

4. Solid LLW: in US LLW is not HLW, TRU, tailings, "acceptable for land disposal" <10 nCi/g of TRU, LLW "produced" and "requiring offsite disposal", management options: on/off site, allowable limits on release

LLW Streams produced by Power Reactors (R), Medical, Academic and Institutional generators (M), Industry (I) and Government (G).

Source	R	M	I	G
Compacted trash or solids			X	X X X
Dry active waste, dewatered ion-exchange resins			X	
Contaminated bulk and plant hardware		X	X	X
Liquid scintillation wastes, absorbed liquids		X	X	X
Biological waste+ animal carcasses		X		

LLRW Policy Amendments Act of 1985: compact states*, surcharge 10-40\$

Management steps*: segregation 10 CFR 61* class A, B, C requirements: stable 300 y, <1% free water, explosive, toxic gases

Sources: tailings: sand + slimes Ra-226, bone, Rn-222 lungs, cancer Composition of Uranium Mill Tailings:

Dry solids (pCi/g) : U₃O₈ : 63, 226-Ra : 450, 230-Th : 430;
Total = 4400 pCi/g = 163 Bq/g

Liquids (g/l) : ammonia : 0.5, Ca : 0.5, Cl : 0.3, Fe : 1, Mn : 0.5, Hg : 7E-5, Mo : 0.1, Na : 0.2, sulphates : 30;

Liquids (pCi/l) : U : 5400, 226-Ra : 400, 230-Th : 1500, 210-Pb, 210-Po, 210-Pb, 210-Bi : 400.

Production: 1800 t/d, 1E+14 Bq/y, onsite impoundments 1

km long, 10 m high, 80 ha, wet/dry, stabilization + closure,
 NRC 1979-2000 20 MCi Rn-222 181 deaths

Tailing sites: 7 US states (NM 50% Wyo 30% Utah + Col
 6% Texas 4% Wash, SD), $9E+7$ m³, 408 kCi, 9 kW;
 remedial actions: $17E+6$ m³, Grand Junction (Col),
 Canonsburg (Pen)

U conversion: refineries, enrichment, 1400 m³, 56 Ci/y, 0.4
 mCi/m³

Reactors: PWR 480 m³/y, BWR 820 m³/y, resins, filters, ..

Decontamination: cooling systems, steam generator tubes,
 resins, chelates

Immediate Decommissioning waste:

Waste Stream	PWR		BWR	
	Volume (ft ³)	Activity (Ci)	Volume (ft ³)	Activity (Ci)
Activated metal	97100	4841300	4900	6552300
Activated concrete	25000	2000	3200	200
Contaminated metal	192000	900	549200	8600
Contaminated concrete	374700	100	59200	100
Dry solid waste (trash)	50600	-	119500	-
Spent resins	1100	42000	1500	200
Filter cartridges	300	5000	-	-
Evaporator bottoms	4700	-	18300	43800
Total	745800	4889300	754800	6605200

Institutions: biological, thrash, accelerator targets, sealed
 sources, paper, rags

Industry: 36000 m³/y, 390 kCi/y, production of RI,

radiopharmaceuticals, industrial LLW Streams (1980):

Waste Stream	Volume (ft ³)	SA (Ci/ft ³)	Activity (kCi)
Medical isotope production	6800	16	109
Industrial tritium	3500	66	231
Sealed sources	200	160	32
Other (A > 1 Ci/ft ³)	2600	6	16
Source and special nuclear material	1103500	8E-5	0.1
Other (A < 1 Ci/ft ³)	162700	8E-5	0.01
Total	1279300	-	388

Government: 1600 m³/y in 1984, 2%, hospitals, research, defense

Phosphogypsum: phosphates, slimes, Florida, Ra ~1 Bq/g, 1E+9 t, 11 Mt/y, 1 kCi

Categories: (non)combustible, (non)compactable

noncombustible + noncompactable: filters, 175/y, R/h

compactable: 210 l drums, boxes

special classes: mixed, toxic, corrosive, inflammable, explosive, few %, GTCC

Technologies: transfer, concentration, conditioning

Compaction + compactors*: no water, explosives, volume reduction VR = 2-6X, 210 l drums, 9100 kg, Baling,

Shredding: VR 3X, paper, clothing

Sectioning: metallic, voids

Decontamination: transfer RA to solution, reuse, high-pressure water, steam, electropolishing,..

Combustion: 50%, paper..,+ VR 20-100X, inert, dry,

inorganic solid; - off-gas, ash, rubber, PVC,

Acid digestion: H₂SO₄ + oxidant, scrubbing, low T, single stage, corrosion, teflon, 5 kg/h

Molten salt: oxidizing agent, feed below surface

Technologies: temperature range 800-110 C, excess air, pyrolysis 500 C oxygen deficient, fluidized bed, batch/continuous

Agitated-hearth: 70 kg/h, ram feeding, scrubbers, HEPA

Controlled-air*: 45 kg/h, 2 chambers, offgas: quenching, scrubber +..

Excess-air*: TRU, scrubbers

Fluidized-bed**: 80 kg/h, solids, resins, sludges, liquids

Rotary-kiln*: 40 kg/h, horizontal, scrubber, HEPA

Slagging pyrolysis: vertical furnace, molten slag

Molten glass*:

Packaging: drums, casks steel/concrete, shielding, remote handling

Disposal: 1963 - 1971, 12E+5 m³+ 90 000 m³/y, LLRWPA 1980

Low-Level Wastes at Commercial Burial Sites (in millions of cubic feet): Barnwell, South Carolina : 18.76, Beatty, Nevada : 3.58, Richland, Washington : 9.87, Maxey Flats, Kentucky* : 4.78, Sheffield, Illinois* : 3.12, West Valley, New York* : 2.47; *inactive sites.

Shallow trench burial: 10 m deep, clay cap, leaks in 3 sites (WV,S,MF), erosion of cap, pockets of water, bathtub effect, MF : H-3, Sr-90 1%; problems: settling, cave-ins;

LLRWPA

Site selection: 10 CFR 61, classes A,B,C, geology, hydrology, drainage, meteo,..licensing: survey, communities, characterization; licence: operation 30 y, monitoring 100 y, public protection 500 y

Design: trenches: simple SLRI, engineered LLRI; simple T: 10 m deep no liner, cap; engineered T***: deeper, liner, concrete raft intrusion, \$, water table, flooding, 2 approaches*; piezometers, boreholes, modelling, biogenic gases, stability, flooding,..

Safety assessment: GW, transport paths, GW flows; RI mobilization: fractional release rates, solubilities, diffusive transport (K), direct exhumation (drilling, wells,..)

Alternative designs: 10 CFR 61, operator exposure, narrow trench, square drums, layered waste; tumuli: mounds SLRI, +: GW, ads, -: erosion; below-ground vault**: drainage, life of concrete ? 500 y;

bunker*: France, earth; above-ground V*: roof, intrusion?, weather;

shaft D: concrete cap + walls, \$; intermediate depth D: class B+C, \$; safety requirements: DoE intruder: 500 mrem/y; costs: facility 196-434 M\$ (1986), 1178-2464 \$/m³, 6580 m³/y volume +50% \$ -75%, -75% \$ +300%

Tailings: 1982, 9E+7 m³, 15E+15 Bq, 9 kw; accessible, dispersible, Ra, Rn, health risk; surface impoundments: leachate migration, airborne emissions, stability; design (Ba) + site selection, NRC 10 CFR-40-A, components: dam, liner

(walls, bottom?), basin, cover; liners: permeability (P-m/s), clay: 0.3-1 m P = 1E-9 ion exchange, bentonite, montmorillonite; synthetic L: PVC, neoprene, gunite, hypalon P=1E-11 to 1E-12 resistance, aging; asphalt, concrete; management program: liquid removal, drainage, cover stabilization (clay, soil, rocks)

Alternative designs: above or below grade (AG, BG): above-grade*: dikes, slurry pipeline, water recycled, active care; below grade*: mines, pits, less erosion; excavated BG trench*: sections, sealing, segregation; upgraded conventional AG impoundment*: erosion, isolation, topography, wind

Sea dumping of RW*: controversy, WW 2, ecology movement, 2 routes: liquid LLW, packaged SLLW + HLW?; deliberate, fallout, air emissions, accidents; history: 1946-67 US 4000 TBq Pacific and Atlantic, Gulf of Mexico, 1200 TBq Seawolf submarine, 2800 m site 38'30"N 72'06"W, 10 sites 46'N 17'W countries (B, N, SZ, UK), LLW from NFC, medicine,.. in Atlantic 1948-82: 142 275 t, alpha 680 TBq: Pu* + Am-241 96%, beta 38000 TBq, H-3 15000 TBq, H-3 + Pu-241 87%; Sr-90, Cs-137, Co-60, dumping rates TBq/y: 0.03 U-238 to 1490 Pu-241, packaging (S/H/T); regulation: LDC 1972-5 ratified by 61 states, proscribed: HLW, TBq/kg alpha > 5E-5, beta (T > 1y) > 2E-2, beta (T < 1y) + H-3 > 3; 1000 t max; recommendations: dose < 1 mSv, site: depth > 4 km, 10000 km² 50 N < site < 50 S latitude, clear of continental margins

islands cables fishing..

Safety assessment: RI not detectable, modelling, ID = 20 mSv/y 200 y mollusc Pu-239/241, CD = 4.2 manSv/y C-14, NEA 1985 site suitable for dumping 5 y* 10X; recent developments: 1983 7th meeting (K+N) ban proposed, 1985 9th meeting ban adopted, 10 cancers/y at 200 y shellfish, 1000 deaths/10000 y, C-14 Pu-241, dose to marine life, studies

