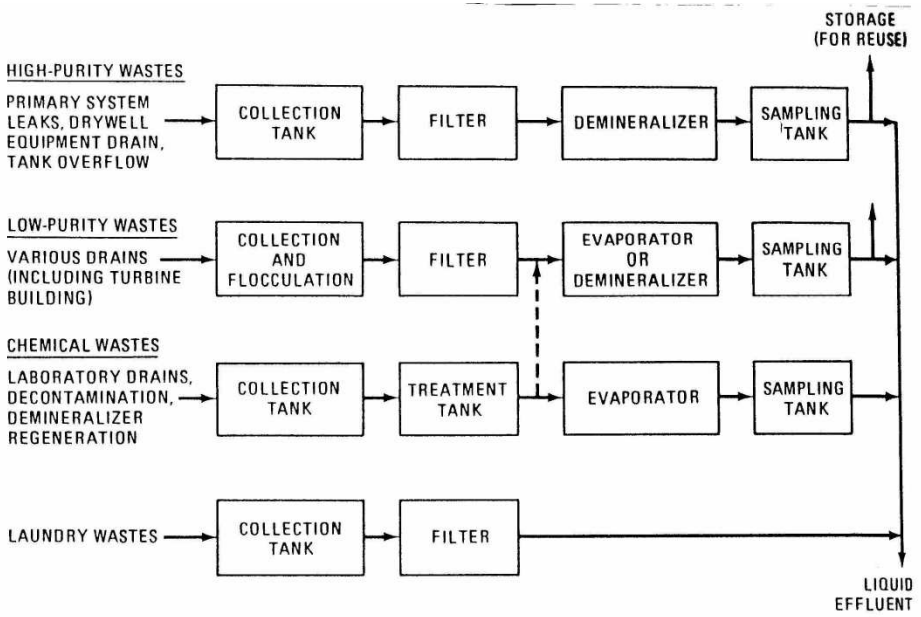

Fig. 9.7. Liquid radwaste system of a BWR.

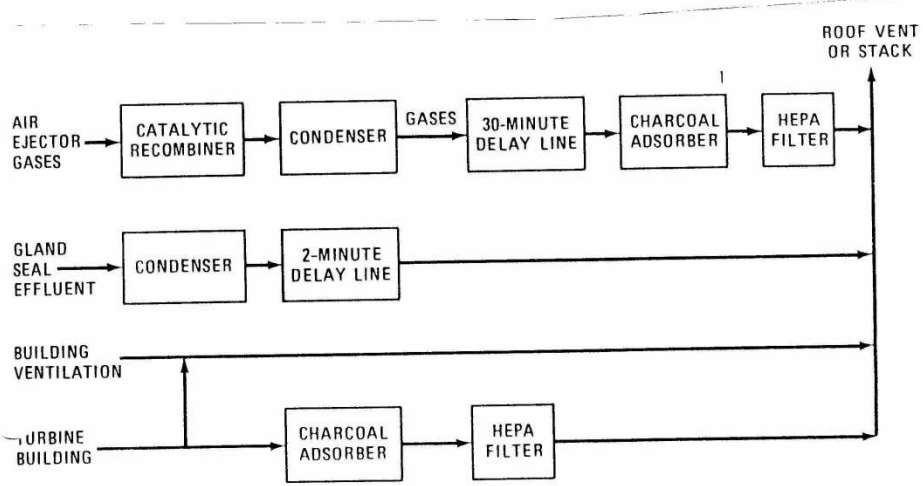

Fig. 9.8. Gaseous radwaste system of a BWR.

Radioactive Waste

High Level Radioactive Waste

The U.S. NRC describes high--level radioactive wastes as the highly radioactive materials produced as a by product of the reactions that occur inside nuclear reactors. High—level wastes take one of two forms:

Spent (used) reactor fuel when it is accepted for disposal

Waste materials remaining after spent fuel is reprocessed

Spent nuclear fuel is used fuel from a reactor that is no longer efficient in creating electricity, because its fission process has slowed. However, it is still thermally hot,, highly radioactive, and potentially harmful. Until a permanent disposal repository for spent nuclear fuel is built, licensees must safely store this fuel at their reactors.

Radioactive Waste

Low Level Radioactive Waste

The U.S. Nuclear Regulatory Commission defines low-level waste as including items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation.

