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) : U_3O_8 : 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 m^3, 408 kCi, 9 kW; remedial actions: 17E+6 m^3, Grand Junction (Col), Canonsburg (Pen)

U conversion: refineries, enrichment, 1400 m^3, 56 Ci/y, 0.4 mCi/m^3

Reactors: PWR 480 m^3/y, BWR 820 m^3/y, resins, filters, ..

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

Immediate Decommissioning waste:

	PWR		BWR	
	Volume	Activity	Volume	Activity
Waste Stream	(ft^3)	(Ci)	(ft^3)	(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 m^3/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 m^3/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 m^3+ 90 000 m^3/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 $/m^3, 6580 m^3/y volume +50% $ -75%, -75% $ +300%

Tailings: 1982, 9E+7 m^3, 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 km^2 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

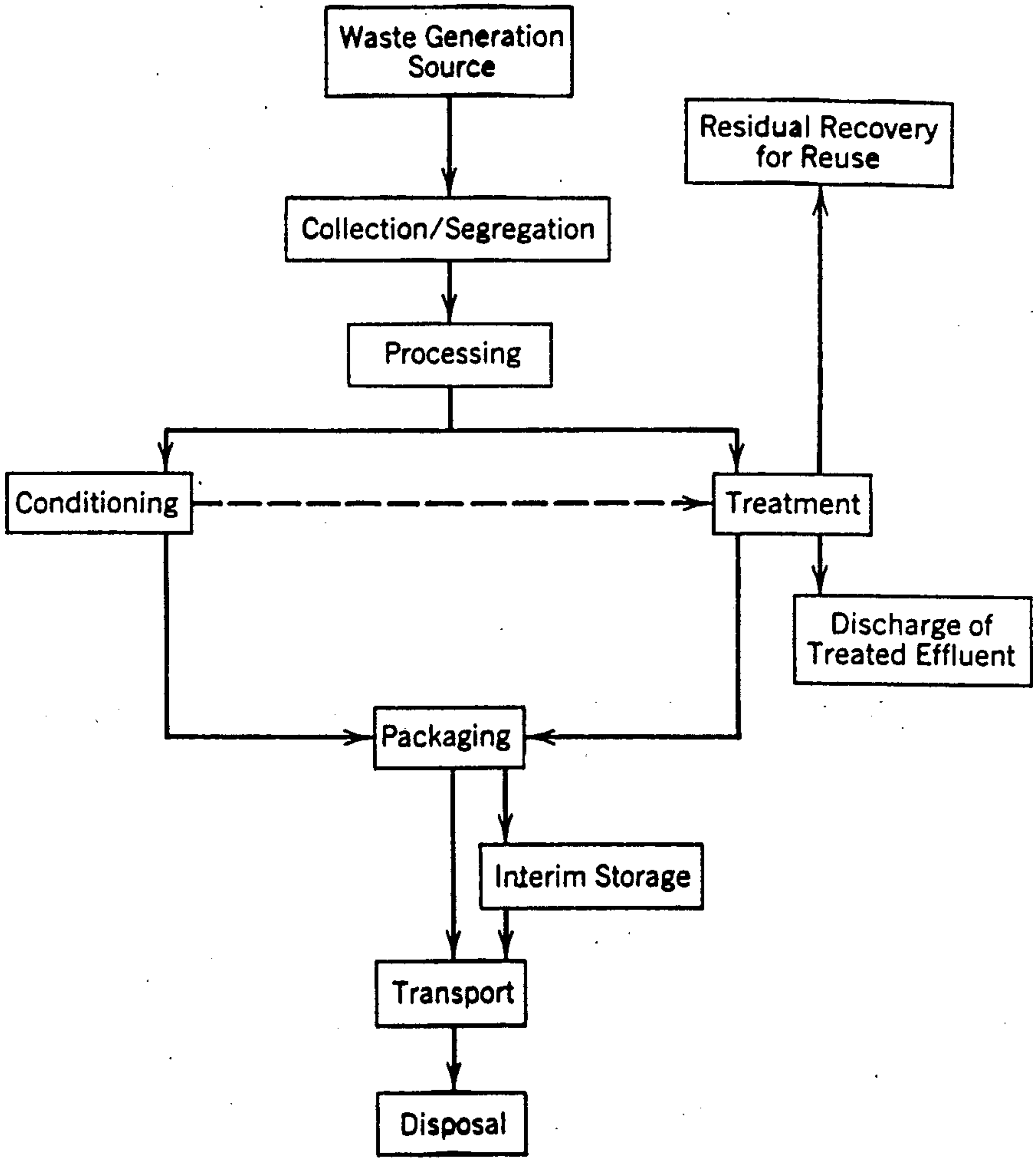
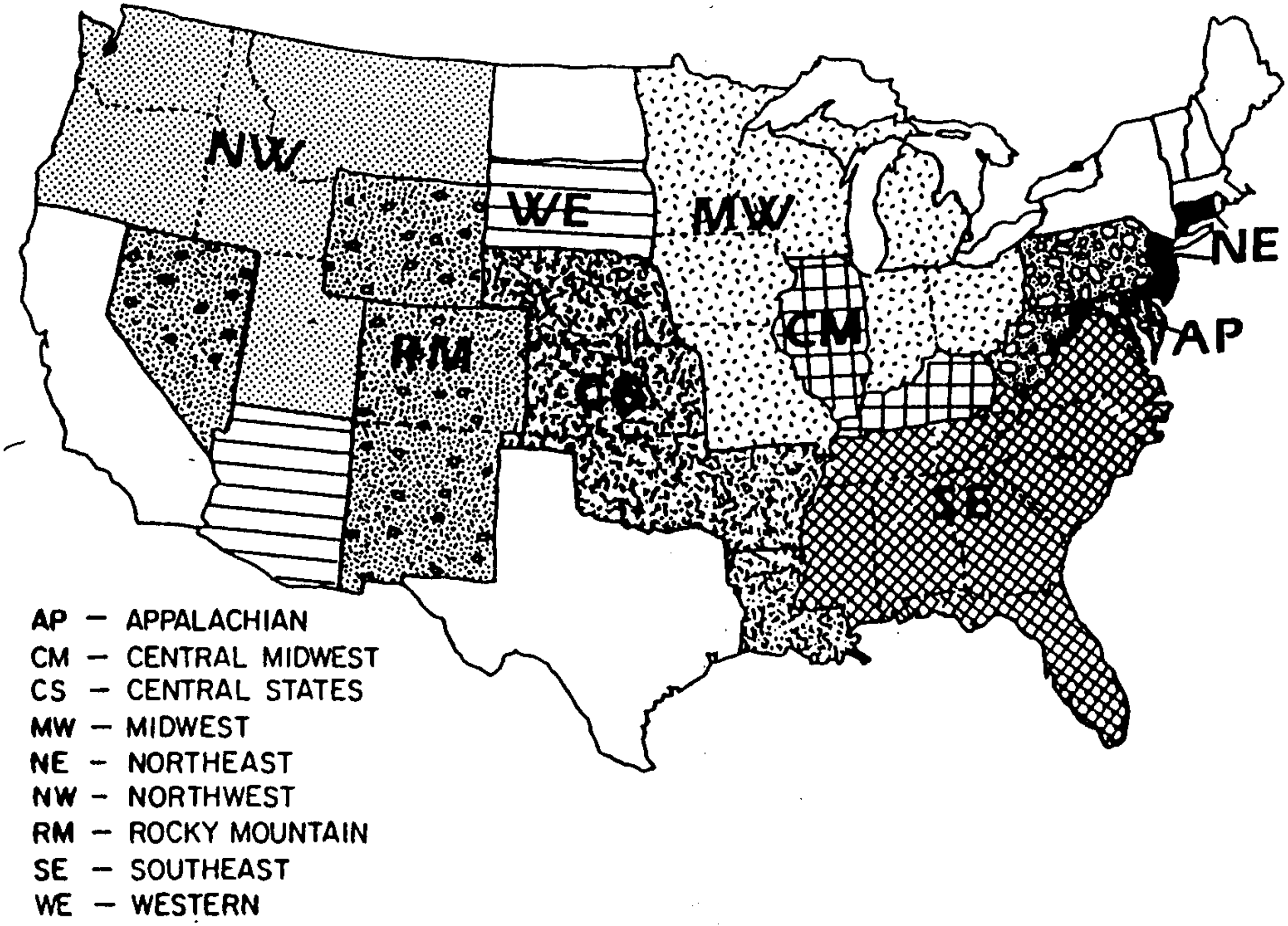


Figure 5-1 Steps in the management of low-level waste.