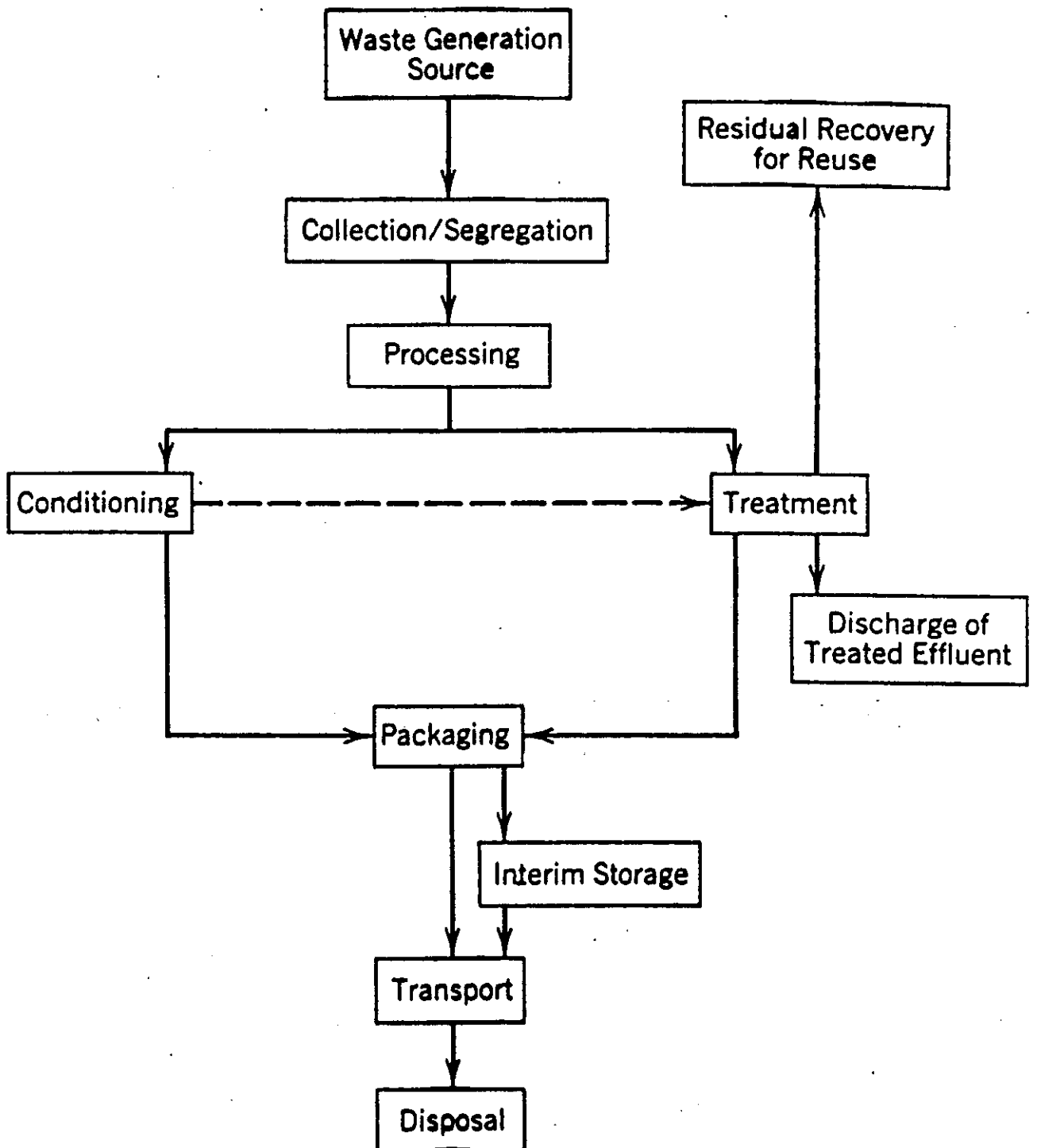
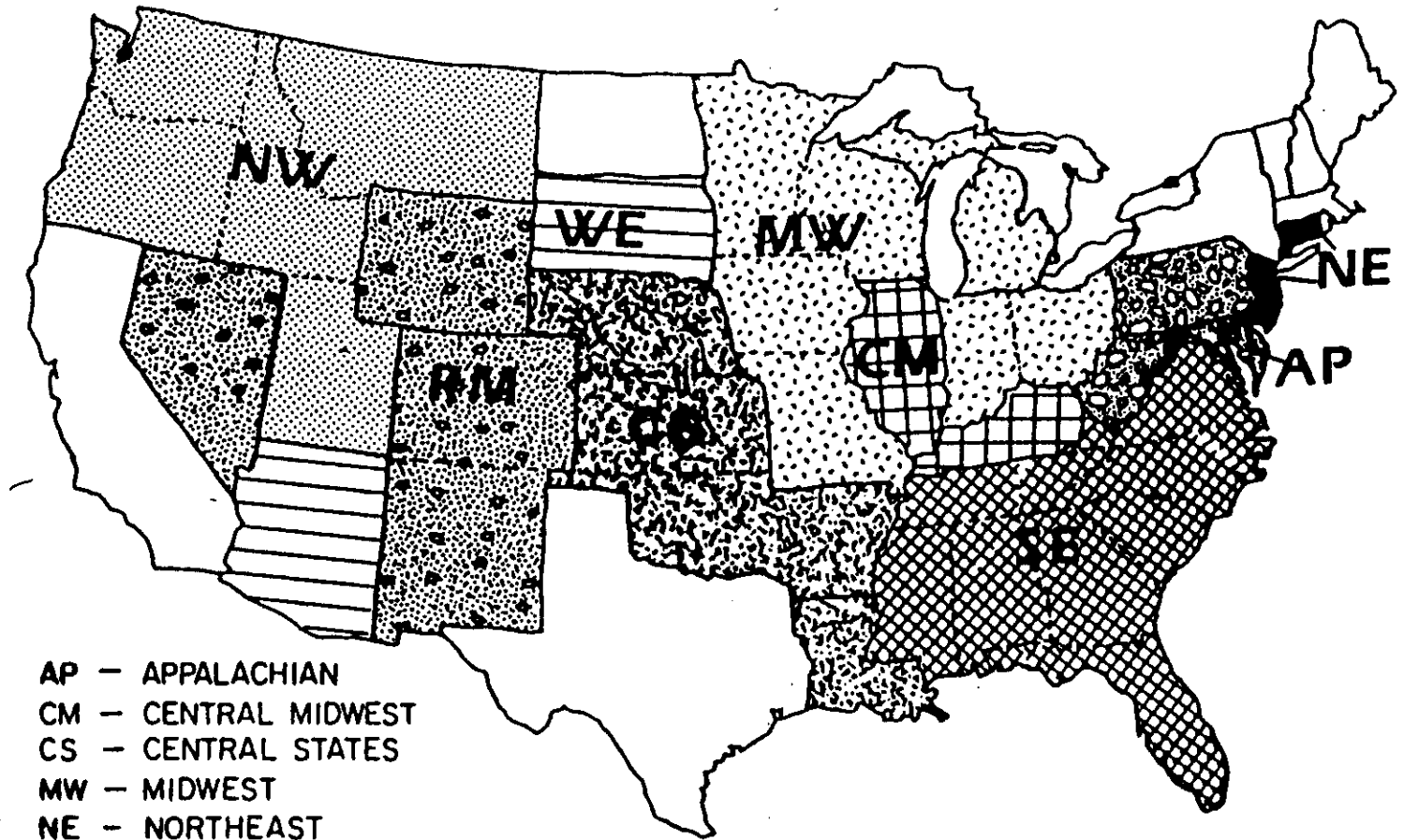


Figure 5-1 Steps in the management of low-level waste.



- AP — APPALACHIAN
- CM — CENTRAL MIDWEST
- CS — CENTRAL STATES
- MW — MIDWEST
- NE — NORTHEAST
- NW — NORTHWEST
- RM — ROCKY MOUNTAIN
- SE — SOUTHEAST
- WE — WESTERN

Interstate compacts for low-level waste disposal. The states without shading have not joined a compact. (Courtesy of *Nuclear News*, American Nuclear Society.)

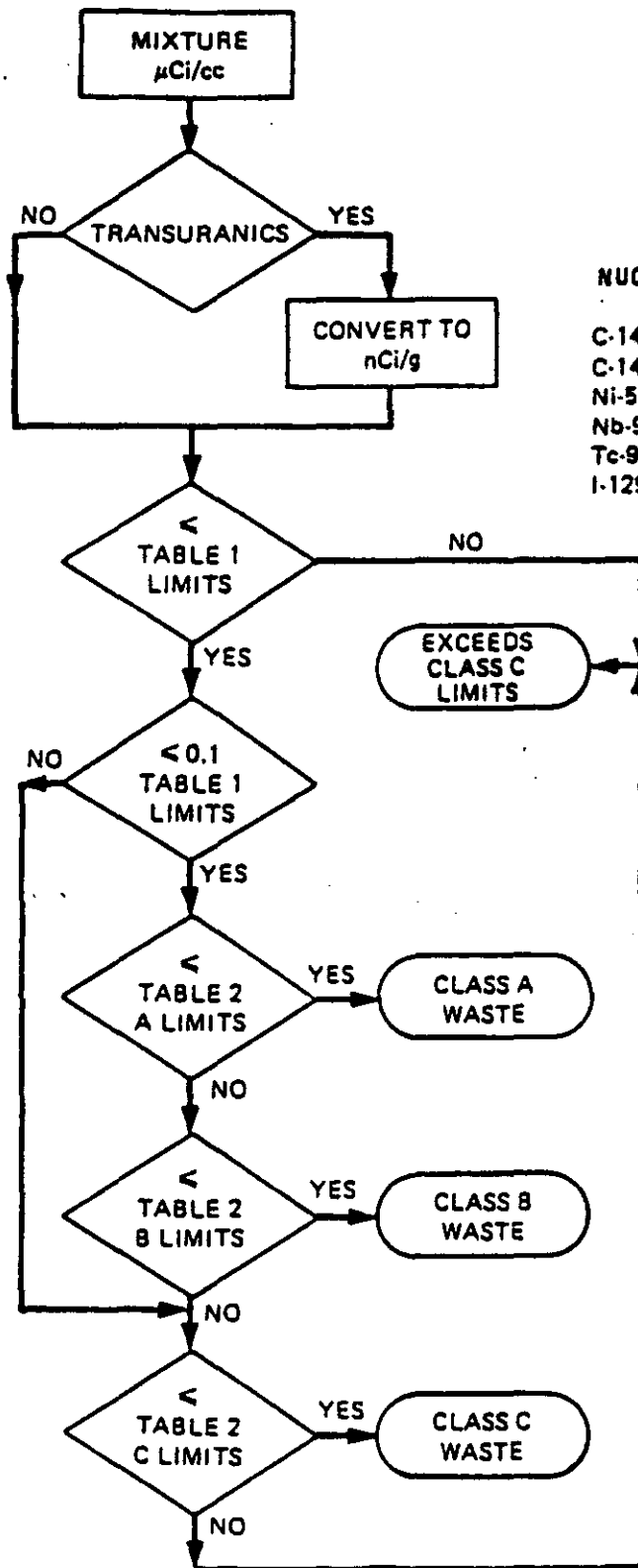


TABLE 1
LONG-LIVED RADIONUCLIDE LIMITS

NUCLIDE	Ci/m ³	NUCLIDE	nCi/g
C-14	8	TRU (t _{1/2} < 5 yr)	100
C-14*	80	Pu-241	3,500
Ni-59*	220	Cm-242	20,000
Nb-94*	0.2		
Tc-99	3		
I-129	0.08		

TABLE 2
SHORT-LIVED RADIONUCLIDE

CLASS A LIMITS

NUCLIDE	Ci/m ³
t _{1/2} < 5 yr	700
H-3	40
Co-60	700
Ni-63	3.5
Ni-63*	35
Sr-90	0.04
Cs-137	1

CLASS B LIMITS

NUCLIDE	Ci/m ³
Ni-63	70
Ni-63*	700
Sr-90	150
Cs-137	44

CLASS C LIMITS

NUCLIDE	Ci/m ³
Ni-63	700
Ni-63*	7000
Sr-90	7000
Cs-137	4600

*IN ACTIVATED METAL

Figure S-2 Classification chart for radioactive waste based on 10 CFR Part 61. Source: (DOE 1984).

