2 f

PNL-2941
UC-70

Summary of National and International Radioactive Waste Management Programs 1979

K. M. Harmon

March 1979

Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

PNL-2941

NOTICE

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy $____*; Microfiche $3.00

*Pages	NTIS Selling Price
001-025	$4.00
026-050	$4.50
051-075	$5.25
076-100	$6.00
101-125	$6.50
126-150	$7.25
151-175	$8.00
176-200	$9.00
201-225	$9.25
226-250	$9.50
251-275	$10.75
276-300	$11.00

PNL-2941
UC-70

SUMMARY OF NATIONAL AND INTERNATIONAL RADIOACTIVE WASTE MANAGEMENT PROGRAMS 1979

K.M. Harmon

March 1979

Prepared for
the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Richland, Washington 99352

CONTENTS

ACRONYMS,* ABBREVIATIONS AND SYMBOLS

AVM	Waste vitrification plant at Marcoule, France
BWR	Boiling water reactor
CANDU	Canadian deuterium-uranium reactor
FBR	Fast breeder reactor
FINGAL/HARVEST	British waste vitrification process
FIPS	West German process for vitrifying high-level waste, developed at Jülich
FRP	Fuel reprocessing plant
GCR	Gas-cooled reactor
GWe	10^9 watts of electricity = 1000 MWe
HLLW	High-level liquid waste
HLW	High-level waste
HTGR	High-temperature gas-cooled reactor
HTR	High-temperature reactor
HWR	Heavy water reactor
INFCE	International Nuclear Fuel Cycle Evaluation
LLW	Low-level waste
LMFBR	Liquid metal fast breeder reactor
LOTES	Low-temperature solidification (waste calcination) process developed by Eurochemic
LWCHW	Light water cooled, heavy water moderated reactor
LWR	Light water reactor
MOX	Mixed (plutonium-uranium) oxide
MTHM	Metric tons (tonnes) heavy metal
MTR	Materials test reactor
MTU	Metric tons uranium
MT SW	Metric tons of separative work (uranium enrichment)
PAMELA	West German and Eurochemic process for converting high-level waste to glass beads and embedding them in a metal alloy
PFR	Prototype Fast Reactor (UK)

*Acronyms for agencies, institutes, etc., are given in the Overview section for each country.

PHWR	Pressurized heavy water reactor
PIVER	Pilot Verres, French HLLW vitrification process
R&D	Research and development
SWU	Separative work unit
THTR	Thorium high-temperature reactor
Tonne	Metric ton
TRU	Transuranic
VERA	West German process for vitrifying high-level waste, developed at Karlsruhe
WAK	Fuel reprocessing pilot plant near Karlsruhe
WIPP	Waste isolation pilot plant (Carlsbad, New Mexico)

1985--	5.5	LWR	(45%)	-- example of symbols used to designate present or projected nuclear power production
↓	↓	↓	↓	
Year	GWe	Reactor Type	Percent of total electric power capacity	

SUMMARY OF NATIONAL AND INTERNATIONAL RADIOACTIVE WASTE MANAGEMENT PROGRAMS 1979

INTRODUCTION

Many nations and international agencies are working to develop improved technology and industrial capability for nuclear fuel cycle and waste management operations. The effort in some countries is limited to research in university laboratories on treating low-level waste from reactor plant operations. In other countries, national nuclear research institutes are engaged in major programs in all phases of the fuel cycle and waste management, and there is a national effort to commercialize fuel cycle operations.

Since late 1976, staff members of Pacific Northwest Laboratory have been working under USERDA/DOE sponsorship to assemble and consolidate openly available information on foreign and international nuclear waste management programs and technology. This report summarizes the information collected on the status of fuel cycle and waste management programs in selected countries making major efforts in these fields. This compilation attempts to provide current information as of the end of January 1979. The situation in many countries is changing rapidly, however, and the data presented may be outdated.

NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT ACTIVITIES

Three tables are included in this section:

- Table 1, Nuclear Waste-Producing Activities, lists the nations which are currently or potentially faced with the problems of safe treatment and disposal of radioactive wastes. Waste-producing activities treated in the table include: reactor operations and the pool-storage of spent fuels; mining and milling of uranium ores; uranium enrichment; mixed oxide (MOX) fuels fabrication; and spent fuel reprocessing. Where available, total plant capacities are given.
- Table 2, Waste Management Activities, lists the nations and international agencies which have active programs for waste treatment and waste isolation--either R&D or commercial-scale.
- Table 3, Major Events of 1978, lists those events during 1978 which were considered by the author to have major significance in the waste management picture.