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

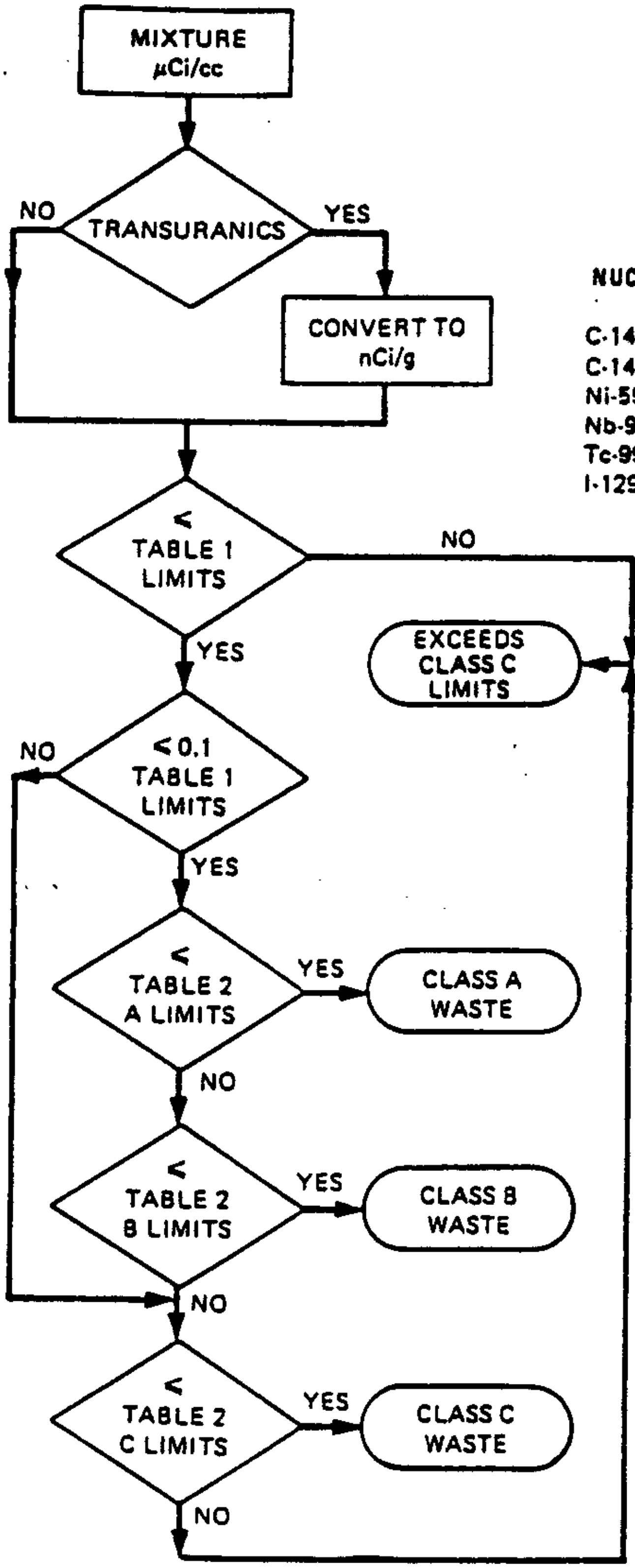


TABLE 1
LONG-LIVED RADIONUCLIDE LIMITS

NUCLIDE	Ci/m³	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/m³
$t_{1/2}$ < 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/m³
Ni-63	70
Ni-63*	700
Sr-90	150
Cs-137	44

CLASS C LIMITS

NUCLIDE	Ci/m³
Ni-63	700
Ni-63*	7000
Sr-90	7000
Cs-137	4600

*IN ACTIVATED METAL

Figure 5-2 Classification chart for radioactive waste based on 10 CFR Part 61. Source: (DOE 1984).

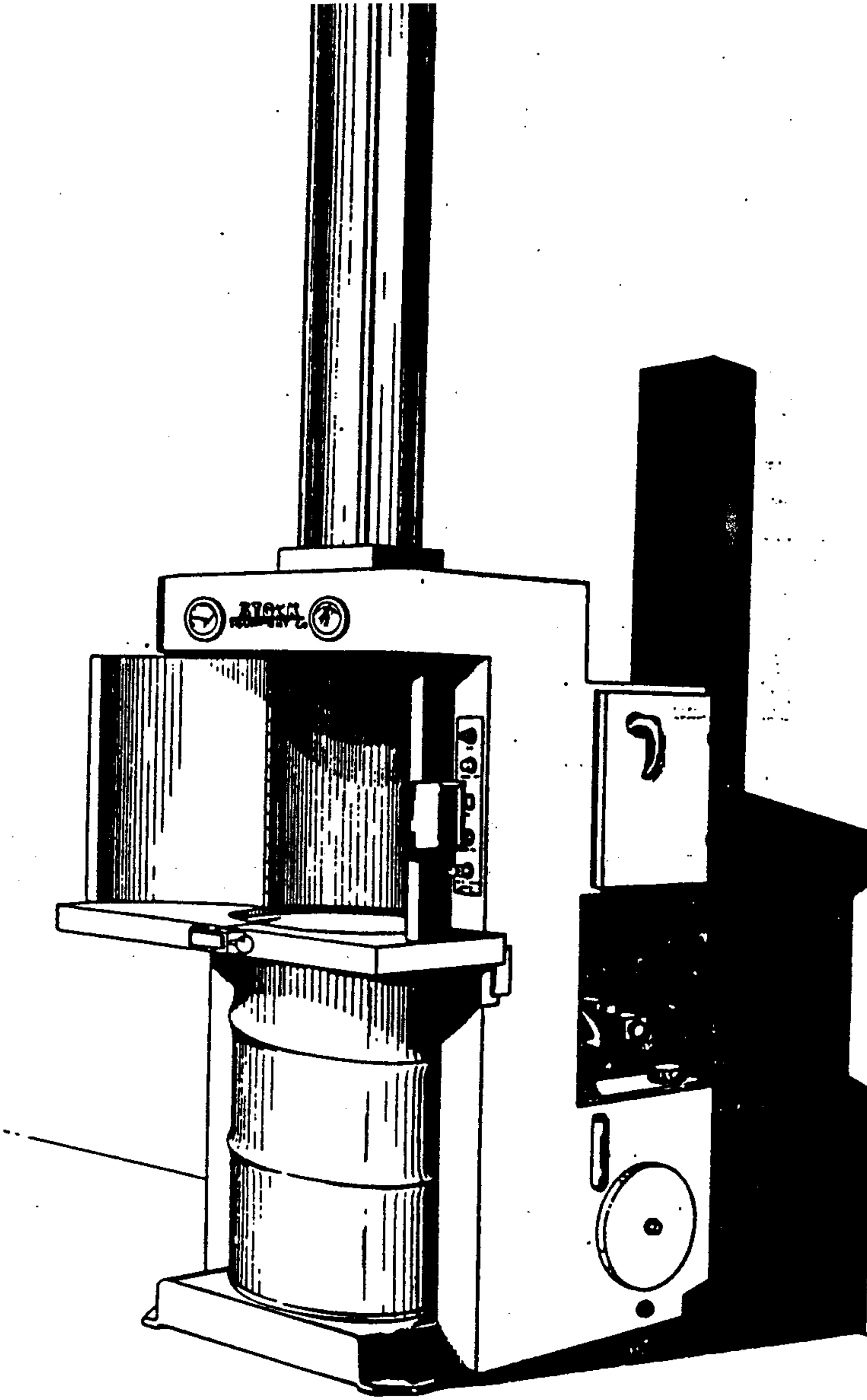


FIG. 13. DRY RADWASTE DRUM COMPACTOR

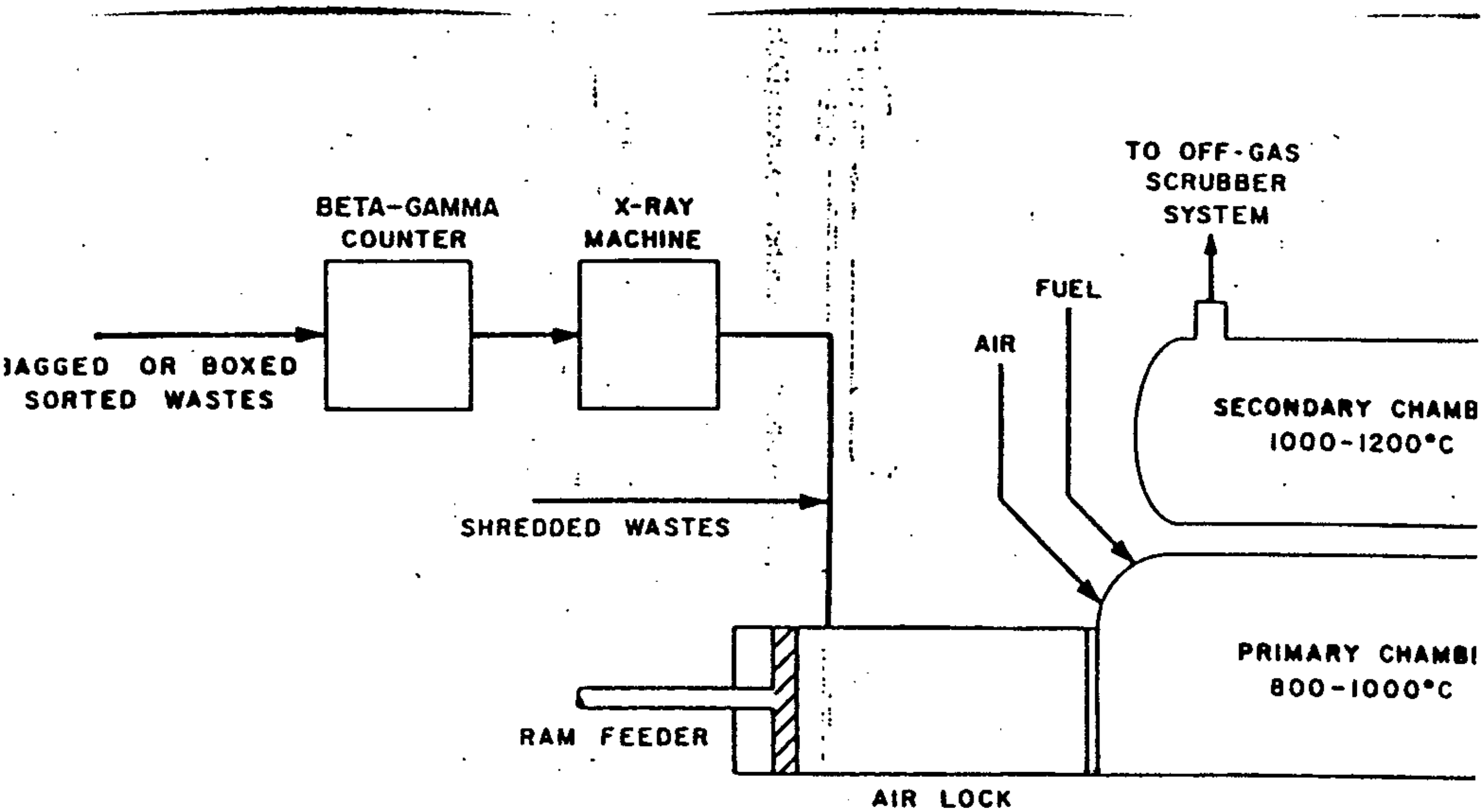


Figure 5-10 Los Alamos National Scientific Laboratory controlled-air incinerator. Source: (DOE 1984).