Low-level waste is typically stored on-site by licensees, either until it has decayed away and can be disposed of as ordinary trash,, or until amounts are large enough for shipment to a low-level waste disposal site in containers approved by the Department of Transportation.

Radioactive Waste

Fuel Reprocessing: Liquid waste

Cladding wastes are the residual zircaloy and SS cladding and structure components-radioactiove due to n-induced isotope Need biological shielding of several inches of lead and heat removal at the rate of 50 to 100 W/ft^3

Regulations call for the reprocessing waste (high level) to be solidified within 5 years after they are generated and for the resultant stable solids to be shipped to a federal repository within 10 years aftre the liquid are generated.

TABLE 1.3: VOLATILE RADIONUCLIDE INVENTORY IN A 1,000 MWe NUCLEAR POWER PLANT

Parameters: 3,040 MWt PWR, operating at full power for 500 days with 1% of the fuel rods having cladding defects*.

Radionuclide	Half-life	Total Activity In: Reactor Core (mega-curies) *	Fuel-Cladding Gap (mega-curies) *	Primary Coolant (curies)
Iodines				
I-131	8.05d	74.9	0.76	465
I-132	2.3 h	114.0	0.14	186
I-133	21. h	171.0	0.64	766
I-134	52. m	206.0	0.12	117
I-135	6.7 h	158.0	0.34	420
Kryptons				
Kr-85	10.8 y	0.66	0.067	334
Kr-85m	4.4 h	33.5	0.95	439
Kr-87	76. m	64.4	0.076	261
Kr-88	2.8 h	93.0	0.149	775
Xenons				
Xe-133	5.3 d	164.0	4.17	52,290
Xe-133m	2.3 d	4.0	0.019	692
Xe-135	9.2 h	43.6	0.084	1,488
Xe-135m	15.6 m	46.4	0.016	42

*Converted from 1,721.4 MWt to 3,040 MWt and core volume adjusted to scale.

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TABLE 1.13: COMPOSITIONS OF LWR AQUEOUS REPROCESSING WASTES

Component	Concentrations* (g/l) Fission Product Waste	Alpha-Active Waste	Solvent Clean-up Waste	Caustic Scrubber Waste**
U^{6+}	0.80	0.018	2.6	-
Pu^{6+}	0.008	0.16	0.008	-
H^{+}	0.95	1.01	-	-
Na^{+}	-	-	159	190
Fe^{3+}	0.6	0.2	-	-
Ni^{2+}	0.08	0.02	-	-
Cr^{3+}	0.08	0.02	-	-
Fission products***	21.1	Trace	Trace	Trace
Actinides	4.43	Trace	Trace	Trace
CO_3^{2-}	-	-	18.2	-
OH^{-}	-	-	-	70
NO_3^{-}	98.0	62.9	388	255
PO_4^{3-}	0.1	-	Trace	-

*Concentrations are based on volumes, in gal/metric ton, of 330 for first column, 15 for second, 30 for third and 10 for fourth.