TABLE 1. NUCLEAR WASTE-PRODUCING ACTIVITIES

Country	Reactor Operations and Spent Fuel Storage, GWe[a]	Uranium Mining and Milling, MTU/yr[b]	Uranium Enrichment MTHM/yr	MOX Fuels Fabrication, MTHM/yr	Spent Fuels Reprocessing, MTHM/yr
Argentina[c]	0.9: PHWR (1981)	280 (1978) 600 (1985)			R&D (pilot plant - future)
Australia[c]	1 (After 1990)	500 (1978) 11,800 (1985)	R&D Centrifuge and Laser		
Austria[c]	2.7: LWR (1985)[d]				
Belgium[c]	5.5: LWR (1985)		Partner in Eurodif	60	LWR: 60 (1984)
Brazil[c]	3.1: LWR (1986)	385 (1985)	R&D: 250 (1983-84)		LWR: 10 kg/d (pilot plant - 1984)
Bulgaria	1.76: LWR (1980)				
Canada[c]	15: PHWR (1988) 75 (2000)	6,450 (1978) 12,500 (1985)			R&D (thorium fuel cycle)
Central African Empire		1,000 (1985)			
Chile	0.6 (1988)				
China	1.2 (1985)	NA	180 (early 1960's)		
Cuba	1.76: LWR (1980's)				
Czechoslovakia	3.25: LWR (1985)				
Denmark[c]	5 (after 1990)	1,000 (potential)			
Egypt	0.6: LWR (1985) 6.6 (2000)				
Finland[c]	1.5: LWR (1979) 7 (1985)				
France[c]	40: LWR, GCR, FBR (1986) 65 (1990)	2,850 (1978) 3,700 (1985)	500 (1978) 10,800 (1981) R&D: 50 to 100	15: LWR fuels 5: FBR fuels (1978)	GCR: 2000(1978) LWR: 400 (1978) + 800 new (1984) + 800 new (1990) FBR: 100 (1990)
Gabon		1,200 (1978)			
Democratic Republic of Germany(c)	2.7: LWR (2980) 10 (1993)				
Federal Republic of Germany (c)	27: LWR, FBR, LMFBR (1984) 40 (1990)	100 (1978) 200 (1985)	1,000 (construction start (1981)	18 (1978) + 500 new (1992)	LWR: 40 (1978) + 1,400 new (1992) HTR: R&D (thorium fuels)
Hungary	1.76: LWR (1984)				

TABLE 1. (Contd)

Country	Reactor Operations and Spent Fuel Storage, GWe[(a)]	Uranium Mining and Milling, MTU/yr[(b)]	Uranium Enrichment MT SW/yr	MOX Fuels Fabrication, MTHM/yr	Spent Fuels Reprocessing, MTH/yr
India[(c)]	1.7: LWR & PHWR (1983) 6 (1991)	200 (1978)			LWR: 160 (1978)
Iran	2.4: LWR (1981)		Partner in Eurodif		
Iraq	0.6	120 (1985)			
Israel	1.8: LWR (late 1980's)				
Italy[(c)]	3.4: LWR, GCR, LWCHW (1985) 8-12		Partner in Eurodif	14 (1982)	
Japan[(c)]	18.5: LWR, GCR, PHWR, LMFBR (1985)	30 (1978)	R&D: 75 4,000 (after 1984)	10 (1978) + new plant - FBR fuels	LWR: 210 (1978) + 1,800 new R&D
South Korea	3.6: LWR & PHWR (1985) 50 (2000)				
Kuwait	3.6 (1999)				
Libya	0.3: LWR				
Luxembourg	1.25: LWR				
Mexico[(c)]	1.3: LWR (1983) 14	20 (1978) 550 (1985)		R&D	
Netherlands[(c)]	0.5: LWR (1978) 3.5		200 (1978) 1,250 (future)		
Niger		2,400 (1978) 9,000 (1985)			
Pakistan[(c)]	0.12: PHWR (1978) 16 (2000)				300 kg/d
Philippines	0.65: LWR (1982) 1.2 (early 1980's)				
Portugal		86 (1978) 270 (1985)			
Poland	0.44: LWR (1985) 23 (2000)				
Romania	0.44: LWR (1980) 10 (1990)				
South Africa	1.84: LWR (1983) 12 (2000)	8,800 (1978) 12,500 (1985)	R&D: pilot plant		
Spain[(c)]	10.2: LWR & GCR (1982)	190 (1978) 1,270 (1985)	Partner in Eurodif		LWR: 2 (pilot plant - future)