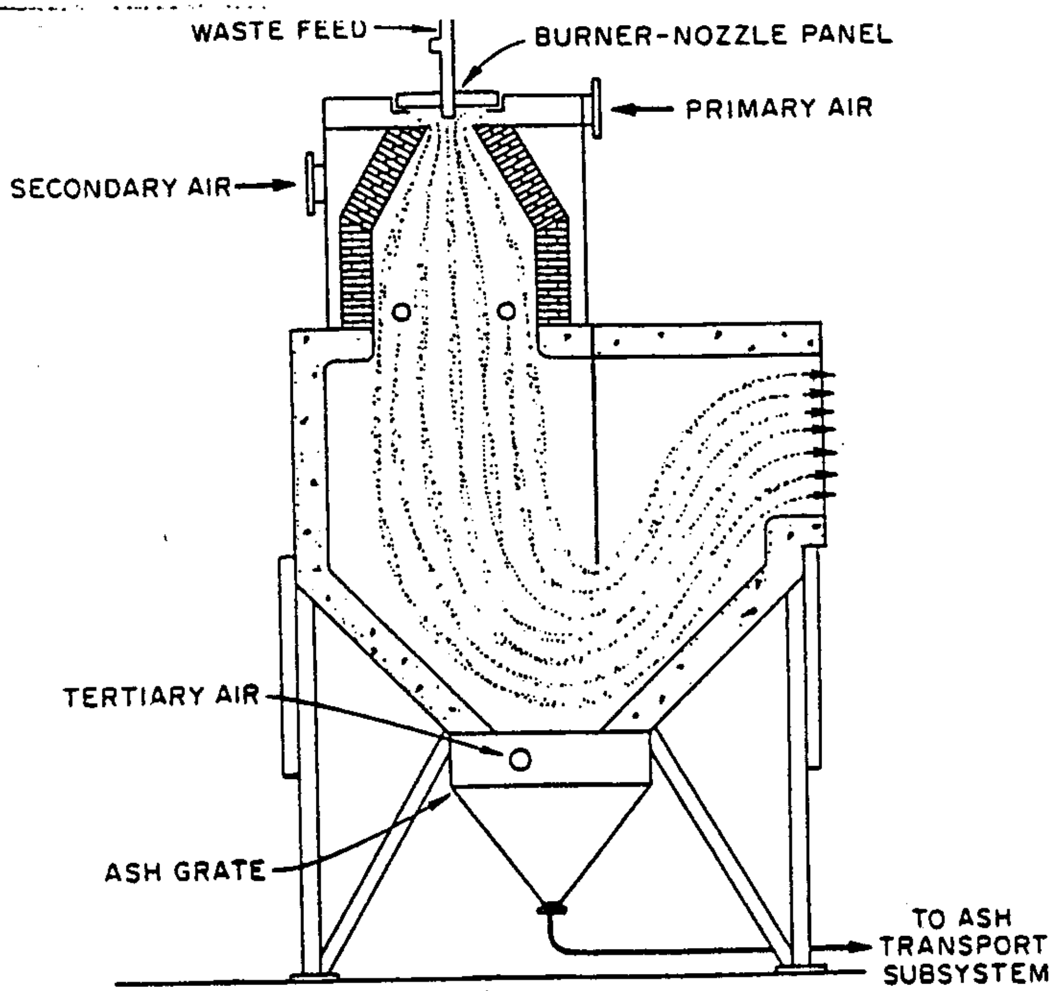


Figure 5-11 Excess-air cyclone incinerator combustion chamber. Source: (DOE 1984).

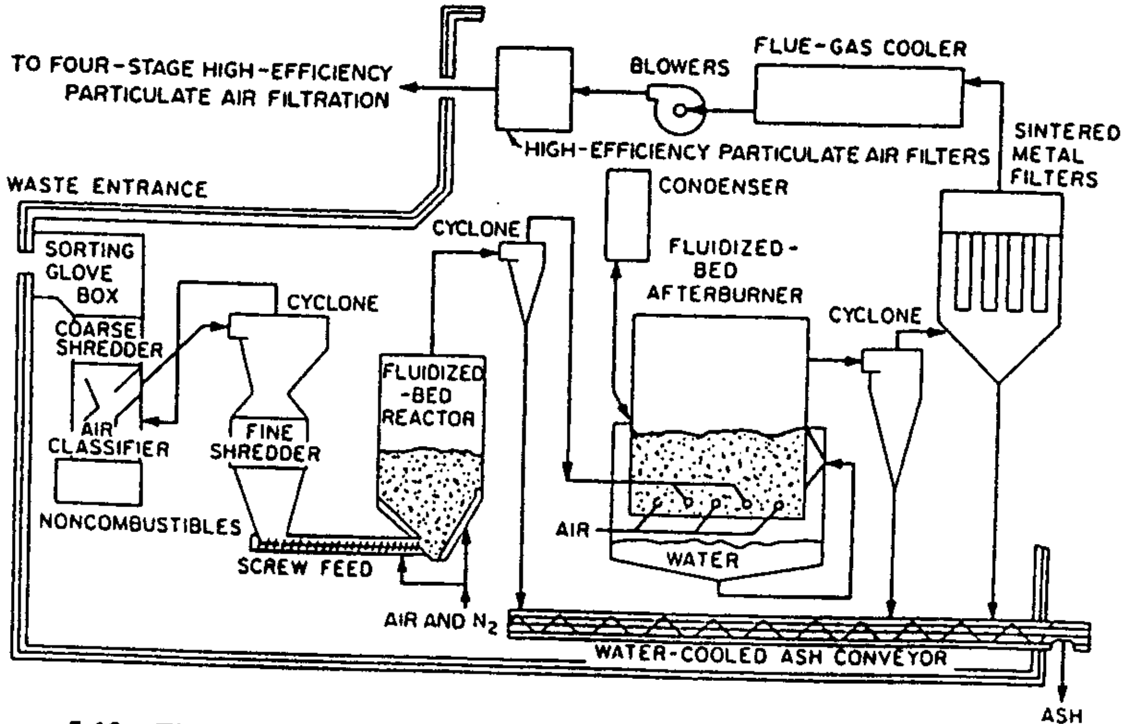


Figure 5-12 Flow diagram of the Rocky Flats Plant fluidized-bed incinerator. Source: (DOE 1984).

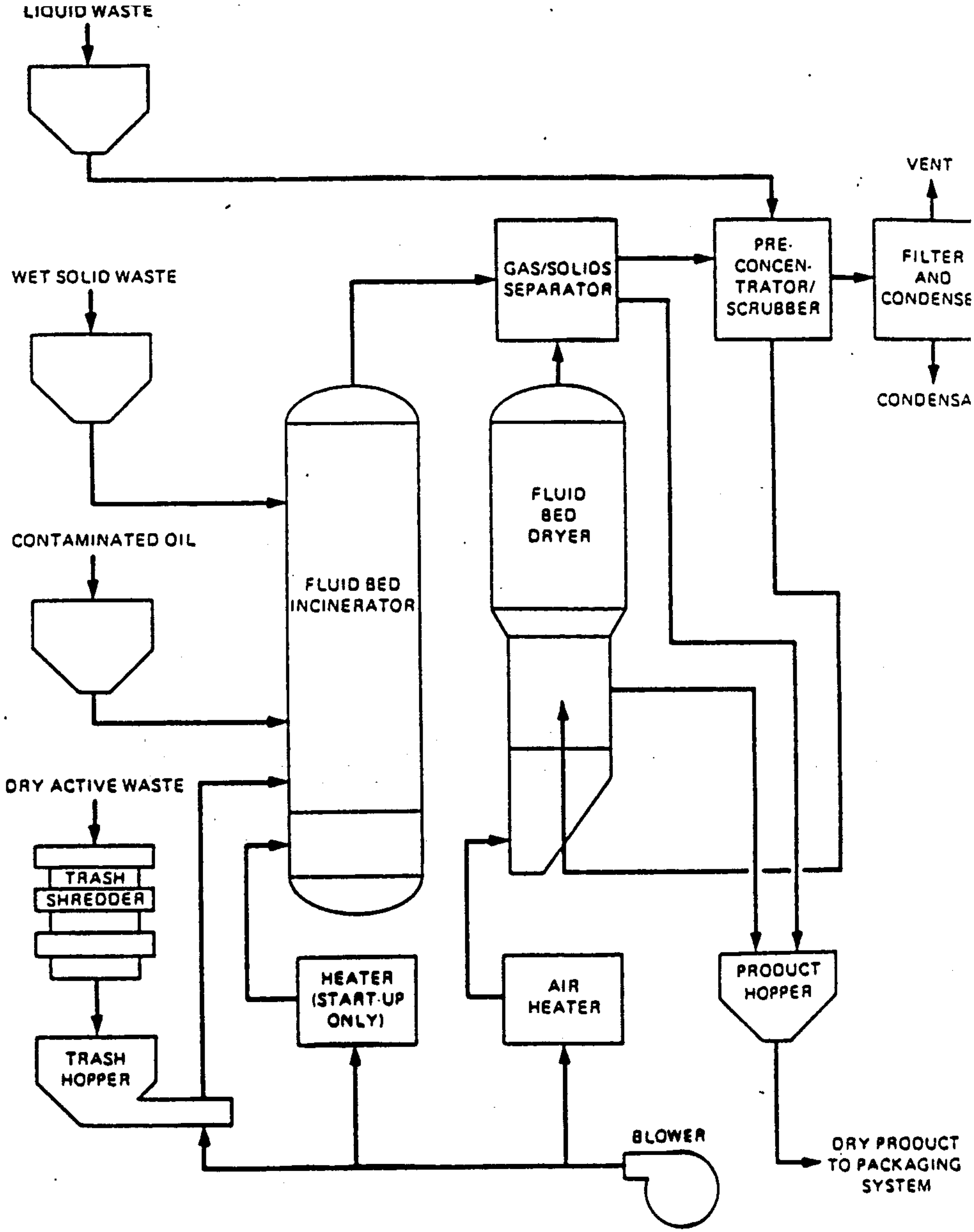


Figure 5-13 Flow diagram of the Aerojet Energy Conversion Company's fluidized-t dryer/incinerator. Source: (DOE 1984).