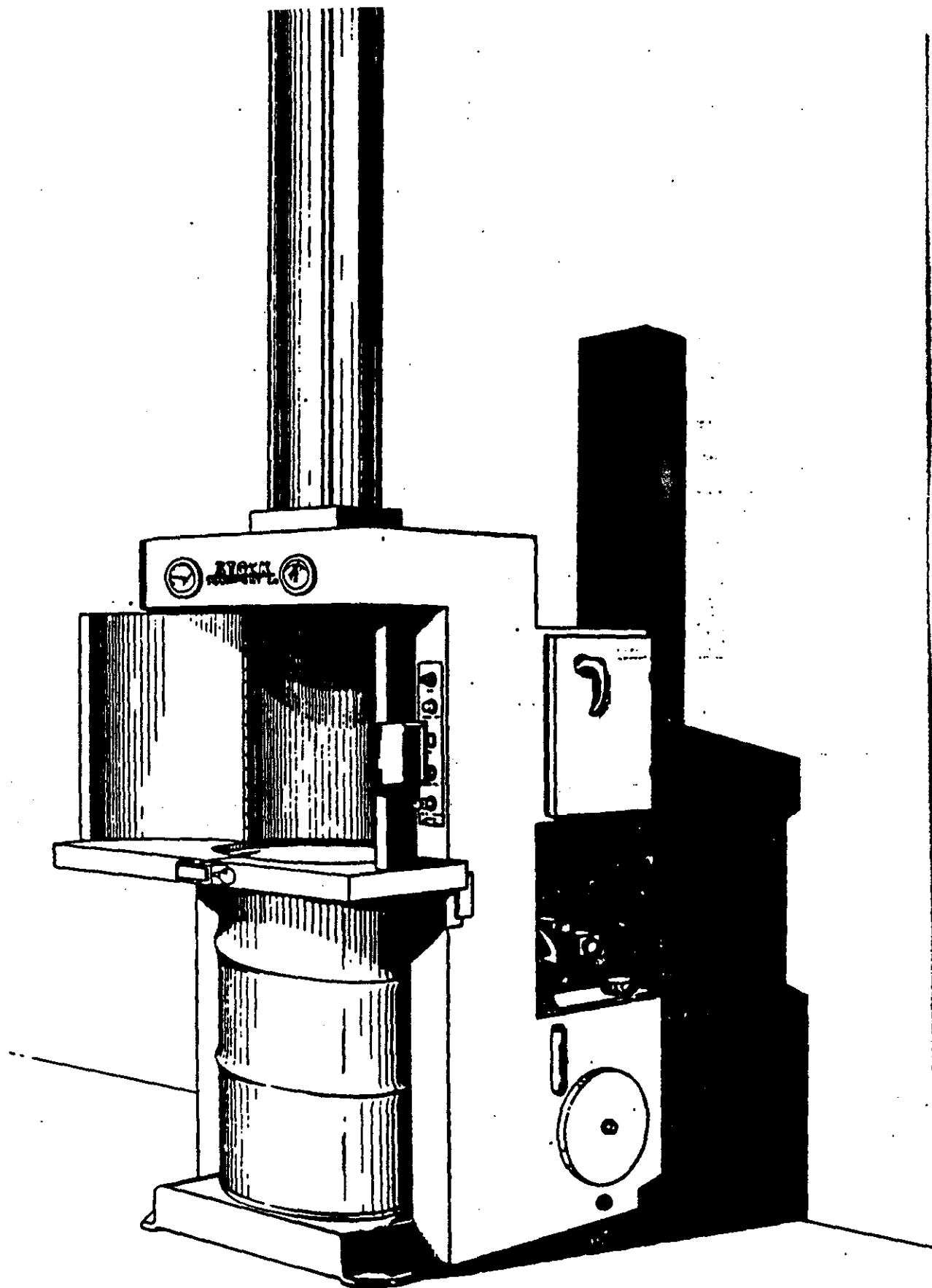


FIG. 13. DRY RADWASTE DRUM COMPACTOR

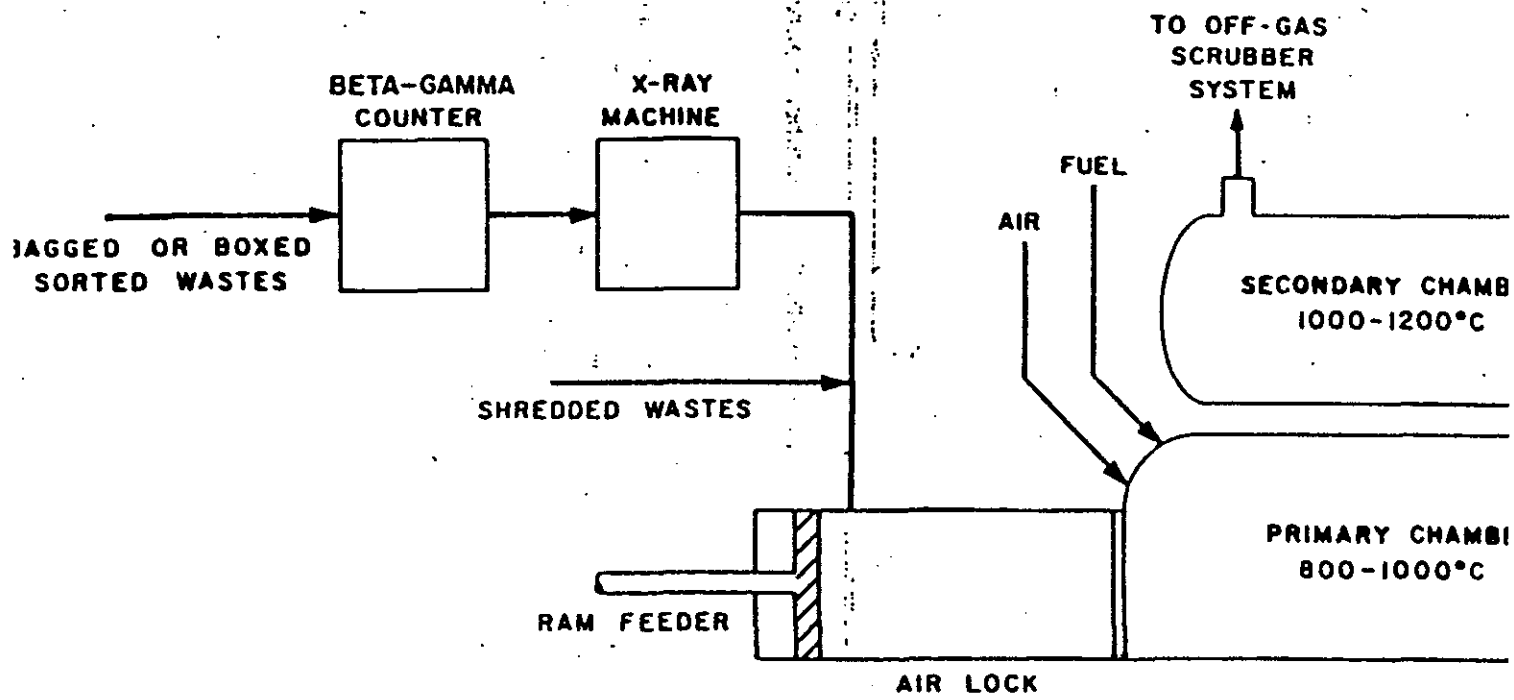


Figure 5-10 Los Alamos National Scientific Laboratory controlled-air incinerator.
Source: (DOE 1984).

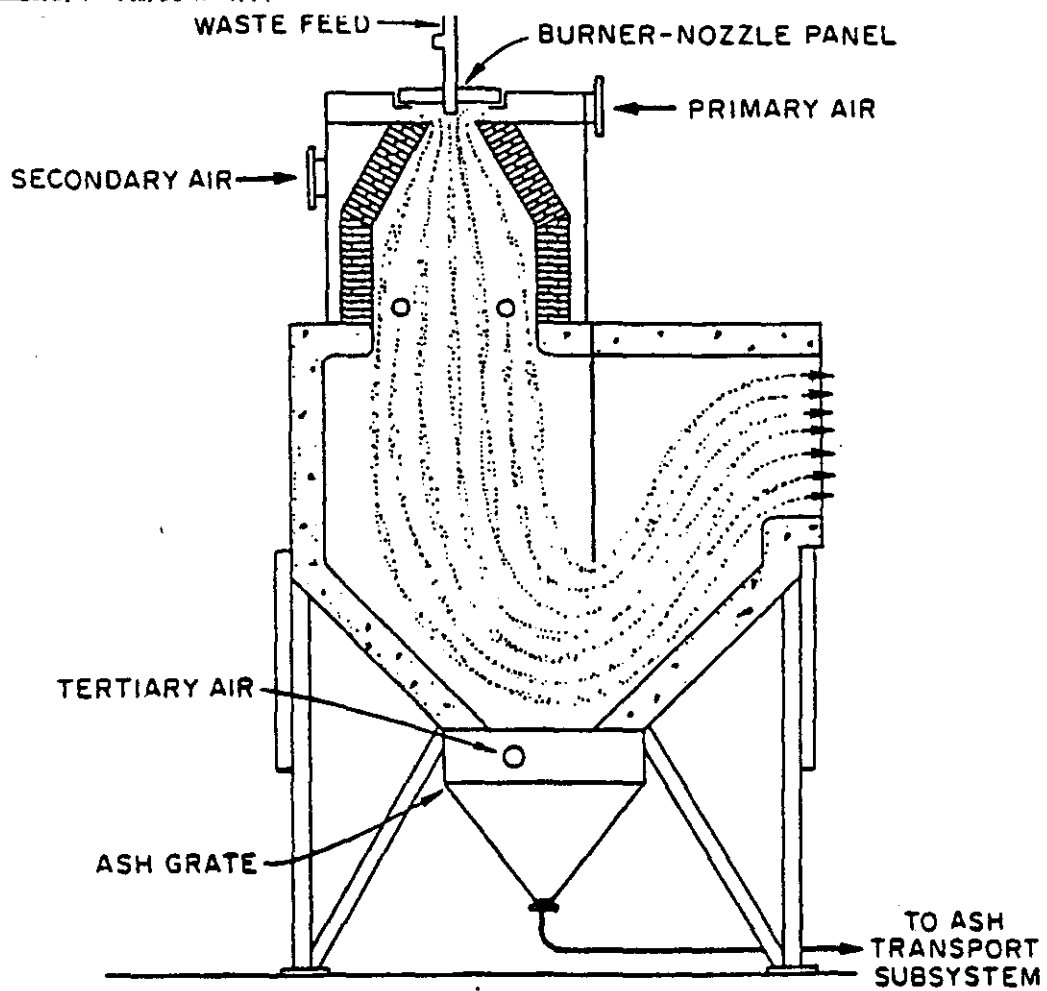


Figure 5-11 Excess-air cyclone incinerator combustion chamber. Source: (DOE 1984).

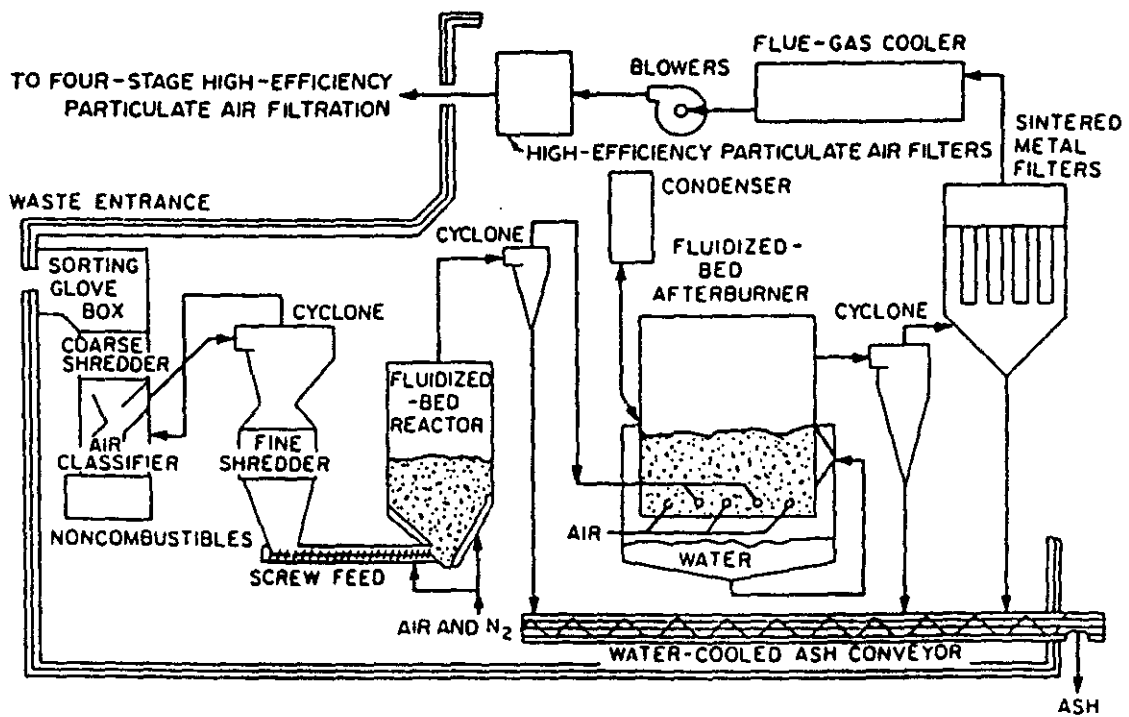


Figure 5-12 Flow diagram of the Rocky Flats Plant fluidized-bed incinerator. Source: (DOE 1984).