**Based on 1% HNO_3 loss from process.

***Based on a fuel exposure of 33,000 MWd/metric ton.

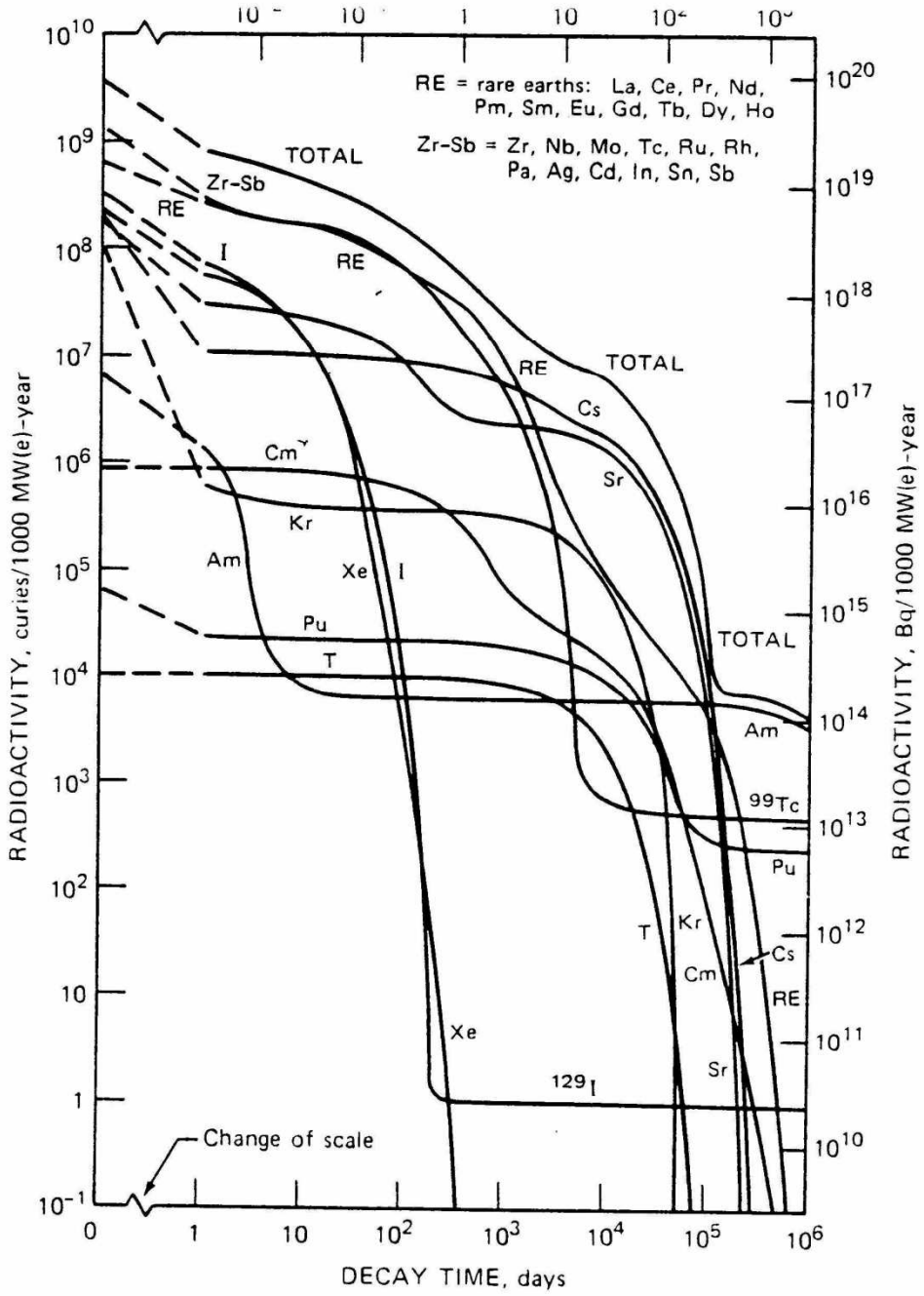

Fig. 8.13. Radioactivity of waste from uranium fuel reprocessing, based on a burnup of 2.85 TJ/kg U (33,000 MW·d/1000 kg) and 99.5 percent plutonium removal (T. H. Pigford [24]).

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Solidfying the Waste

Spray Calcination : Liquid sprayed into the top of a cylindrical tower heater in a furnace –solid calcine collected at bottom

Fluidized Bed Calcinations: Water evaporated in a heated fluidized bed of particles made from previous dried waste

For long term storage – Calcine heated with glass-forming frit containing borax and silica-borosilicate glass less leachable by water +high thermal conductivity

1000 MWe LWR plant:" 30-35 MT of spent fuel per year→3.2 m^3 of high-level solid waste→(0.3m Diax3m High) cylinder x15 containers

Storage Facility

Water Cooled Storage: Typically hold 50 to 150 MT of irradiated fuel. Storage of packed LWR fuel assemblies – water circulation in a closed loop system through a filter and dematerialize. The pool gives cooling, shielding and visual inspection

Air Cooled Vaults: Good for fuel after 3-4 years for solidified high level waste. Used for CANDU reactor

Packaging of Spent Fuel – Seal the fuel assembly inside a container after filling the container with solid or gaseous heat transfer medium. Typically containers are SS for water cooled and Al for air/gas cooled.

Calcine heated with glass-forming frit containing borax and silica-borosilicate glass less leachable by water +high thermal conductivity

1000 MWe LWR plant:" 30-35 MT of spent fuel per year→3.2 m^3 of high-level solid waste→(0.3m Diax3m High) cylinder x15 containers

Waste Storage and Dosposal

Spent fuel Vs reprocessed fuel waste

(1) Spent fuel contains volatile and gaseous fission products,

(2) Pu and U will be present ; U activity small initially increases with time due to alpha decay. Pu initial activity 200 times greater than solid reprocessed waste, but decreases with time.