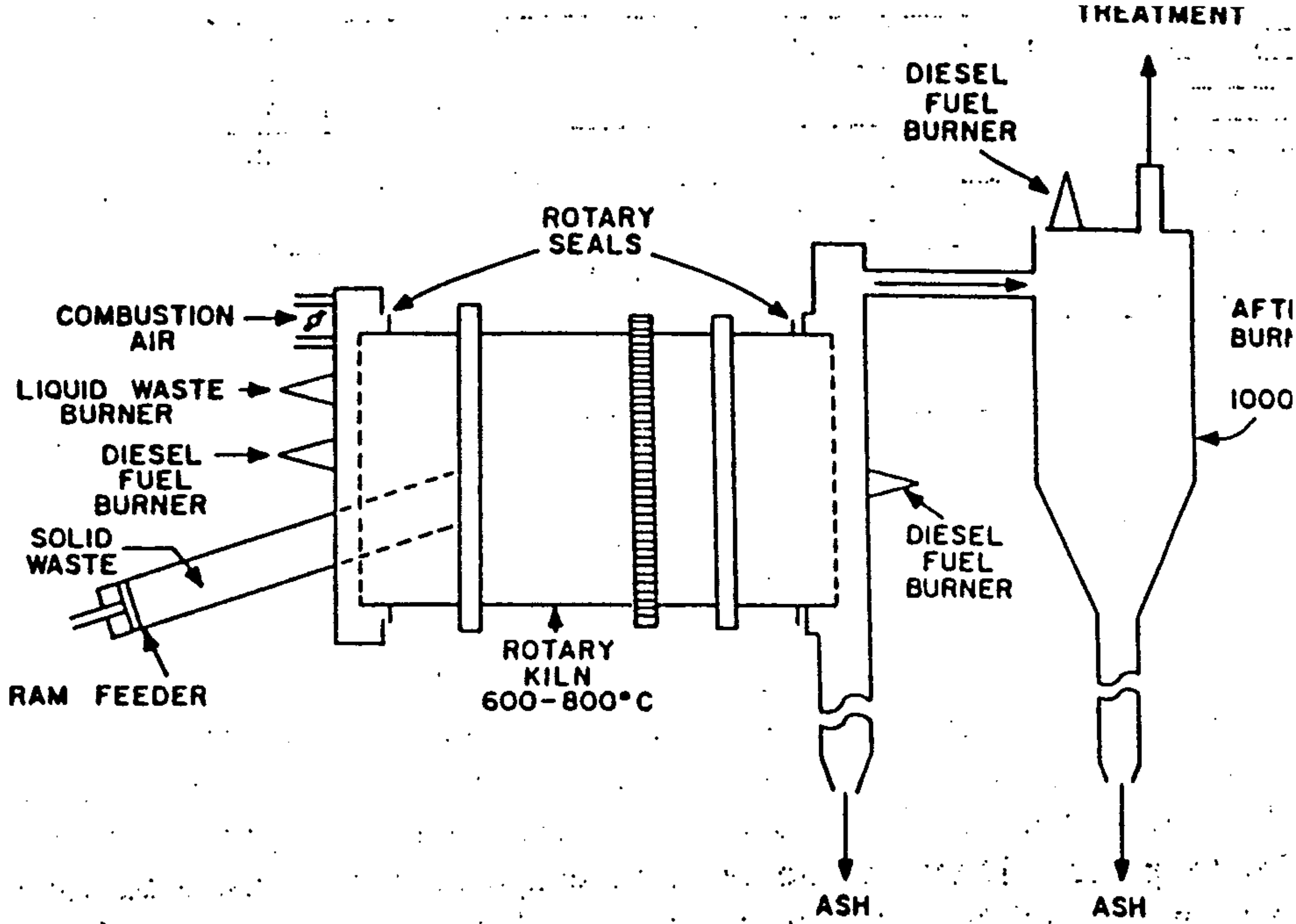


Figure 5-14 Rocky Flats Plant rotary-kiln incinerator. Source: (DOE 1984).

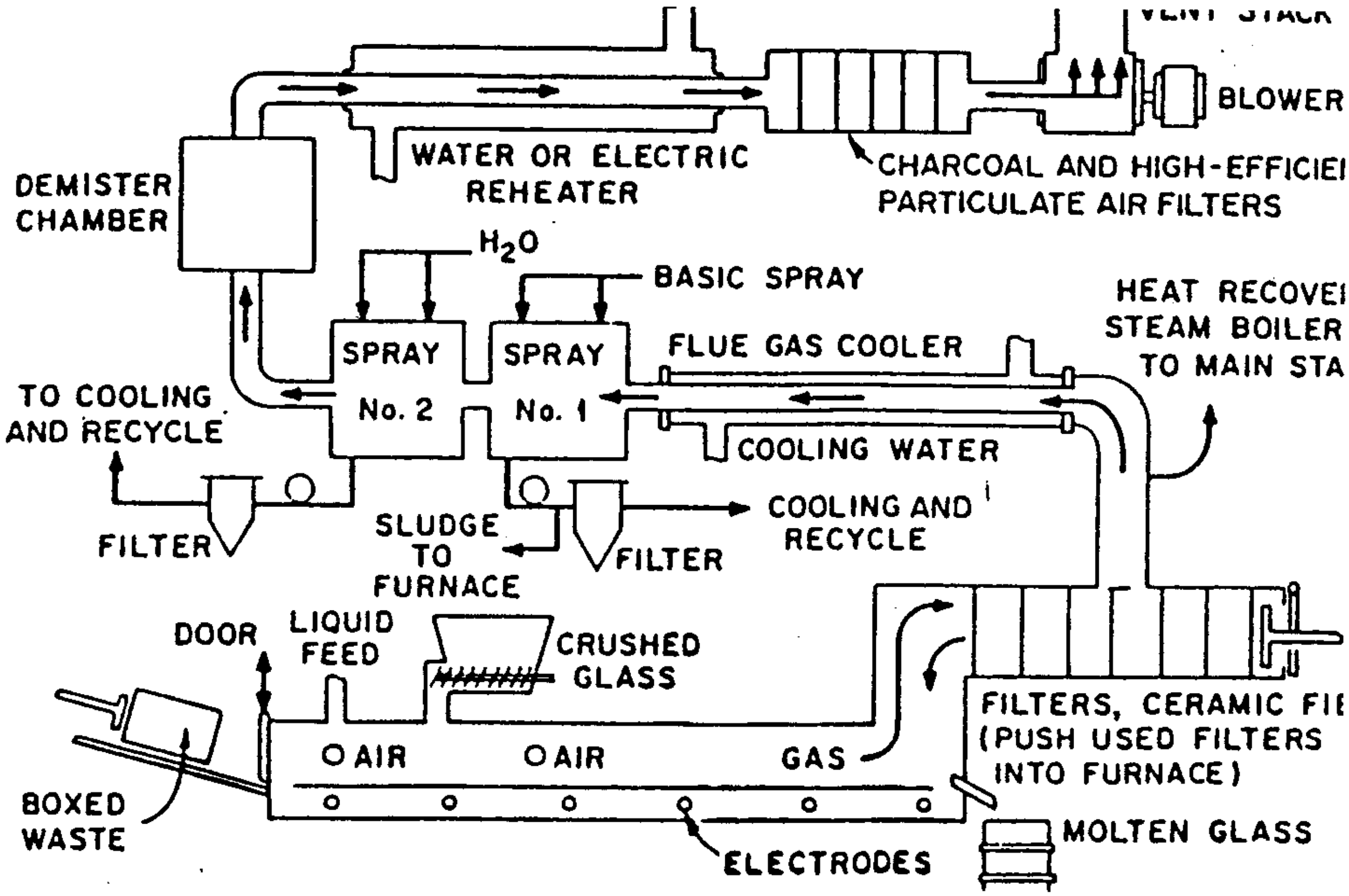
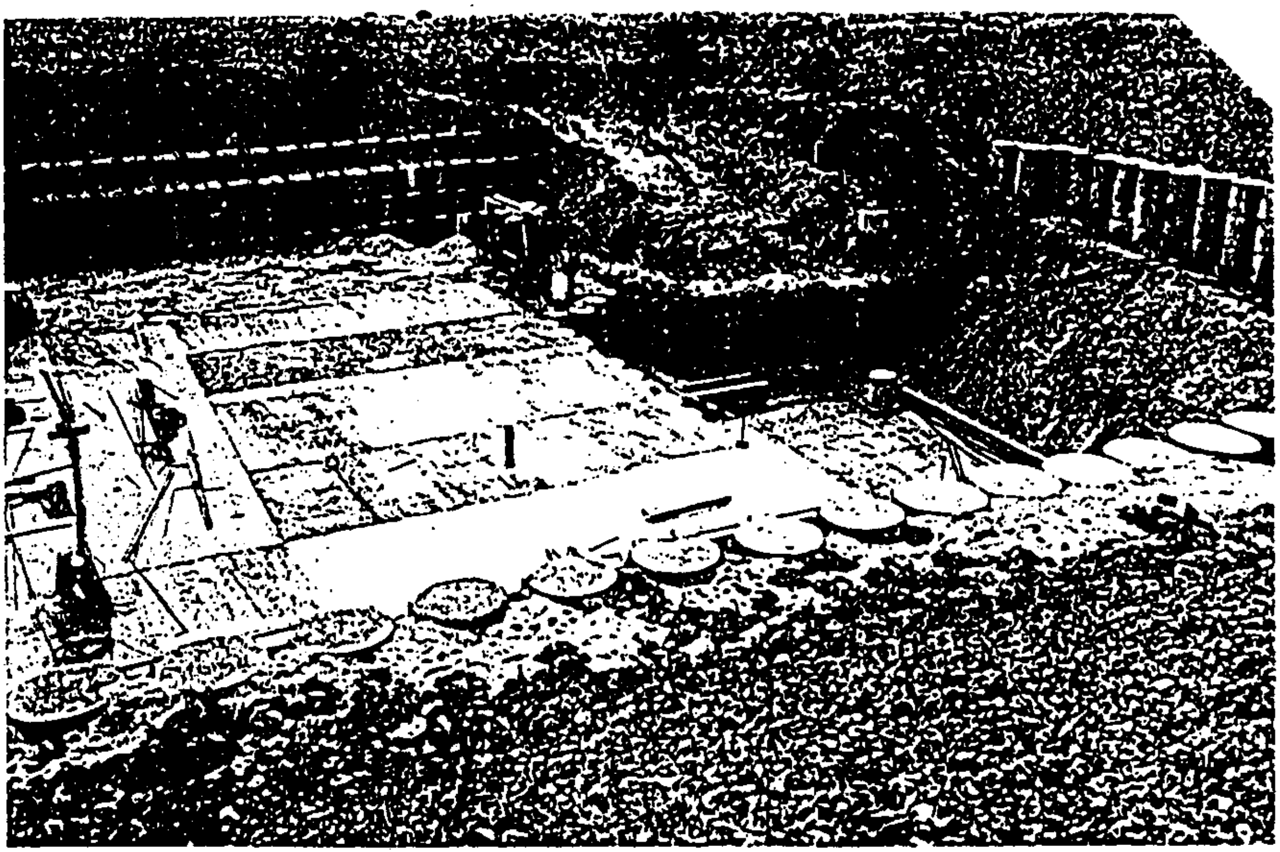
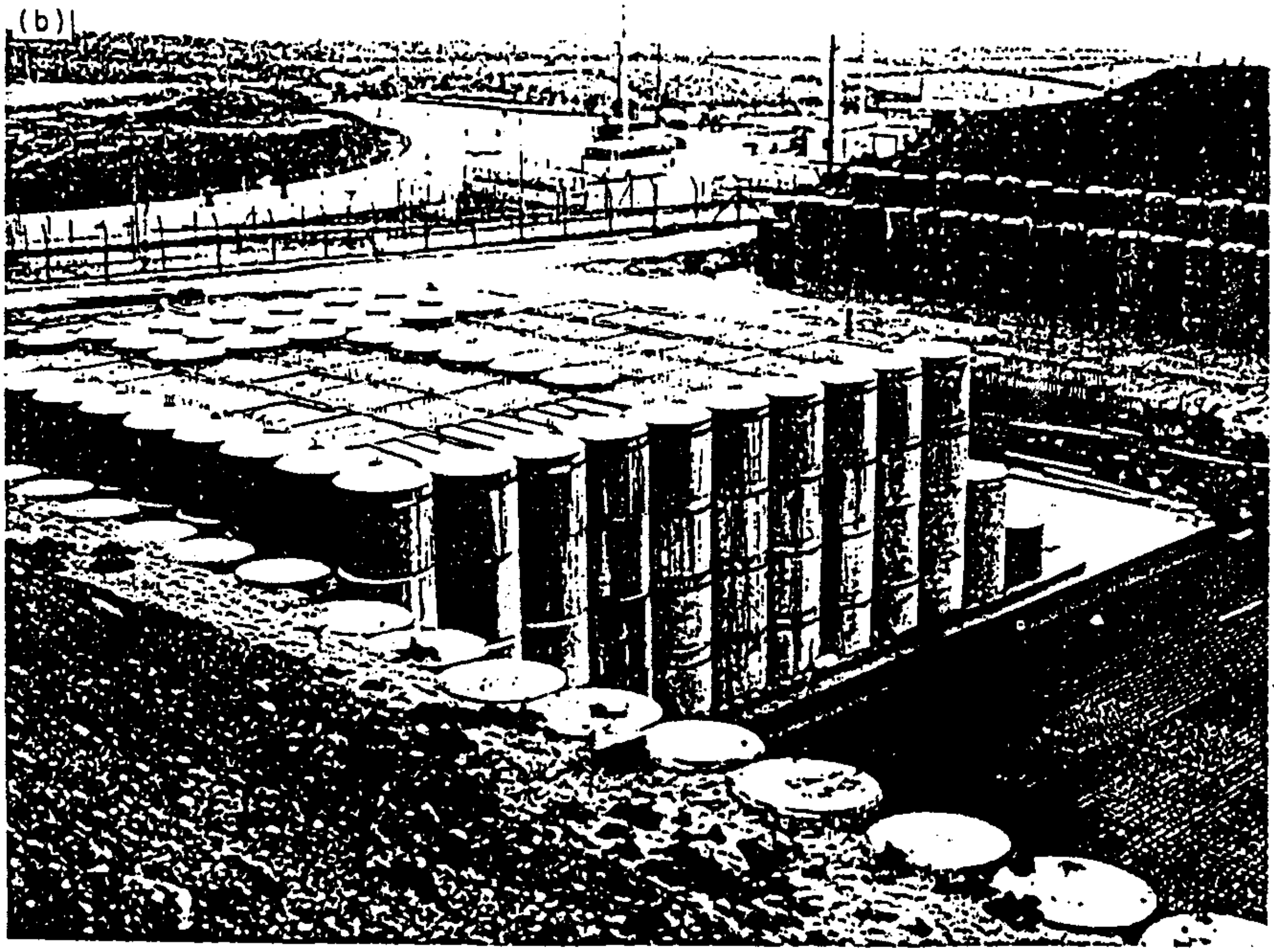