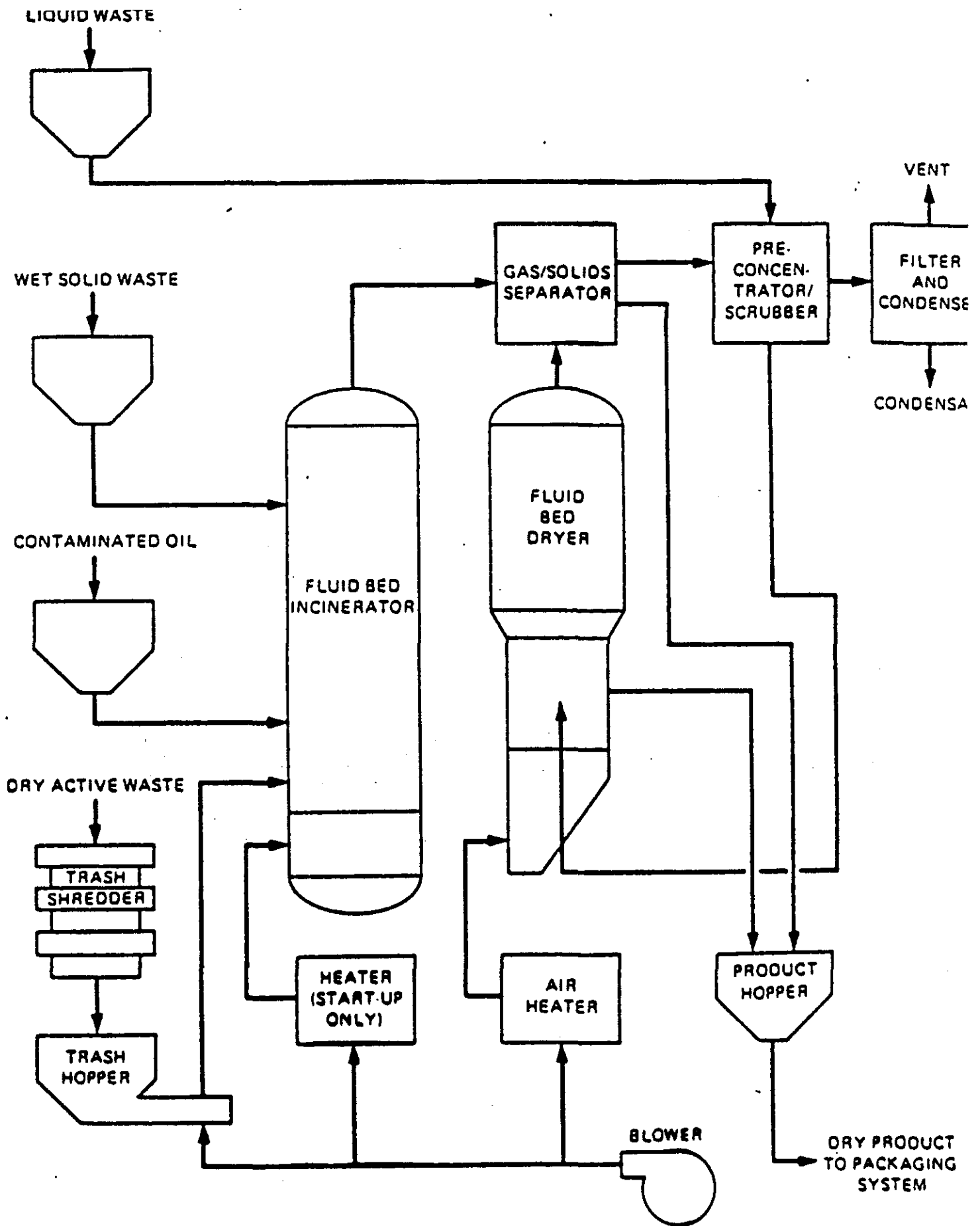


Figure 5-13 Flow diagram of the Aerojet Energy Conversion Company's fluidized-bed dryer/incinerator. Source: (DOE 1984).

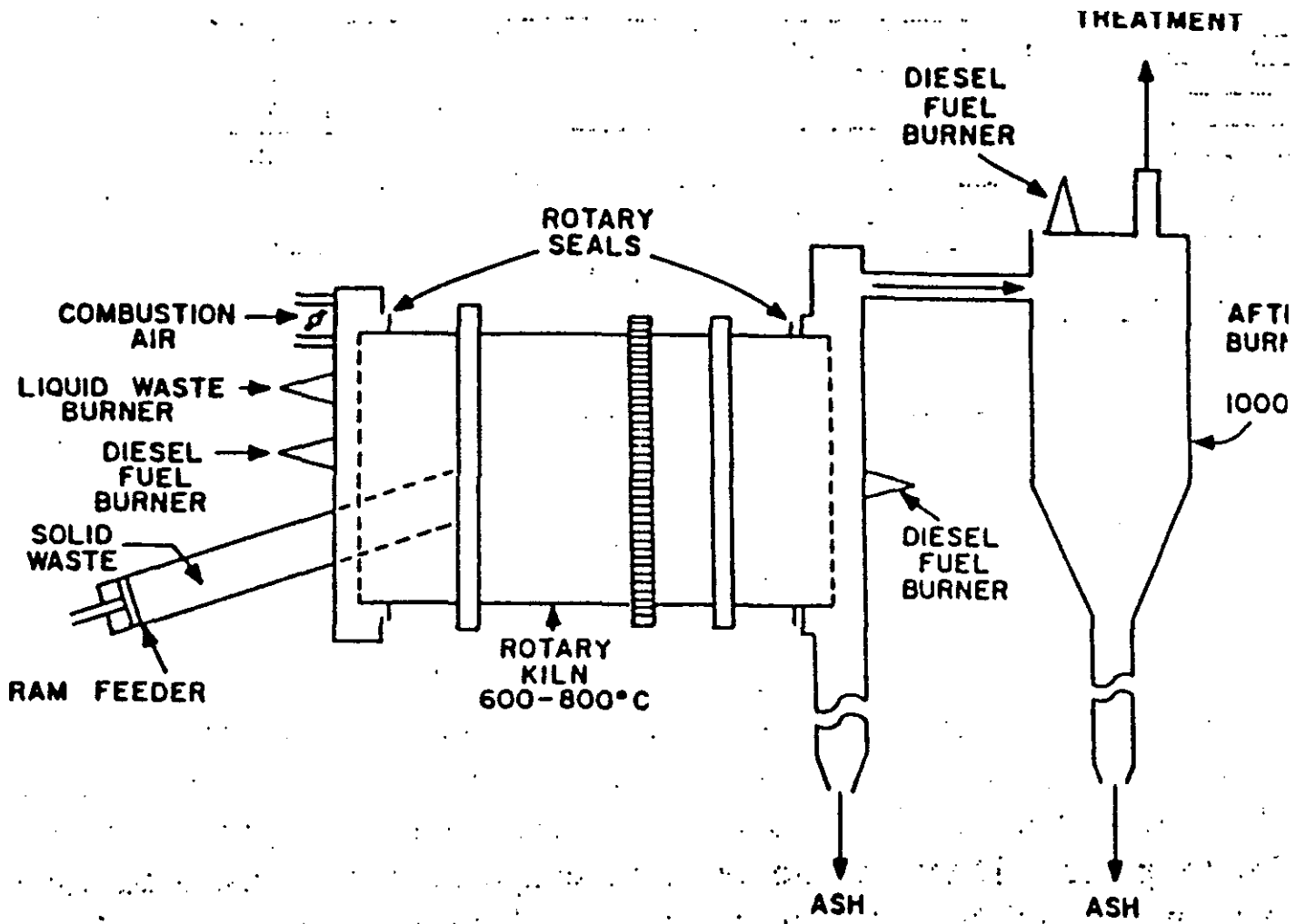


Figure 5-14 Rocky Flats Plant rotary-kiln incinerator. Source: (DOE 1984).