TABLE 1. (Contd)

Country	Reactor Operations and Spent Fuel Storage, GWe[a]	Uranium Mining and Milling, MTU/yr[b]	Uranium Enrichment, MT SW/yr	MOX Fuels Fabrication, MTHM/yr	Spent Fuels Reprocessing, MTHM/yr
Sweden[c]	9.4 (1985)	1,500 (potential)			
Switzerland[c]	3.8: LWR (1986)				
Taiwan	4.9: LWR (1985)				
Turkey	5 (1990)	100 (1985)			
United Kingdom[c]	11.8: GCR, HWR, LMFBR (1981) 25 to 40 (2000)		700 to (1978) 900 to 1100 (future)	5 to 10 (1978) + 20 new (1984) + 50 new (1987)	GCR: 2,000 (1978) LWR: 400 (1981) + 1,200 new (1987) FBR: 10 (1978)
USA	184: LWR & HTGR (1992) Up to 380 (2000)	19,300 (1978) 36,000 (1985)	17,230 (1978) 26,000 (1984)		
USSR[c]	21: LWR & LMFBR (1980)				LWR: 1,500 R&D
Yugoslavia	0.6: LWR 11 (2000)	180 (1985)			

(a) Forecasts of nuclear power capacity were taken from the February 1979 issue of Nuclear News and recent issues of Nucleonics Week, The Energy Daily, Nuclear Engineering International, and Energy in Countries With Planned Economies.
(b) Data on uranium mining and milling were taken primarily from the OECD/ NEA publication, Uranium Resources, Production and Demand, December 1977.
(c) Further details are provided in the National Overview Section.
(d) Startup of Tullnerfeld reactor vetoed by public vote in Nov. 1978; future is uncertain.

TABLE 2. WASTE MANAGEMENT ACTIVITIES

Country	Treatment									Geologic Isolation
				Fuel Recycle Plant Wastes						
	Milling Wastes	Reactor and Fuel Storage Wastes	Spent Fuels	HLLW	TRU	Non-HLLW	Hulls	Solids	Gaseous Wastes	
Australia	R&D			R&D						
Austria		R&D		R&D						R&D (rock)
Belgium		R&D commercial		R&D commercial --1984	R&D commercial	R&D	R&D	R&D commercial	R&D	Test repository --1980/81 (clay)
Canada	R&D	R&D commercial	R&D						R&D	Test repository --1989 (rock, salt)
Denmark		R&D								R&D (salt)
Finland		R&D								R&D (rock)
France	R&D	R&D commercial		R&D commercial	R&D commercial	R&D commercial	R&D commercial	R&D commercial	R&D	Test repository --1985 (rock, salt)
Democratic Republic of Germany										Bartensleben Salt Mine
Federal Republic of Germany										Asse Salt Mine Repository--1991 (salt)
India				R&D commercial --79/80	R&D	R&D Commercial	R&D			R&D (rock, sediments)
Italy				R&D	R&D					Test repository --mid 1980's (clay)
Japan		R&D commercial		R&D	R&D	R&D Commercial		R&D Commercial	R&D	Repository--2000 (rock)
Netherlands		R&D								R&D (salt)
Spain		R&D	R&D	R&D		R&D				Test repository --late 1980's
Sweden				R&D						Test repository --mid 1980's
Switzerland										R&D
United Kingdom				R&D commercial --1987	R&D	R&D	R&D	R&D	R&D	Test repository --1992 (rock, clay)
United States	R&D	R&D	R&D	R&D					R&D	Test repository--1992
USSR		R&D		R&D	R&D		R&D			R&D