Figure 5-15 Flow diagram of the Penberthy molten-glass incinerator (electrom system. Source: (DOE 1984).



F9.3a Shallow trench



F9.3b TUMULUS

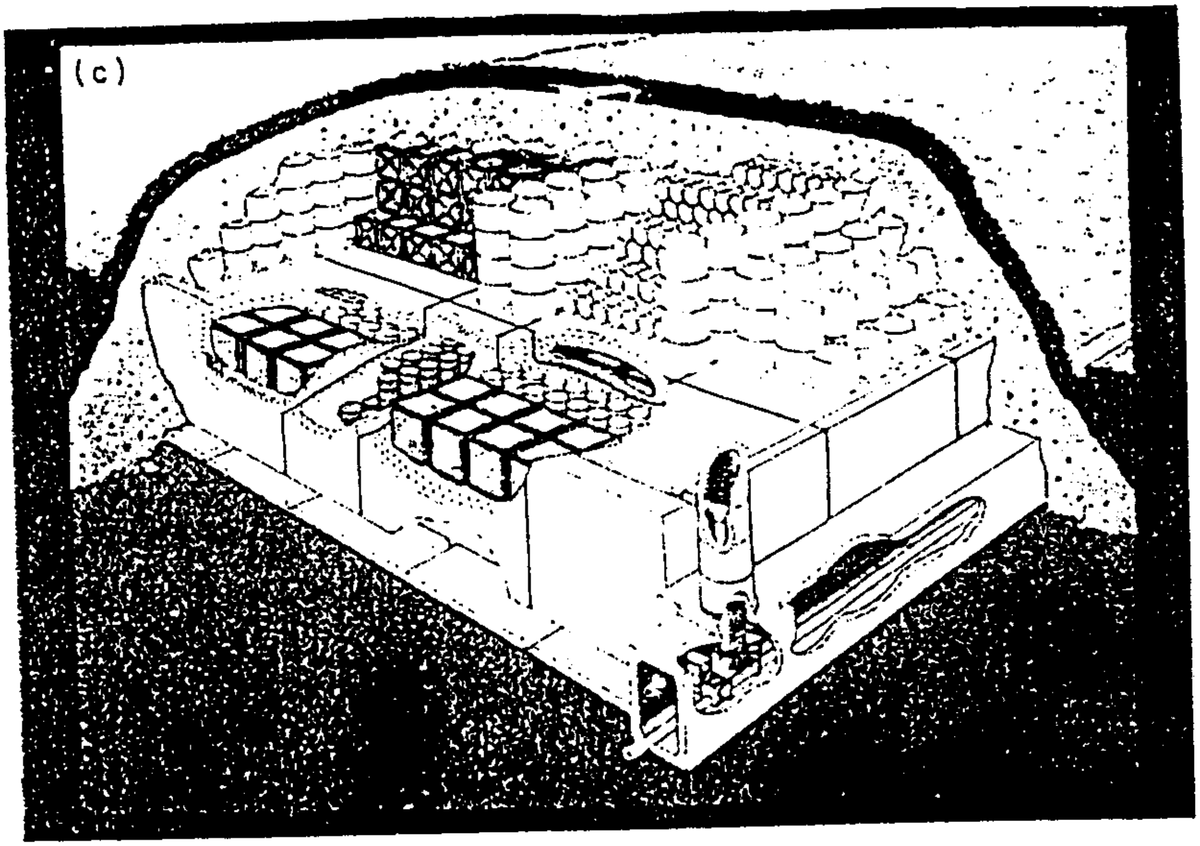


Figure 9.3 The near-surface LLW/ILW disposal facility at Centre Manche, Cap la Hague, France, showing engineered disposal of wastes in concrete containers in (a) shallow trenches capped off with more wastes (b) in a tumulus; shown schematically in (c). Courtesy of CEA/Andra