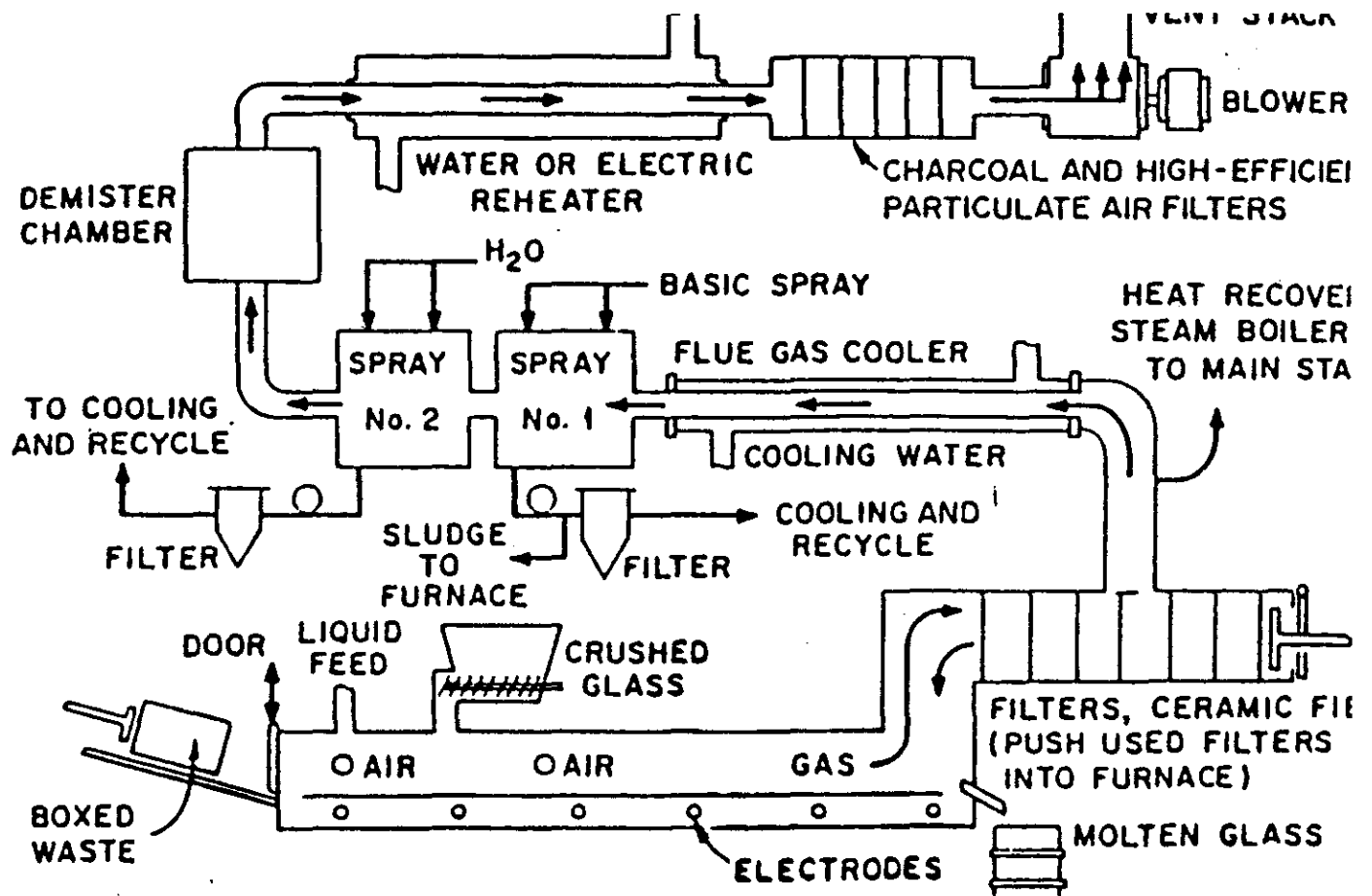
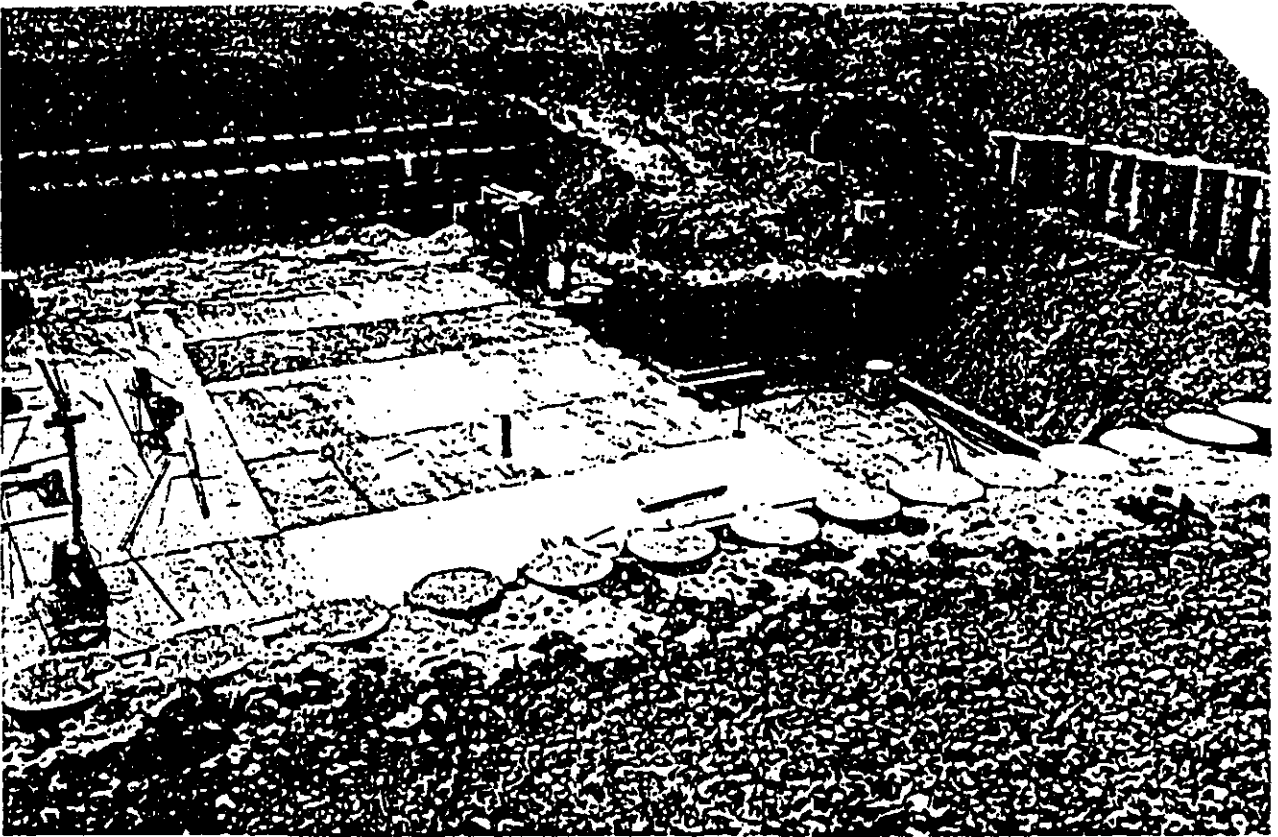
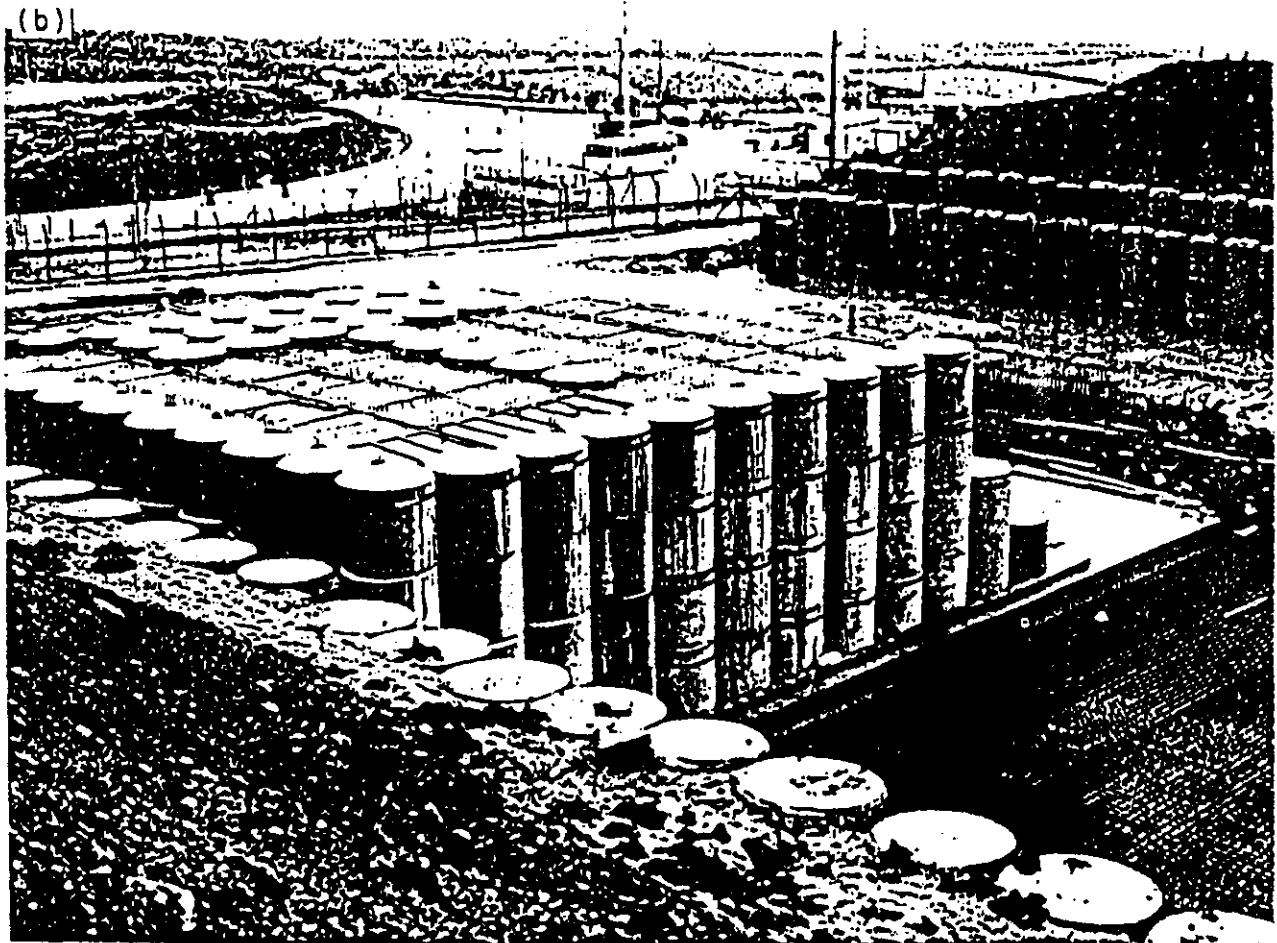


Figure 5-15 Flow diagram of the Penberthy molten-glass incinerator (electrom system. Source: (DOE 1984).



F.9.3a Shallow trench



F9.36 TUMULUS

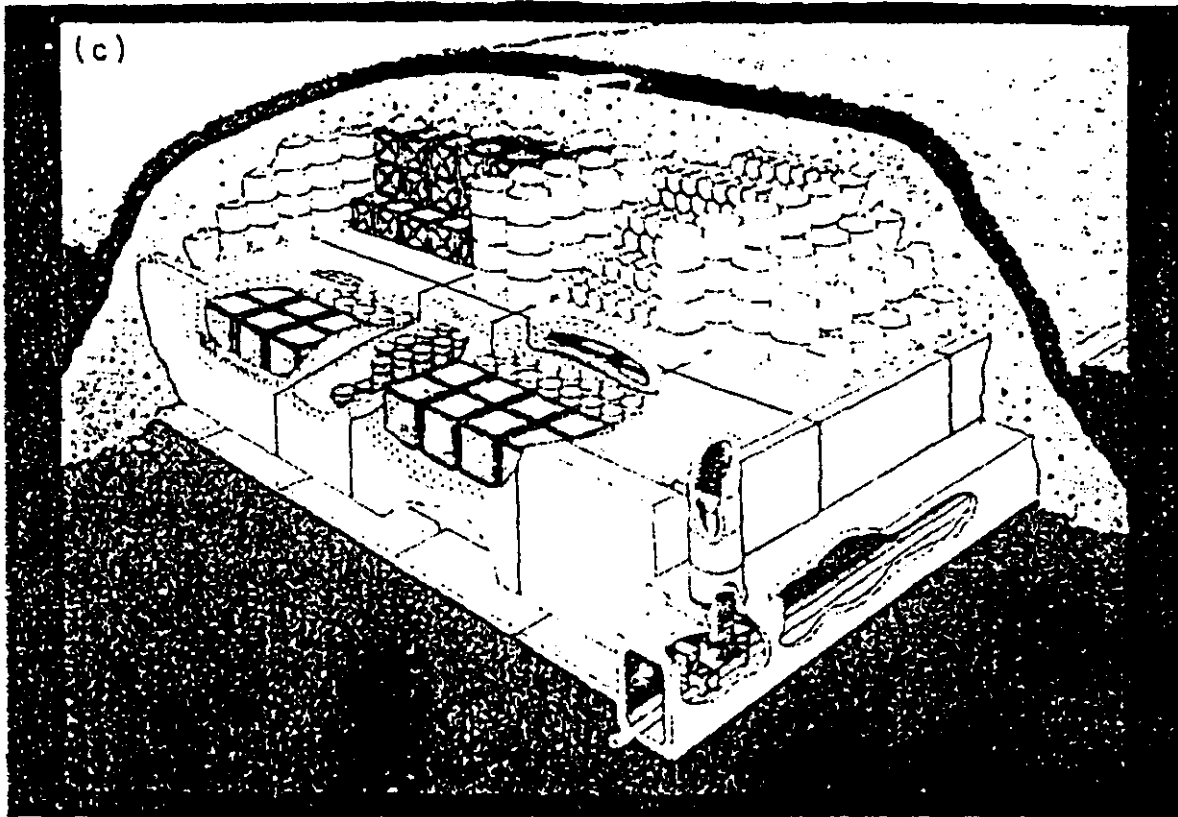


Figure 9.3 The near-surface LLW/ILW disposal facility at Centre Manche, Cap la Hague, France, showing engineered disposal of wastes in concrete containers in (a) shallow trenches capped off with more wastes (b) in a tumulus; shown schematically in (c). Courtesy of CEA/Andra