TABLE 3. Major Events, December 1977 - March 1979

Country	Event
Austria	A national plebiscite voted against nuclear power and vetoed operation of Tullnerfeld BWR. (11/78)
Belgium	The Eurochemic Board decided to use the AVM process to solidify stored high-level waste produced during earlier operation of the Eurochemic reprocessing plant at Mol. (12/77)
	The Belgian government and the Eurochemic Board approved transfer to Belgium of all Eurochemic facilities at Mol--to be effective in mid-1982. (7/78) Belgium plans to refurbish and operate the 60 MT/yr reprocessing plant.
	CEN/SCK reported that bituminized wastes tend to crack and reject nitrate as they age, showing an increase in leach rate. (10/78)
Canada	The Federal government approved a major AECL Research Company program to develop a geologic waste repository for HLW or spent fuel (probably in crystalline rock). Target: about the year 2000. (Summer, 1978)
France	France announced plans to build a uranium enrichment pilot plant based on a new chemical-exchange process. (12/77)
	The Eurodif enrichment plant started up. (2/78)
	COGEMA received government approval to reprocess LWR oxide fuels on an industrial basis. (2/78)
	The AVM HLW vitrification plant at Marcoule completed cold operations (3/78) and started up with aged high-level Marcoule wastes. (6/78)
	COGEMA has signed contracts to reprocess spent LWR fuels from the following countries: Austria, Belgium, Japan, The Netherlands, Sweden, Switzerland, and West Germany.
Federal Republic of Germany (FRG)	Land for the NEZ was purchased at Gorleben by DWK.
	Shallow drilling at Gorleben, to characterize the salt dome, was approved by the government. (9/78)
	DWK decided to build an AVM-type vitrification plant to treat waste from the WAK fuel reprocessing plant and to build a PAMELA-type pilot plant at Mol, Belgium.

TABLE 3 (contd)

Country	Event
Federal Republic of Germany (FRG) (contd)	Waste disposal operations in the Asse II salt mine were suspended when the operating permit expired (12/78) and the government of Lower Saxony refused to extend it without going through extensive licensing procedures. (1/79)
India	Fuel reprocessing operations were begun at the Tarapur reprocessing plant.
Japan	FUGEN, an advanced thermal reactor, was taken to full power with a mixed fuel load--some assemblies containing MOX fuels.
	The Tokai Mura reprocessing plant was shut down, for as long as a year, by a leak in an evaporator section in the acid recovery part of the plant. (11/78)
Pakistan	The planned construction of a fuel reprocessing plant using French technology became very doubtful when France insisted that the plant design be changed to the coprocessing concept and Pakistan refused to accept the change.
Sweden	Legal requirements which had to be met before new reactors could be fuelled were met when 1) Sweden and France contracted for reprocessing of Swedish spent fuel at La Hague (3/78), and 2) the KBS report on waste disposal was accepted and fuelling of two new reactors was approved. (10/78)
	Following a change in government, the installation of a total of 11 reactors in Sweden was approved. (11/78)
United Kingdom	A major inquiry into the justification for construction of a new LWR fuel reprocessing plant in the UK was completed, and the government approved construction of THORP, a 1200 MTHM/yr facility to be built at Windscale. (5/78)
	BNFL signed contracts for the transport and reprocessing of spent nuclear fuel from Japan. (5/78)
International	INFCE studies continued. In general, the data-gathering effort was completed and evaluation started.

NATIONAL AND INTERNATIONAL PROGRAM OVERVIEWS

Brief overviews of fuel cycle and waste management activities are provided for the following nations and international organizations.

- Argentina
- Australia
- Austria
- Belgium
- Brazil
- Canada
- Denmark
- Finland
- France
- Germany, Democratic Republic of
- Germany, Federal Republic of (FRG)
- India
- Iran
- Italy
- Japan
- Mexico
- Netherlands
- Pakistan
- Spain
- Sweden
- Switzerland
- United Kingdom
- USSR
- IAEA
- European Communities (including JRC-Ispra)
- OECD/NEA
- CMEA

ARGENTINA

NUCLEAR POWER POLICY

National objectives are to develop extensive nuclear power production capability and to achieve domestic self-sufficiency in production of uranium fuel and heavy water (for PHWR's).

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Comision National de Energia Atomica (CNEA), Buenos Aires (National Atomic Energy Commission)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1981--0.9 PHWR; 2000--7.5 (23%).
2. Uranium mining and milling (MTU/yr): 1978--280; 1985--600.
3. Fabrication of UO_2 fuels: At present, Argentine yellowcake is converted to UO_2 pellets in West Germany. The pellets are returned to Argentina for fabrication into fuel rods and assemblies.

FUEL CYCLE AND WASTE TREATMENT R&D

1. Fuel reprocessing: Plans to construct an "experimental" reprocessing plant at the Ezeiza Atomic Centre near Buenos Aires were announced in December 1978 by the Atomic Energy Commission.
2. Waste treatment: The Argentine government has announced plans to build an experimental solidification plant for "high activity" wastes (not defined; the plant is probably not intended for high-level waste). Startup--1985.