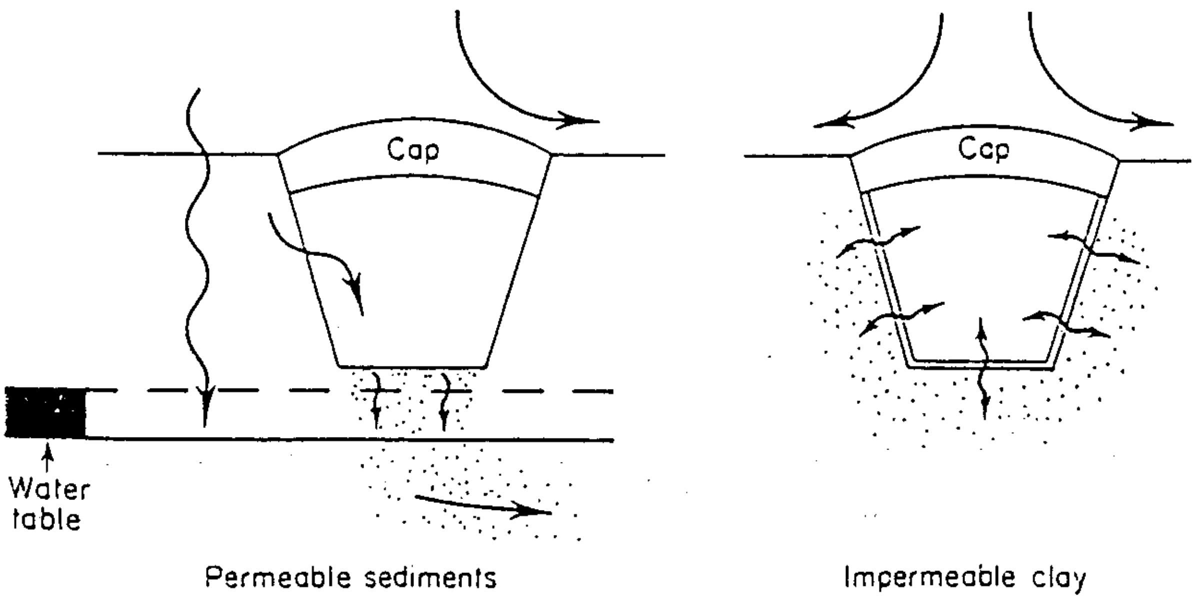
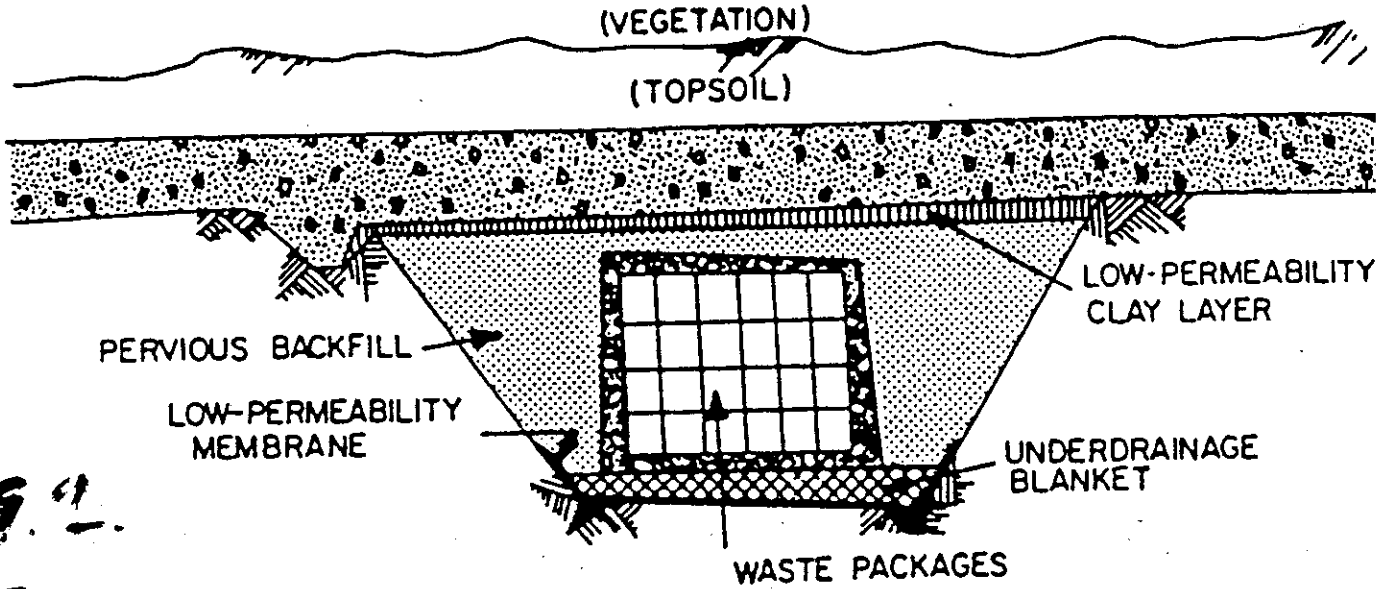


Figure 9.4 Schematic diagram of the concept of trench disposal in permeable sediments above a fluctuating water table, and in impermeable clays below the water table, where transport mechanisms are dominated by diffusion. Directions



F.G. 4.

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

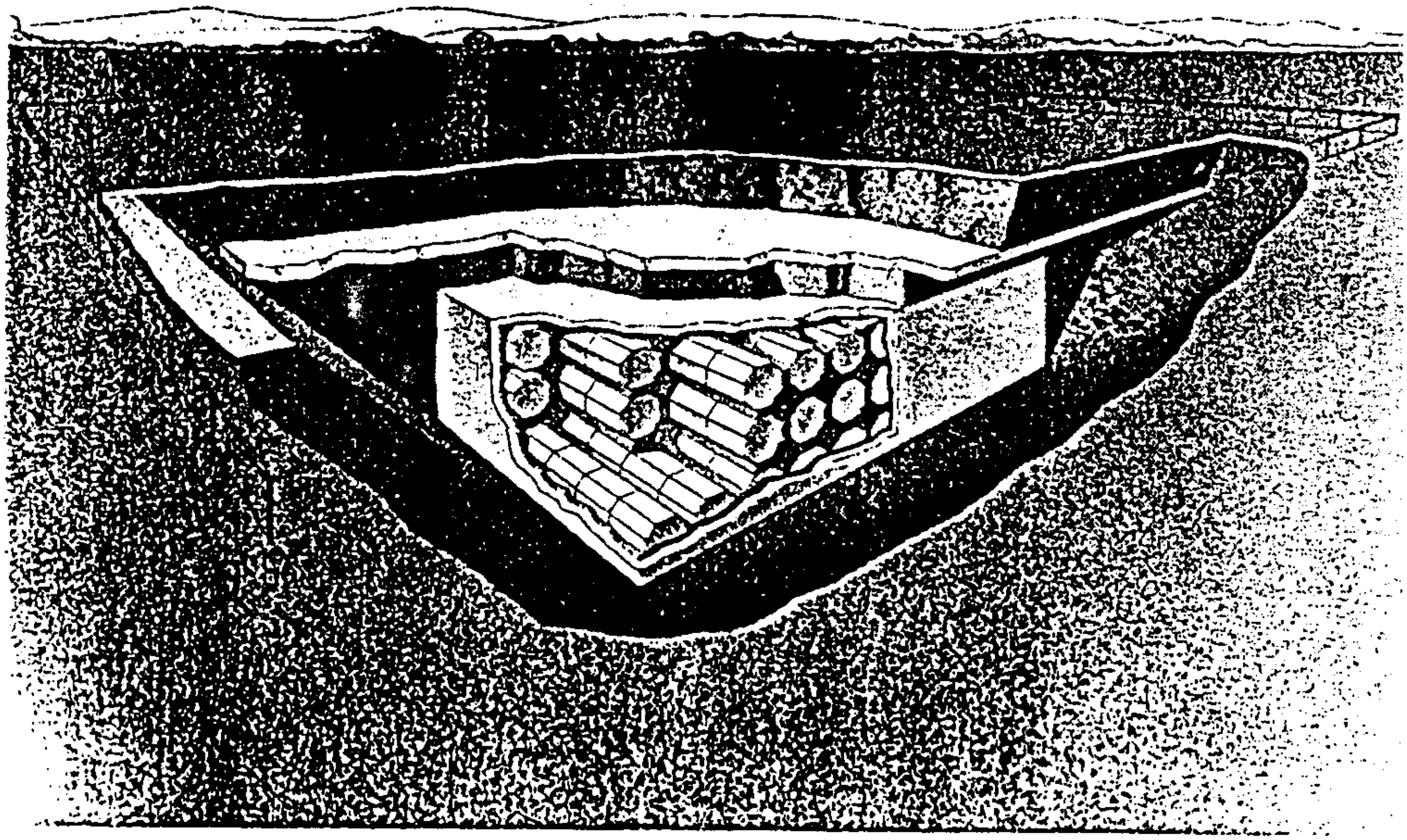
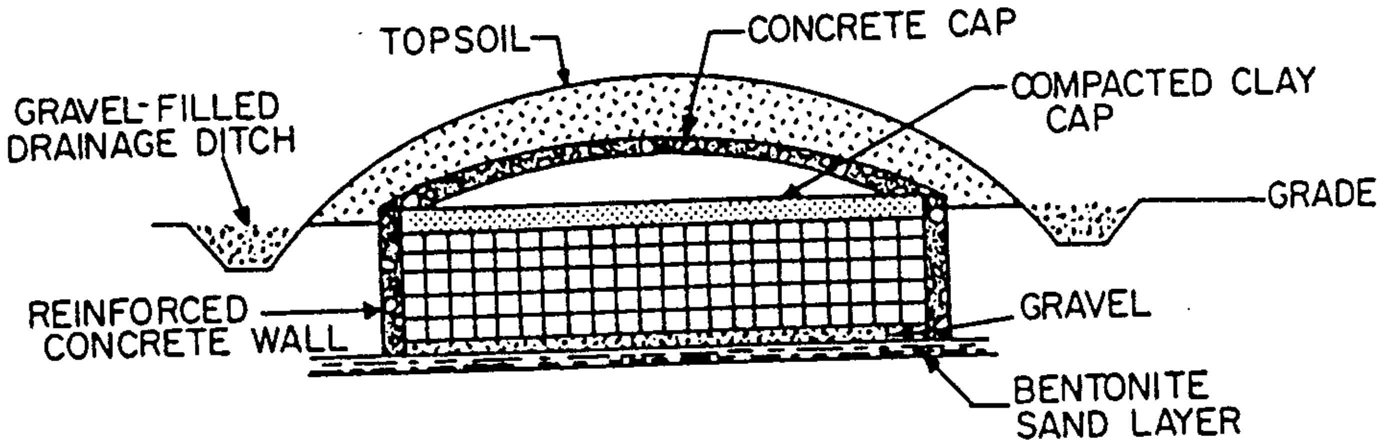
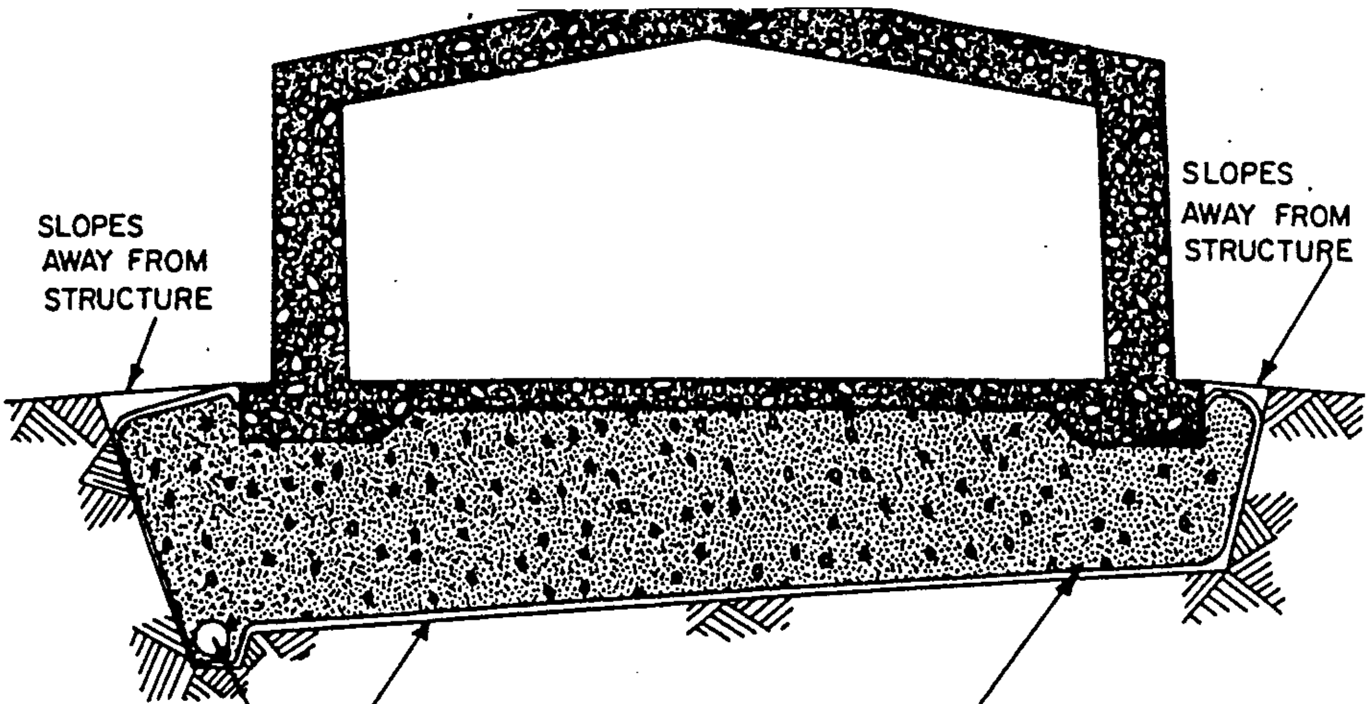