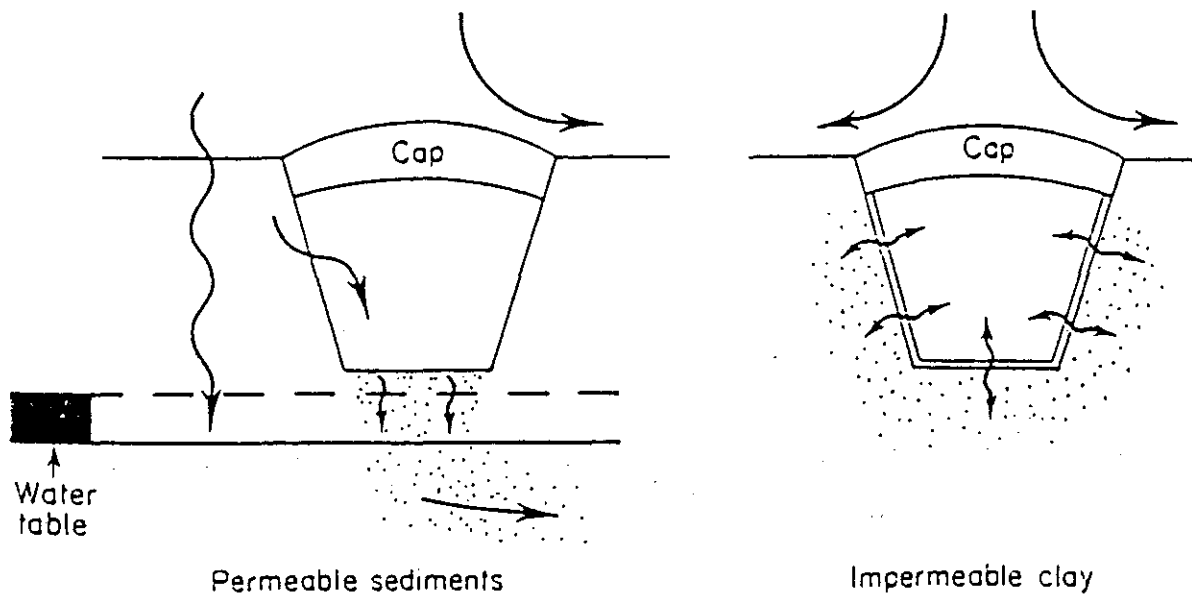


Figure 9.4 Schematic diagram of the concept of trench disposal in permeable sediments above a fluctuating water table, and in impermeable clays below the water table, where transport mechanisms are dominated by diffusion. Directions

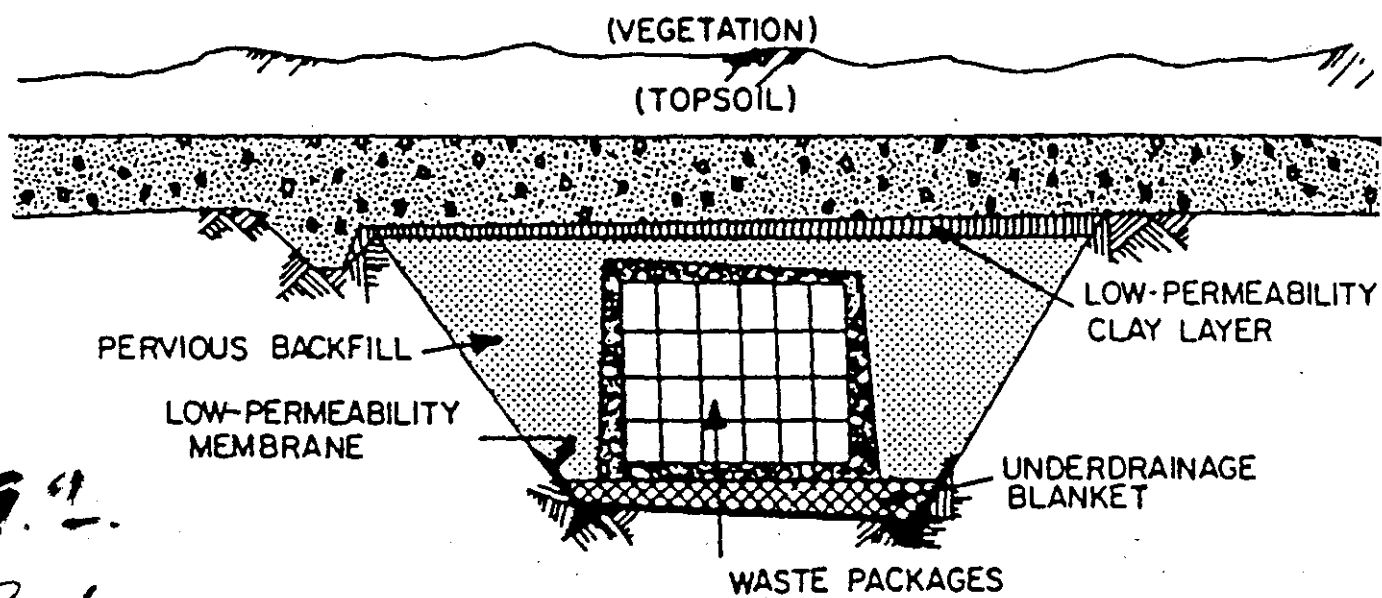


FIG. 1.

Below

-ground vault. (Courtesy of U.S. Nuclear Regulatory Commission.)

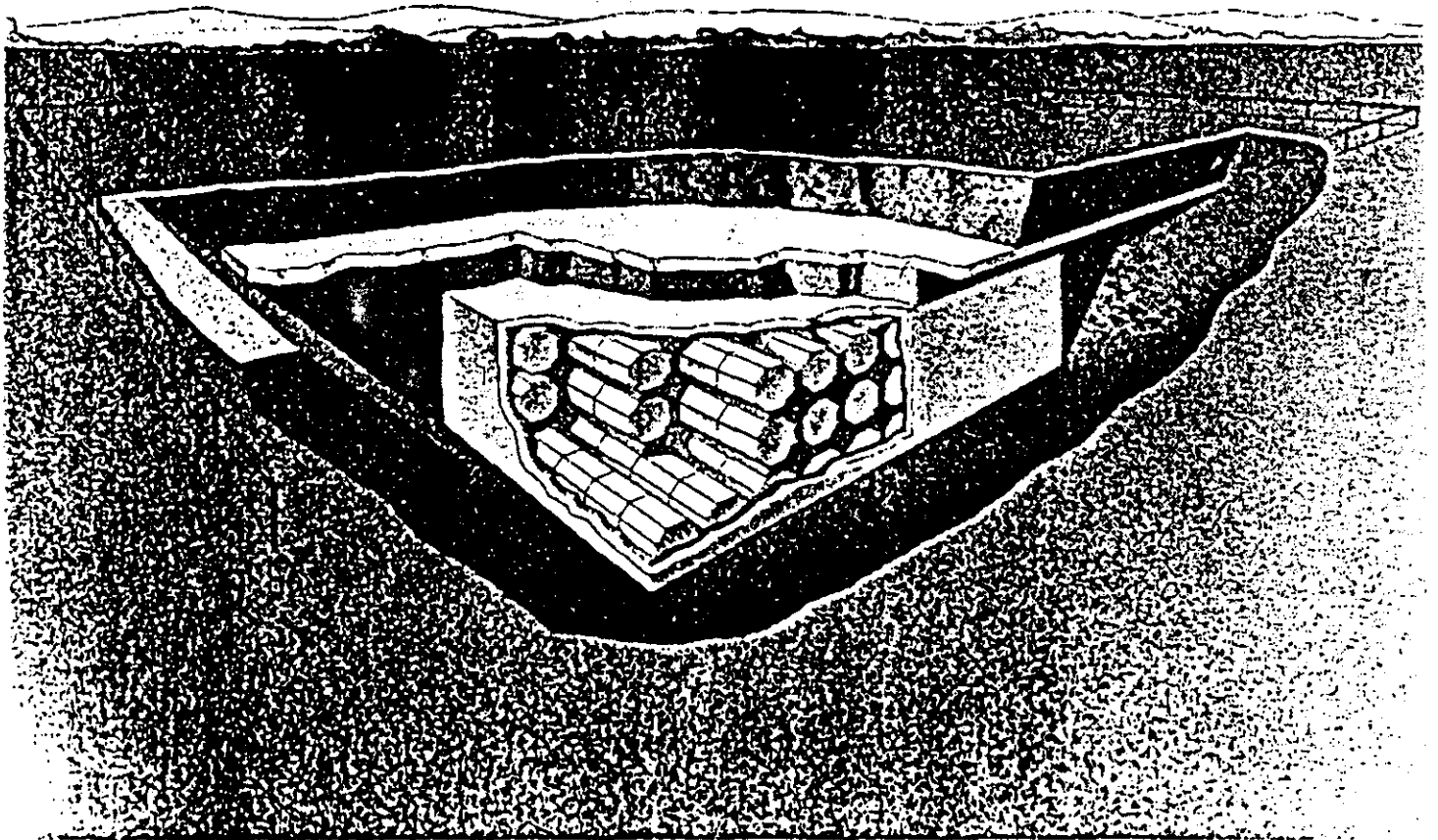
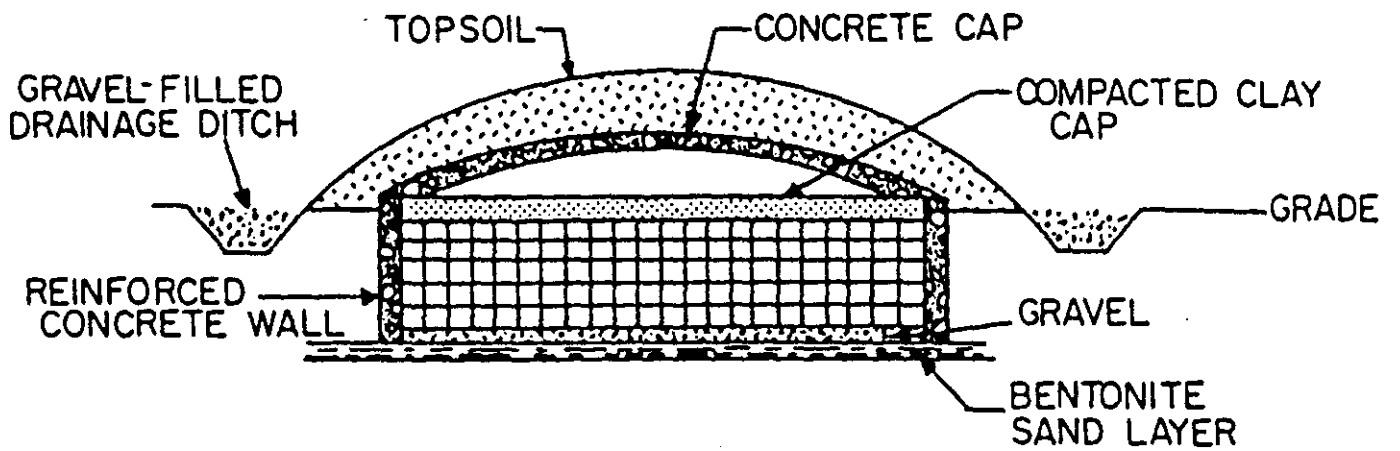
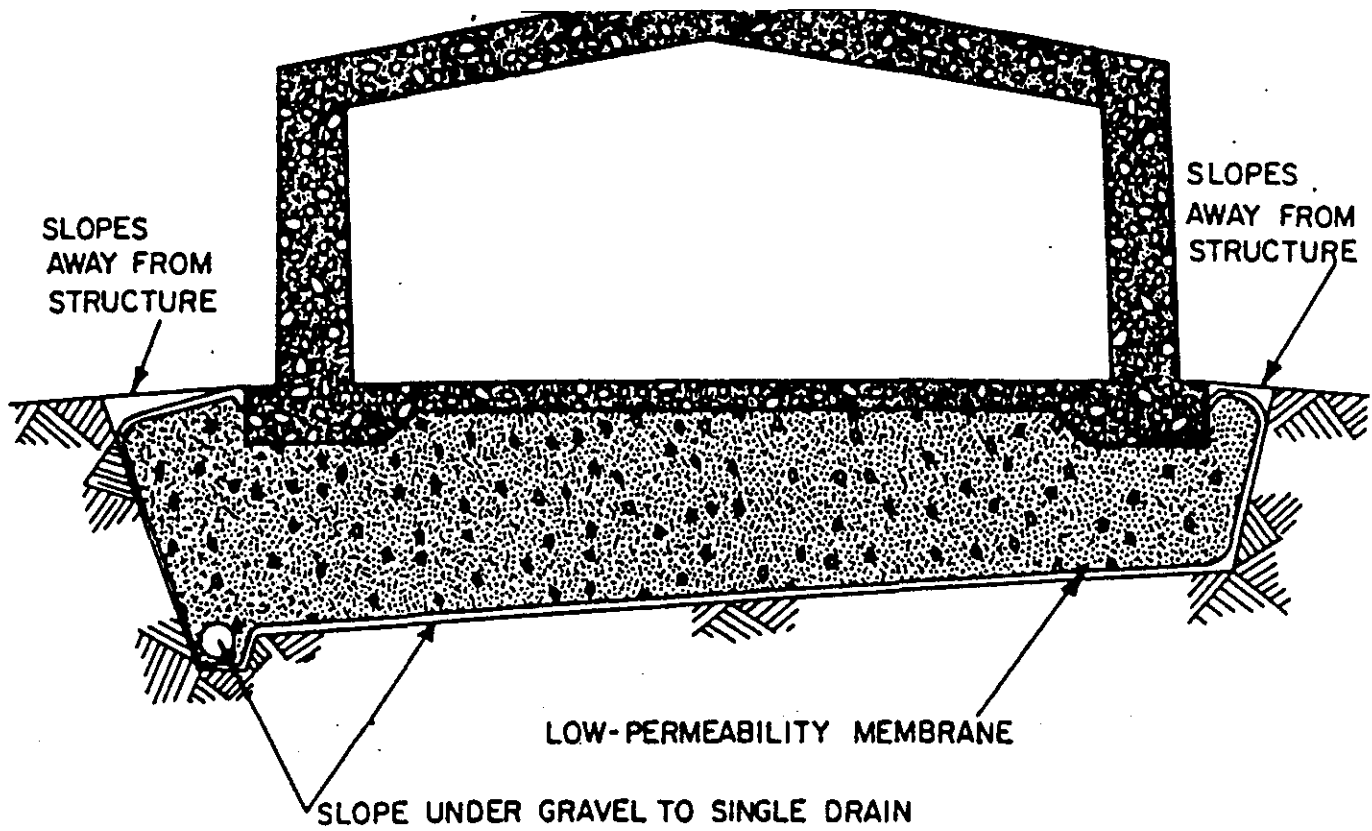