(3) Approximately activity values for the solid waste at and after 600 years are also applicable to spent fuel

(4) Mass of spent fuel is 10 times greater than solid waste and 16 times volume required to store

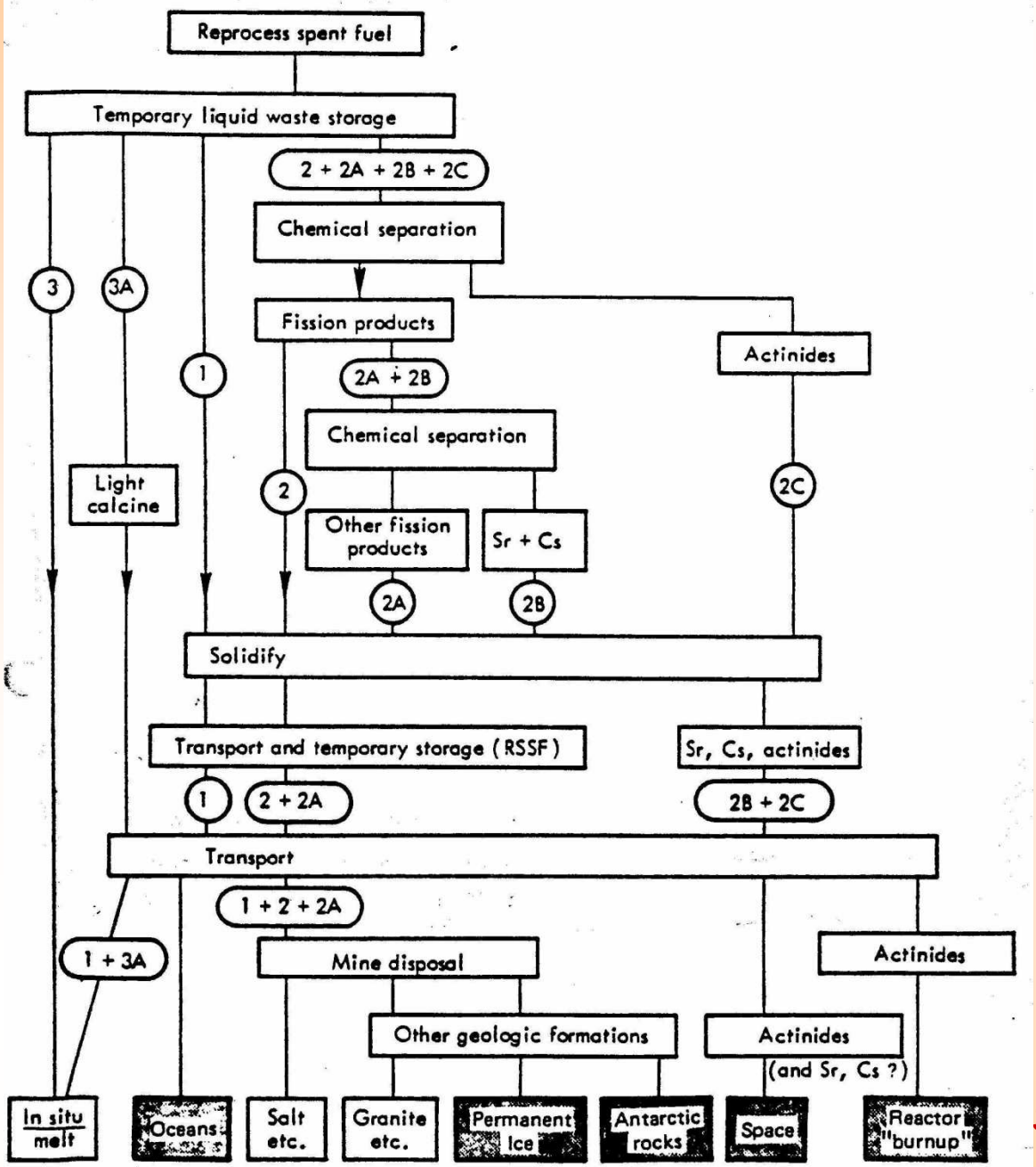
Isolation –Public and environment

Storage –retrievable, Disposable- permanent isolation

In US no reprocessing is done –Store spent fuel

For longer stoarge- dry geological formations -Yucca mountain

Waste Disposal Options