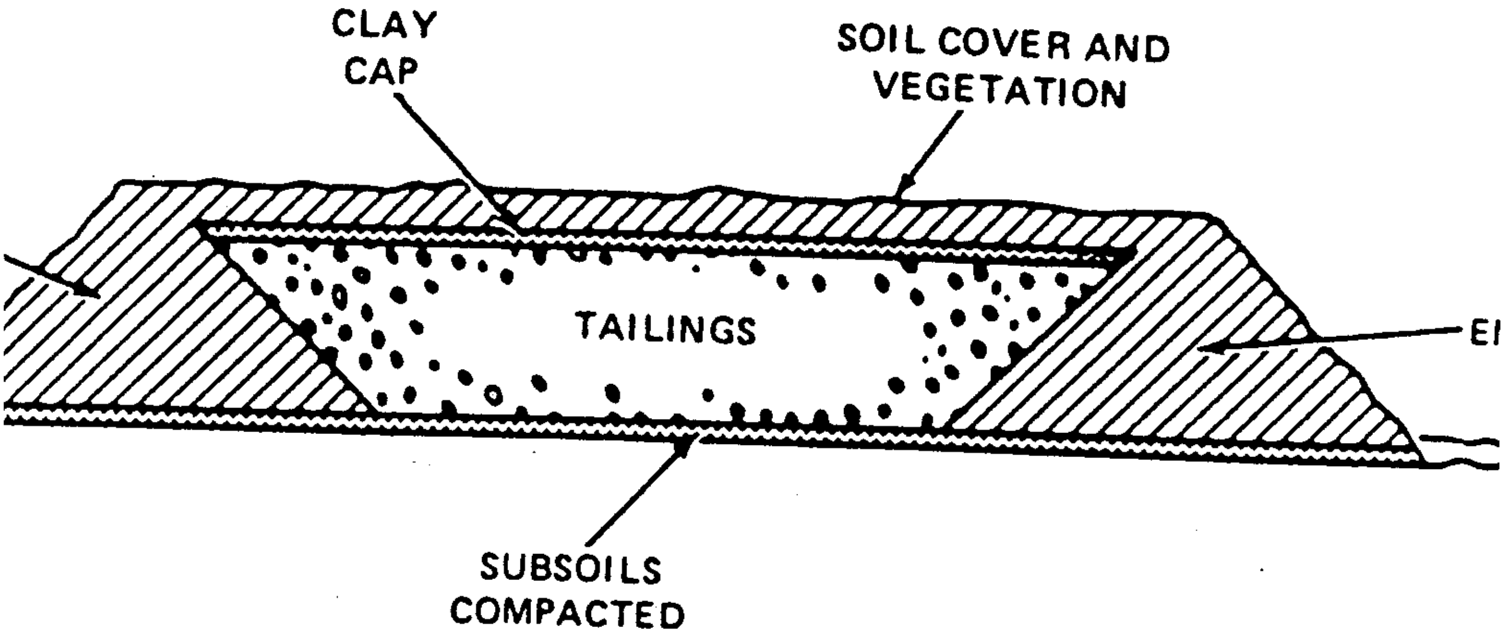
Figure 9.2 Conceptual diagram of an engineered near-surface disposal facility for so categories of low or short-lived intermediate level wastes. The packaged wastes : embedded in cement in a concrete structure, situated below a separate concrete r. designed to protect against inadvertent intrusion (courtesy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



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



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



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

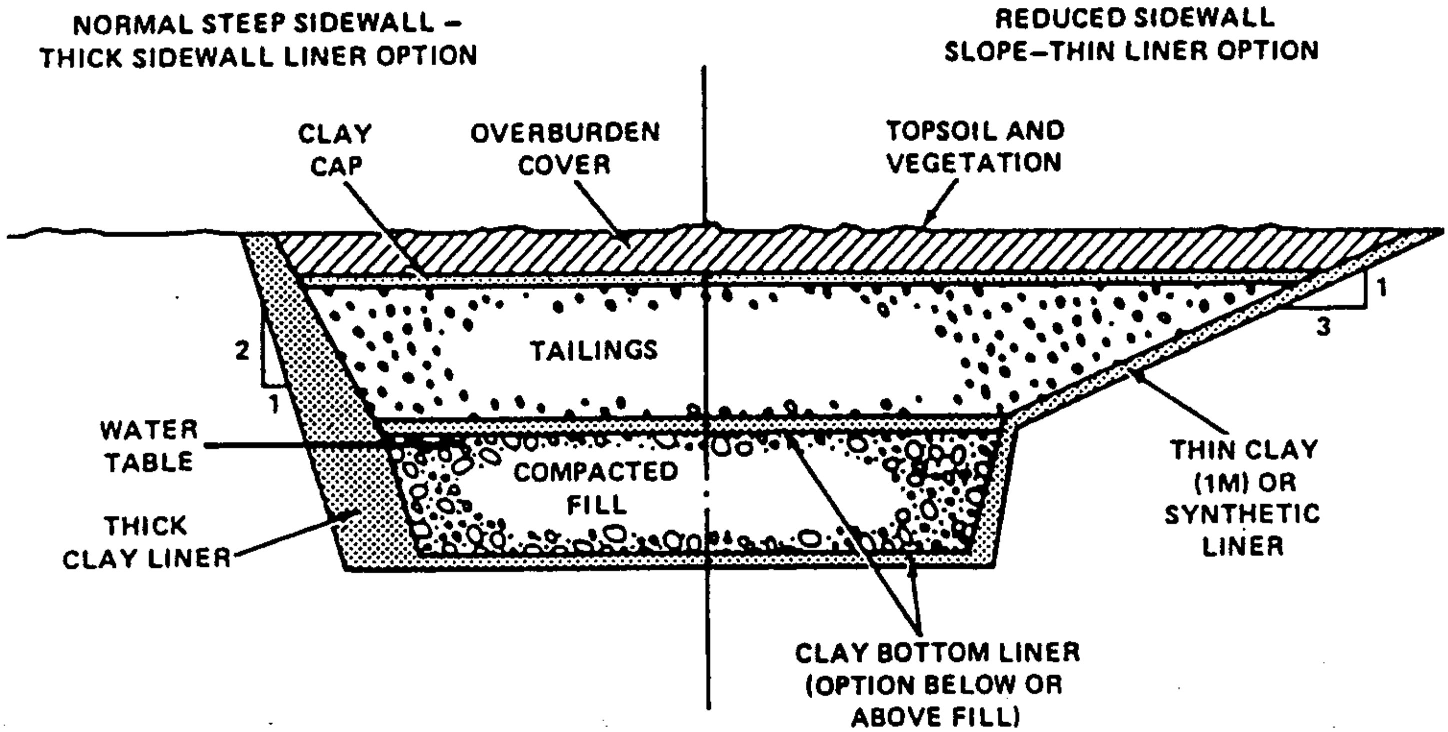
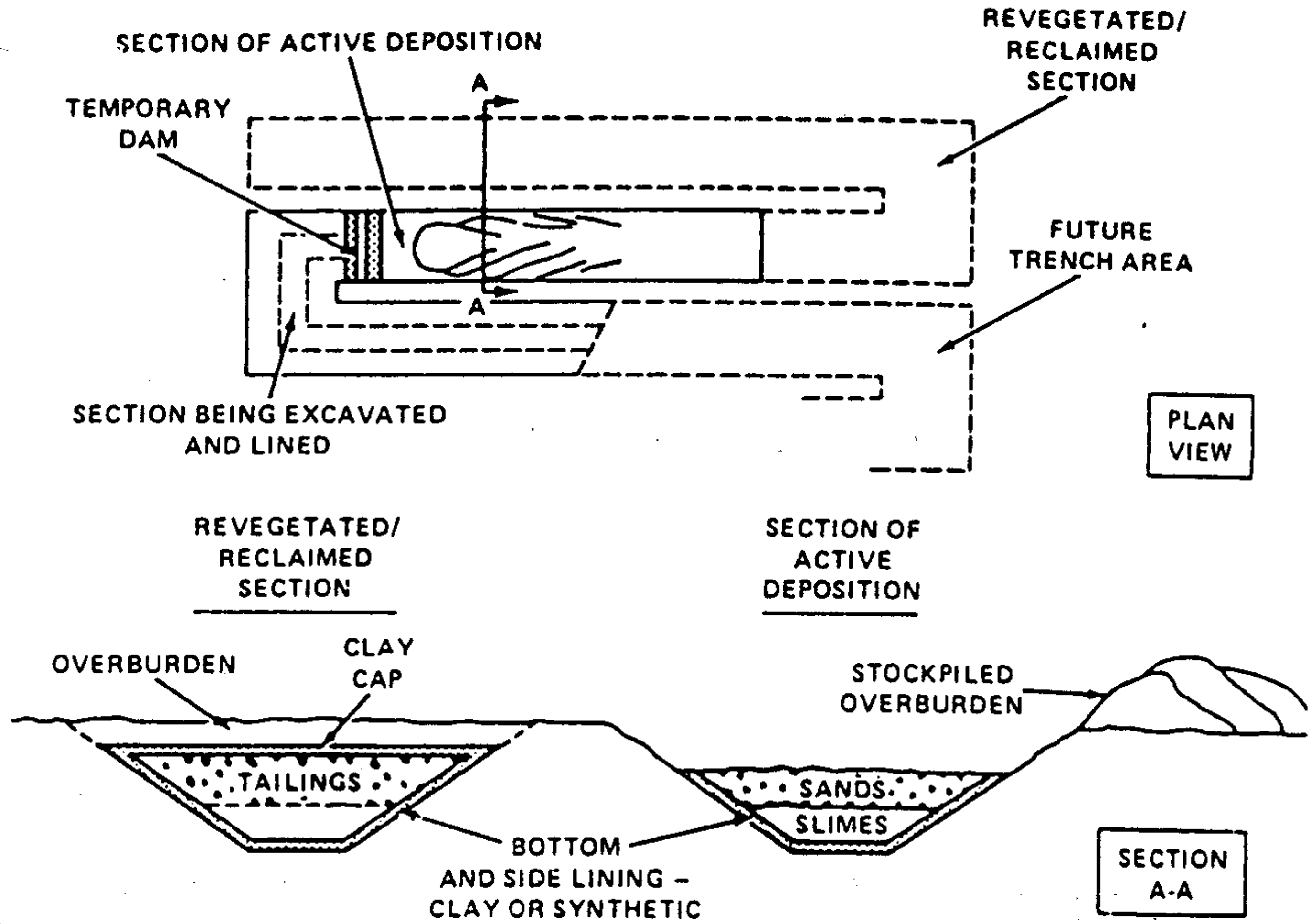