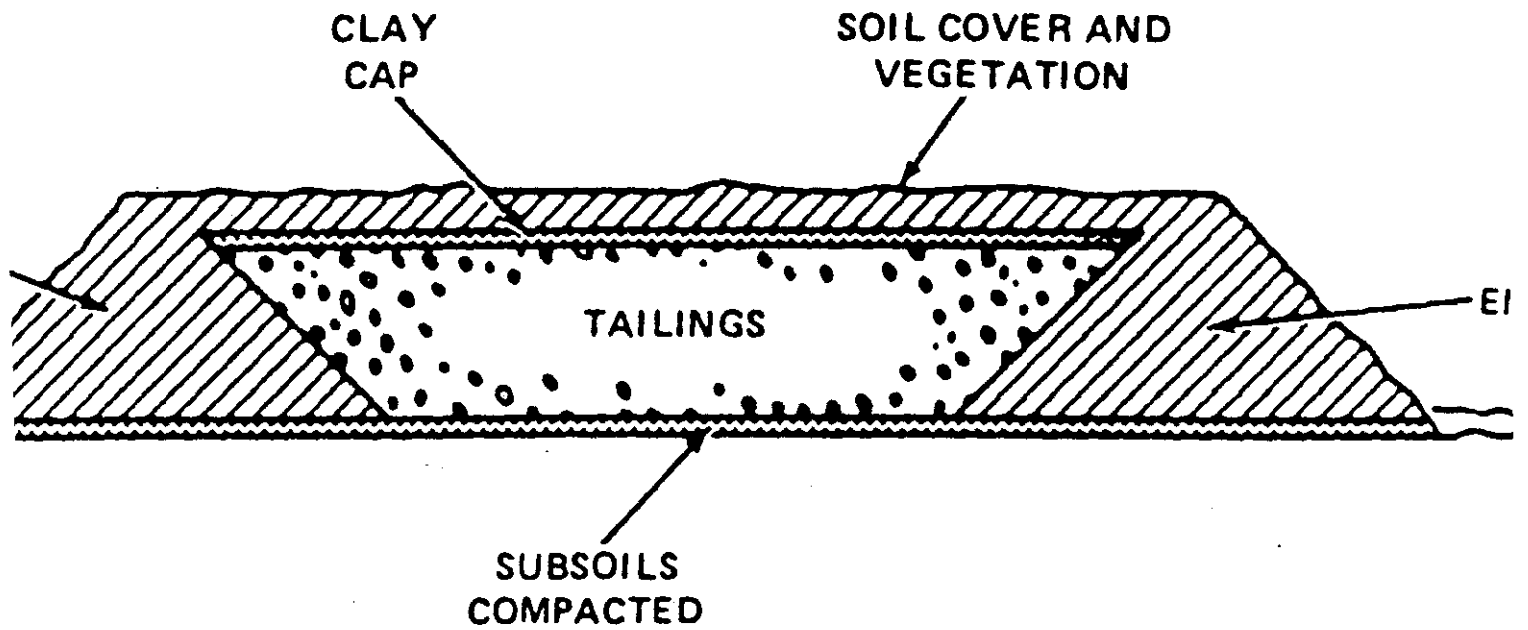
Figure 9.2 Conceptual diagram of an engineered near-surface disposal facility for some categories of low or short-lived intermediate level wastes. The packaged wastes are embedded in cement in a concrete structure, situated below a separate concrete cap designed to protect against inadvertent intrusion (courtesy of UK Nirex Ltd)



Earth-mounded concrete bunker, developed by the French. (Courtesy of the U Nuclear Regulatory Commission.)



above-ground vault. (Courtesy of U.S. Nuclear Regulatory Commission.)



above-grade disposal of uranium tailings. Source: (NRC

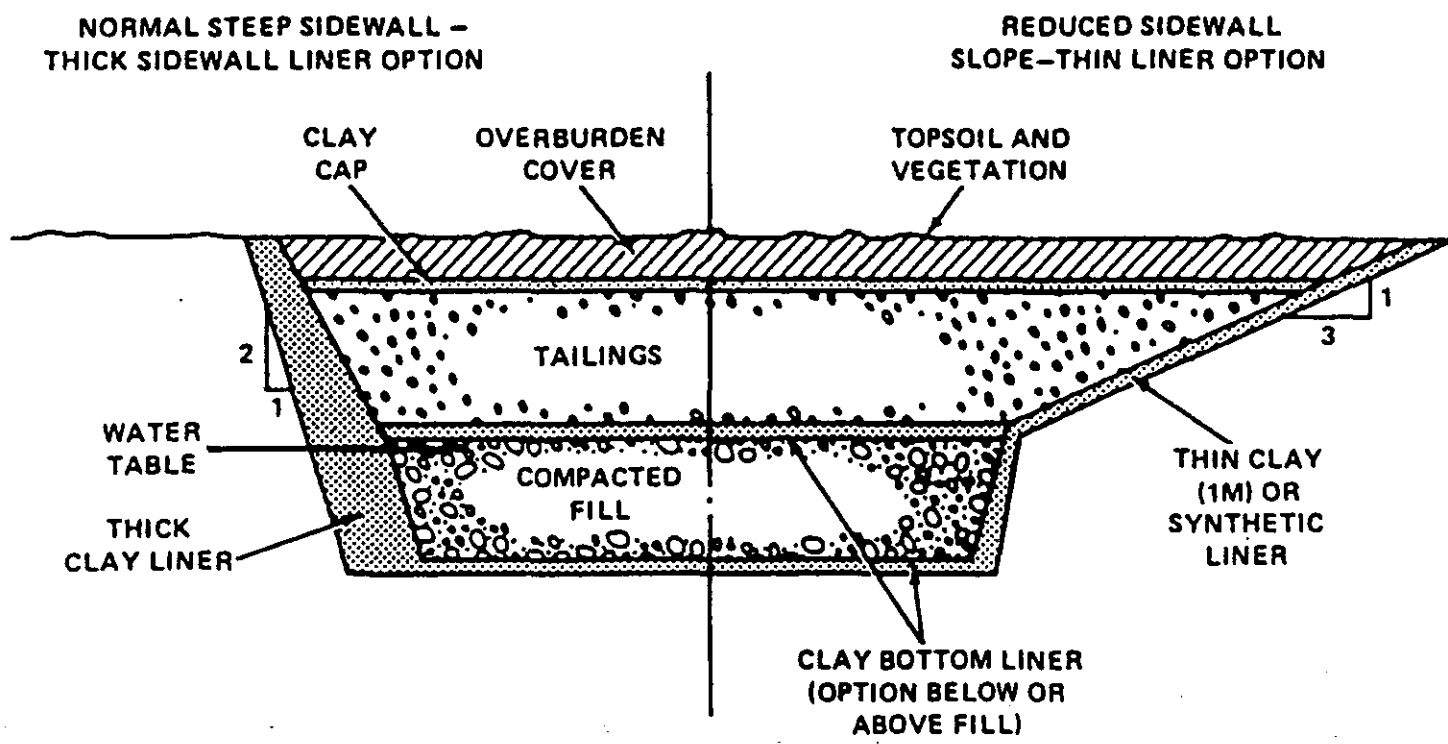
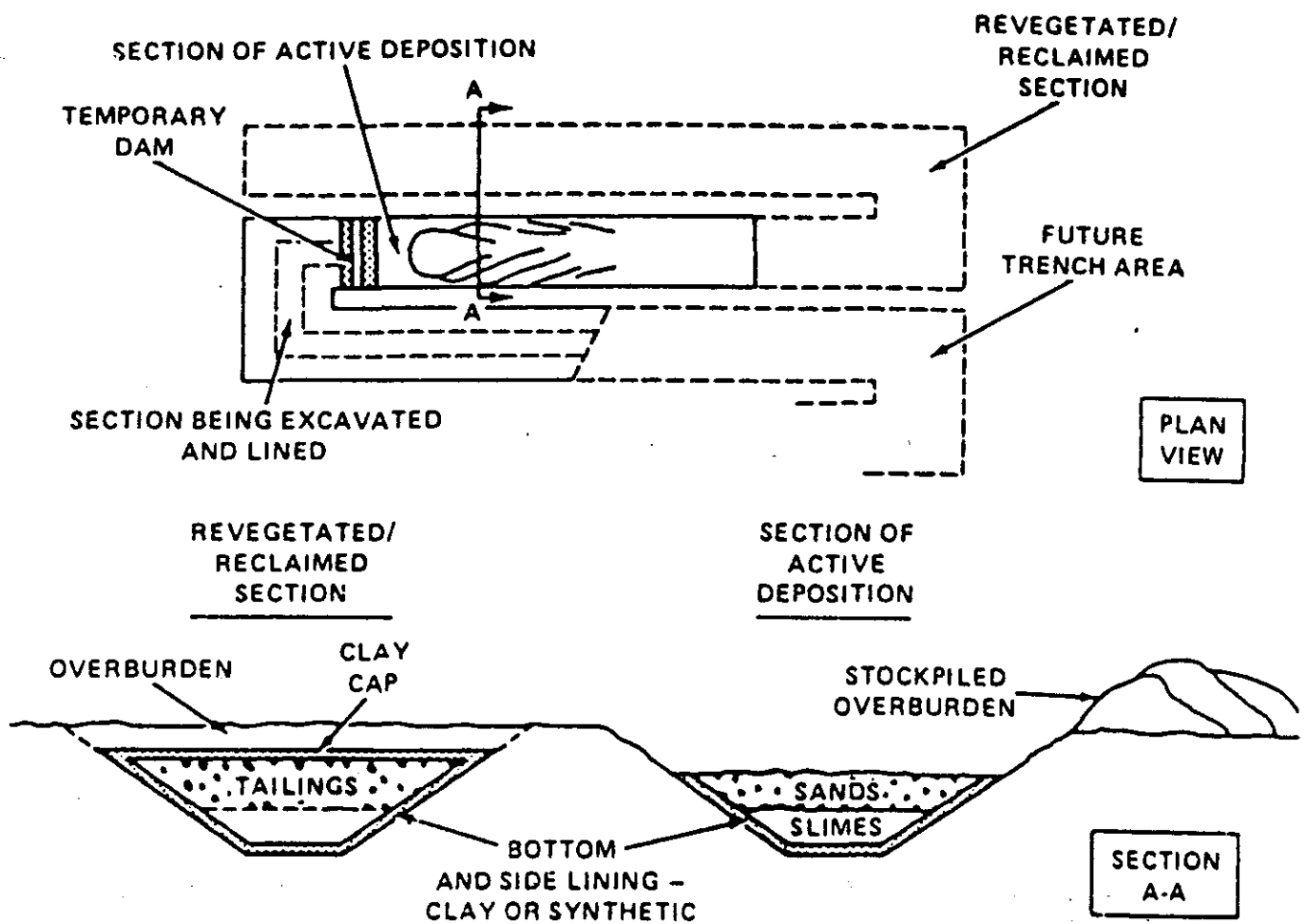