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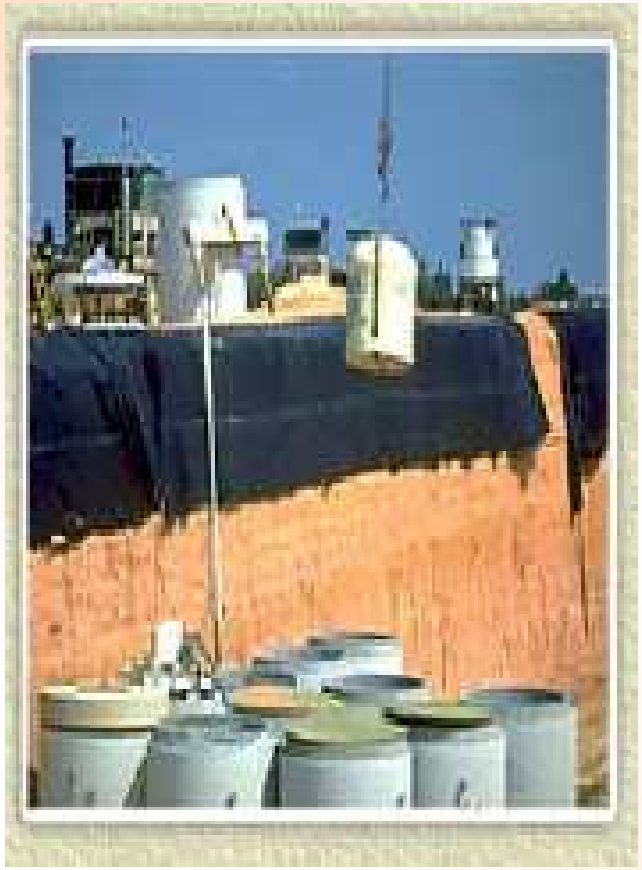
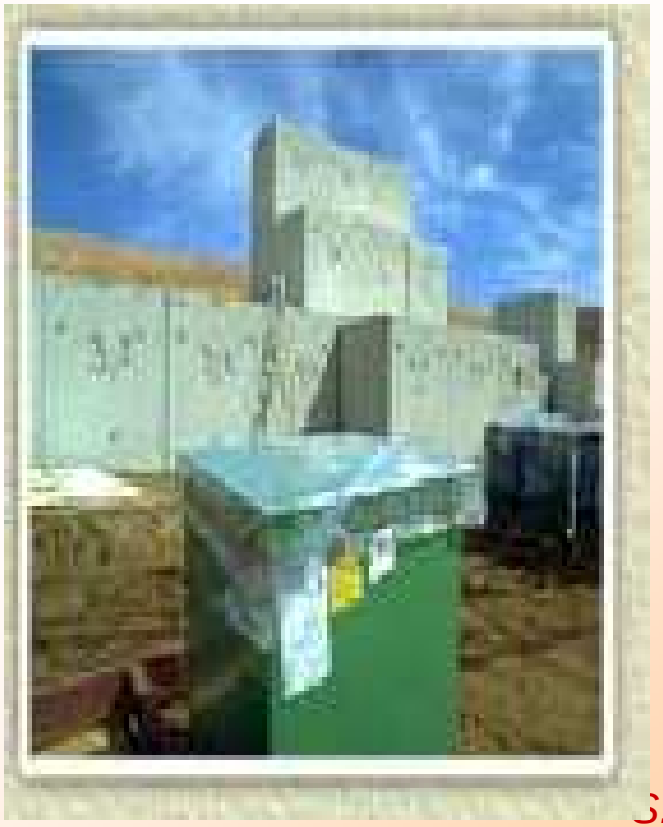
Waste Disposal/handling

Low Level Waste

Three existing low level radioactive waste disposal facilities
Barnwell SC, Hanford WA, and Clive UT

Low Level Radioactive Waste is encapsulated either by solidification or placement in High Integrity Containers.





Dry Fuel Storage

Temporary Dry Fuel Storage at Power Plant Site

- ENERCON Services has provided engineering services for 18 Dry Fuel Storage Projects throughout the US.