Figure 6-15 Disposal of tailings slurry in available open-pit mine. Source: (NRC 19



5-16 Disposal in specially excavated below-grade trench. Source: (NRC 1979).

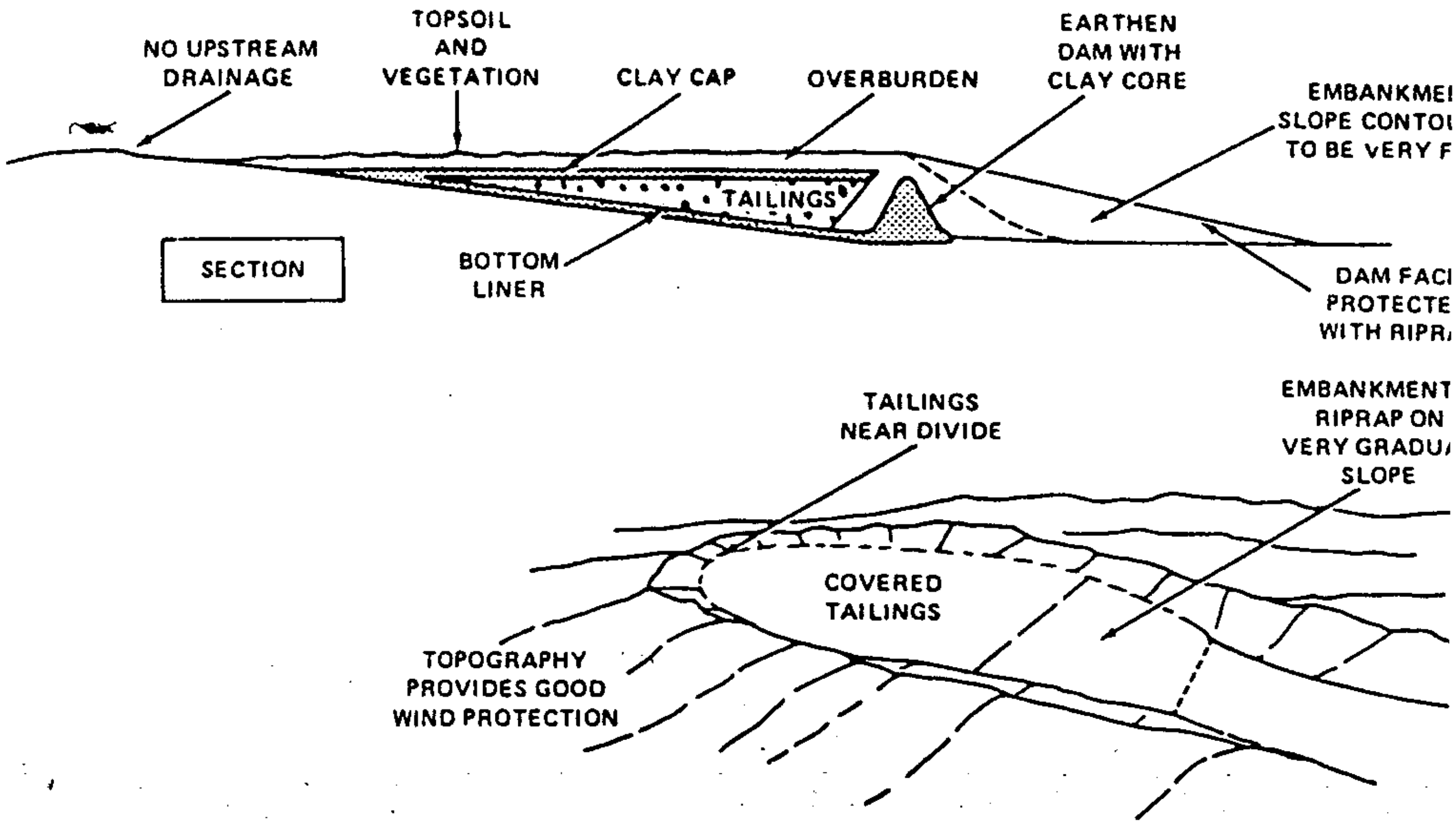


Figure 6-17 Tailings Disposed above grade with special siting and design featu
Source: (NRC 1979).

.re 2: Radioactive waste container on the floor of the Atlan
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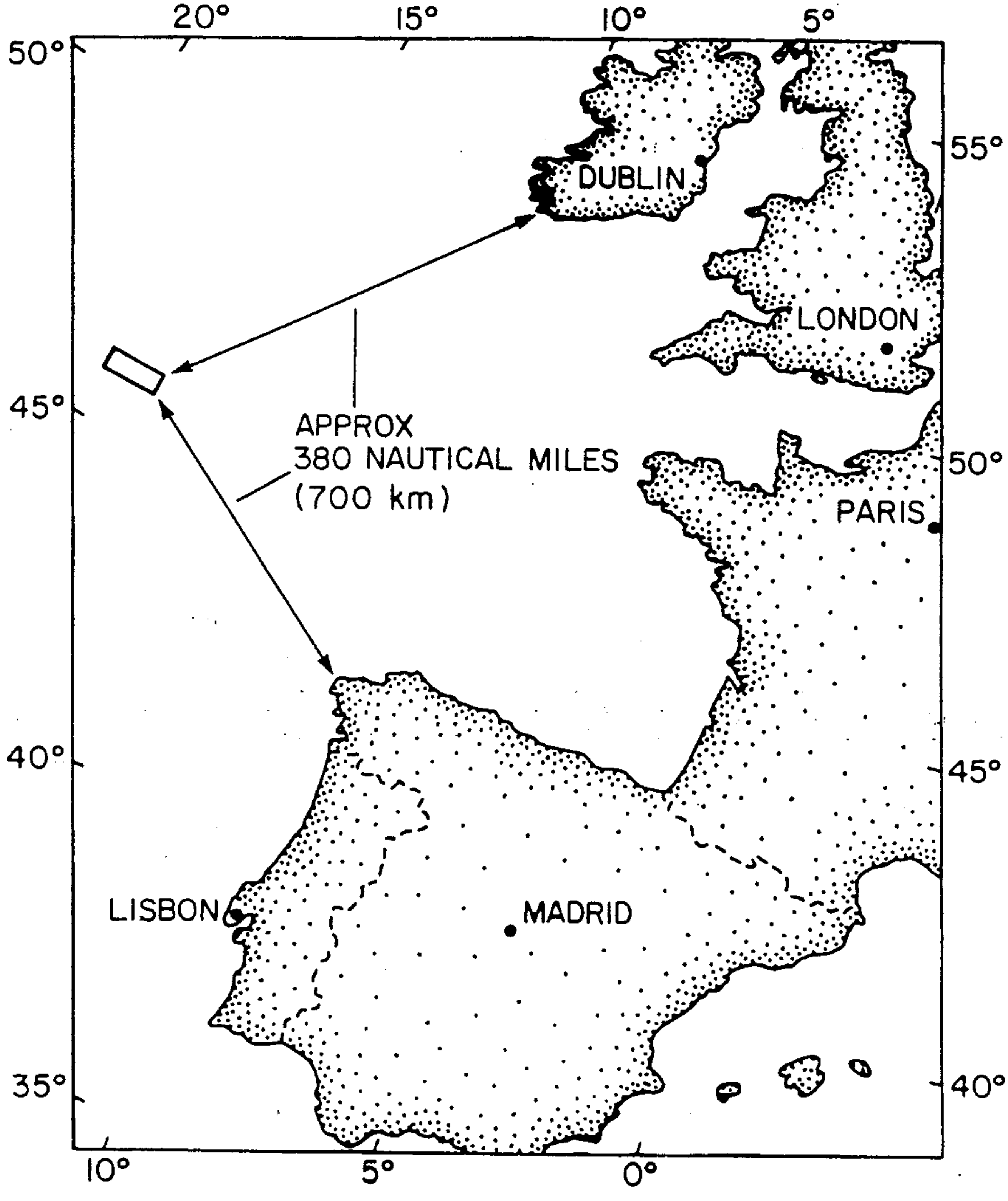

Figure 1: Location of the North-East Atlantic Dumpsite.