Figure 6-15 Disposal of tailings slurry in available open-pit mine. Source: (NRC 19



6-16 Disposal in specially excavated below-grade trench. Source: (NRC 1979).

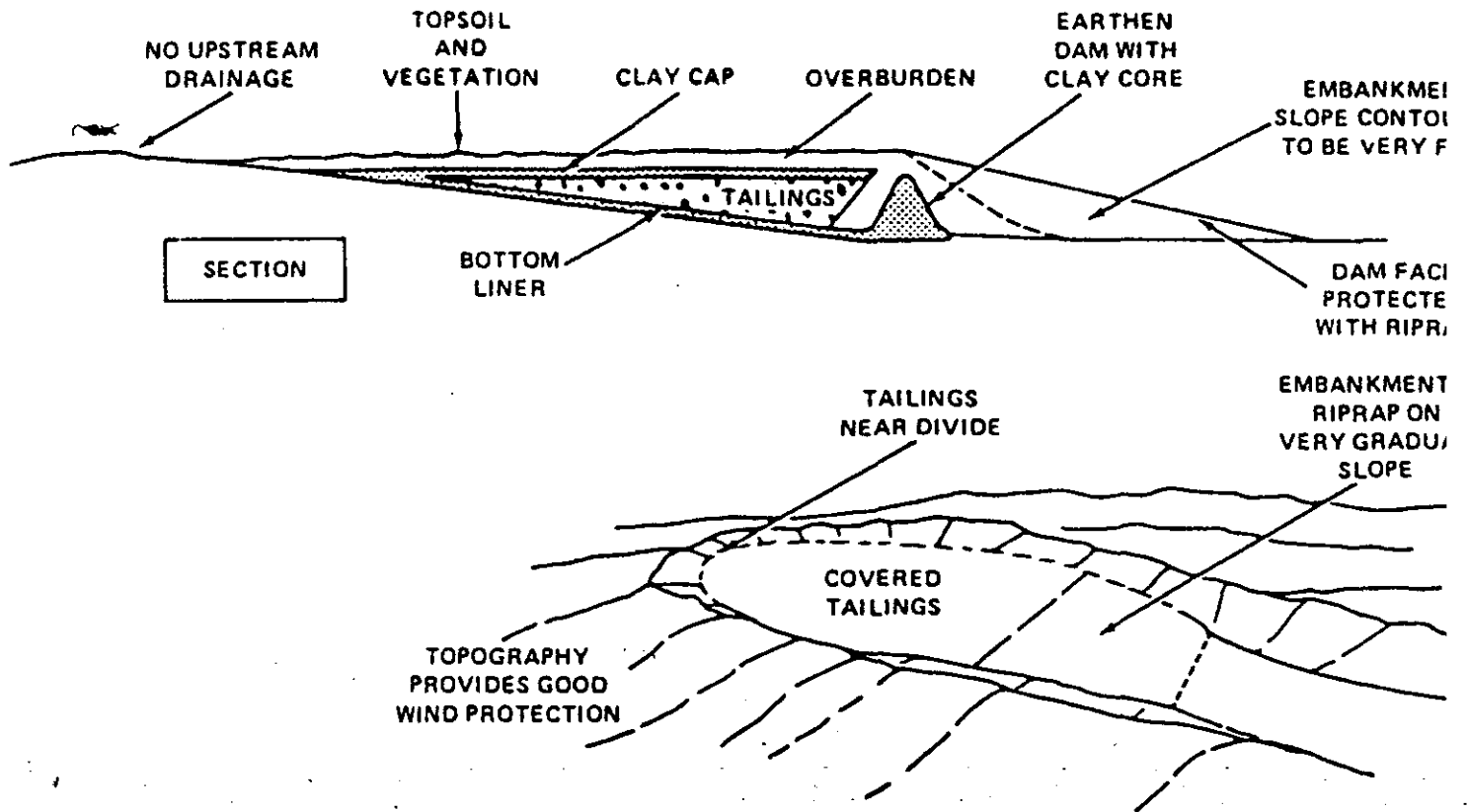


Figure 6-17 Tailings Disposed above grade with special siting and design features
 Source: (NRC 1979).



Figure 2: Radioactive waste container on the floor of the Atlantic. The United States Environmental Protection Agency acknowledged for providing permission to reproduce this photograph.

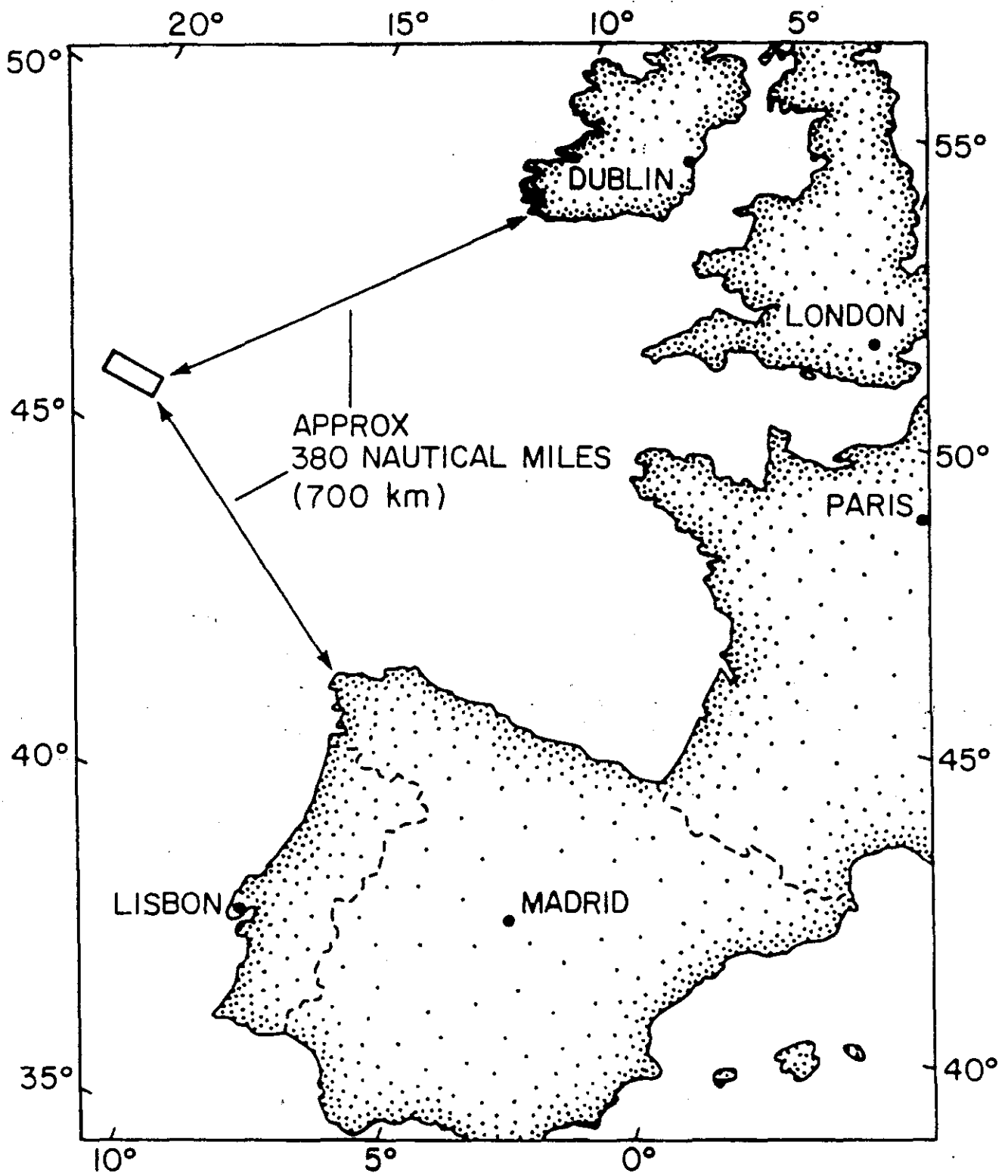


Figure 1: Location of the North-East Atlantic Dumpsite.