- Dry Fuel Storage Projects include design and engineering for:
  - Storage Pad
  - Facility Security
  - Electrical
  - Federal Licensing
  - Local and State Permitting
  - Cask Heavy Load Lifting

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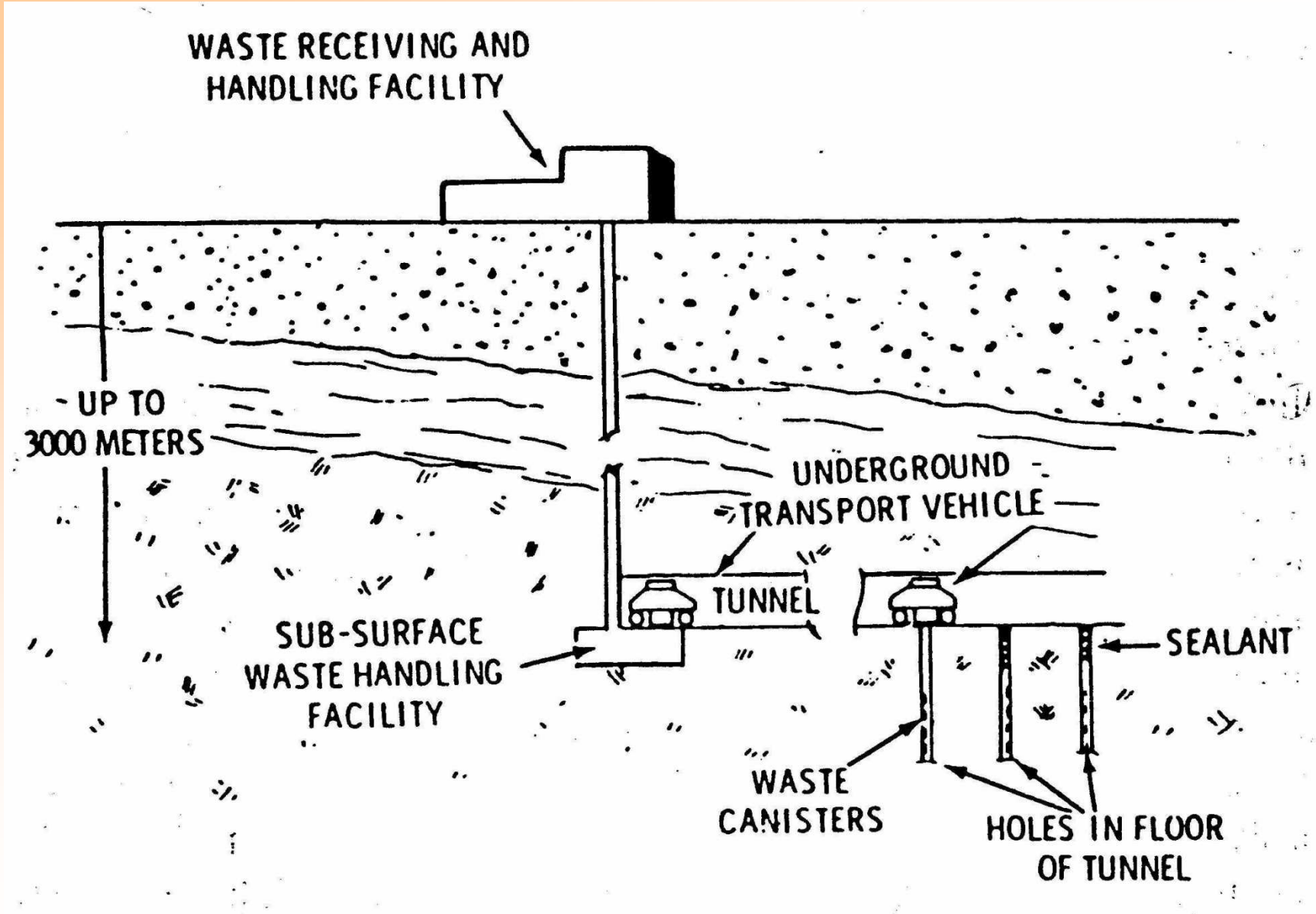

Fig. 22.6. Nuclear waste isolation of geologic emplacement.

At the Repository, Fuel Will Be Transferred to a Special Disposal Container

Transportation Containers Are Strong and Safe

Yucca Mountain Being Considered As Disposal Site

Yucca Mountain Has Been Thoroughly Investigated

Seven Miles of Tunnels Built in Yucca Mountain

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