AUSTRALIA

NUCLEAR POWER POLICY

Beyond a 1978 announcement by the West Australian government that the province will need a nuclear power station by 1990, the nation has made no commitment to nuclear power production. Uranium resources are being developed and marketed, in the face of opposition from environmentalists and certain unions, and the feasibility of an Australian uranium enrichment venture is under study.

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Australian Atomic Energy Commission (AAEC), Coogee, New South Wales
- AAEC Lucas Heights Research Establishment, Sutherland, New South Wales

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1 GWe after 1990.
2. Uranium mining and milling (MTU/yr): 1978--500; 1985--11,500.

FUEL CYCLE AND WASTE TREATMENT R&D

Lucas Heights

1. Uranium mill tailings:
   - treatment to prevent radium leaching

- migration of naturally-occurring radionuclides in situ (clay, sandstone and calcite formations)
- dating of underground waters.

2. Uranium enrichment: gas centrifuge and laser.

Australian National University, Canberra

High-level waste solidification: Radionuclides are incorporated in synthetic minerals which are stable in high-temperature aqueous environments. The "Synroc" process is based on concepts similar to those developed in a DOE-sponsored program at Penn State University. The Australian program has been confined to lab-scale R&D studies at the Australian National University.

AUSTRIA

NUCLEAR POWER POLICY

The Austrian utilities and government have been planning to install a number of nuclear power stations. In a November 1978 plebiscite, however, the Austrian voters by a small margin rejected the startup of the country's first power station (Tullnerfeld, near Vienna), leaving the future of nuclear power highly uncertain.

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Österreichische Studiengesellschaft für Atomenergie GmbH (SGAE), Vienna (Austrian Company for Atomic Energy Studies)
- SGAE Forschungszentrum Seibersdorf, near Vienna (Seibersdorf Research Centre)
- International Atomic Energy Agency (IAEA), Vienna

COMMERCIAL NUCLEAR ACTIVITIES

Spent fuel disposal: If the Austrians reverse the 1978 Tullnerfeld decision in the next few years, spent fuels are to be reprocessed at the La Hague plant in France. Vitrified waste and recovered uranium are to be returned to Austria; recovered plutonium, although Austrian property, would remain at La Hague for the time being.

WASTE TREATMENT R&D

Seibersdorf

1. HLW solidification: lab-scale R&D efforts to develop ceramic coatings for waste particles and to develop a vitrification process
2. Treatment of non-high-level wastes:
   - immobilization in concrete and bitumen
   - incineration of solid wastes

WASTE DISPOSAL

Objective: Evaluate the feasibility of providing an Austrian waste repository.

Status: Kernkraftwerks-Planungsgesellschaft has been assigned to search for suitable repository sites, and Seibersdorf is conducting supporting R&D on heat transfer, corrosion, diffusion, barrier materials and risk analysis. Granite formations are being emphasized.

BELGIUM

NUCLEAR POWER POLICY

The Belgian government and utilities are working towards well-rounded advanced reactor and fuel cycle capability through 1) participation in multinational projects such as the Dragon HTR (OECD), Kalkar LMFBR (FRG and The Netherlands) and the Eurodif enrichment plant (France and other partners), and 2) development of domestic fuel reprocessing, MOX fuel fabrication, and waste treatment and geologic waste disposal facilities.

SELECTED AGENCIES, NUCLEAR RESEARCH CENTRES AND COMPANIES

- Belgonucléaire SA, Brussels
- Centre d'Etude de l'Energie Nucleaire, Studiecentrum voor Kernenergie (CEN/SCK), Mol
  (Nuclear Research Centre)
- Commissariat a l'Energie Atomique (CEA), Brussels
- Commission of the European Communities (CEC), Brussels

- Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH (DWK), Hannover, FRG and Mol, Belgium (German Fuel Reprocessing Company)
- European Company for the Chemical Processing of Irradiated Fuels (Eurochemic), Mol.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1978--1.6 LWR; 1985--5.5 (45%).
2. MOX fuels: The Belgonucléaire plant at Dessel fabricates MOX fuels for recycle to LWR's. Capacity--60 MT/yr.
3. Fuel reprocessing: The Eurochemic plant at Mol, Belgium, with a capacity of 60 MTHM/yr of low-enriched uranium fuels, operated from 1966 to 1974. The plant has been decontaminated and is to be turned over to a Belgian company for modernization and future use in reprocessing spent fuels from Belgian reactors. Startup--1984.
4. HLW solidification: The Eurochemic Company (OECD/NEA-sponsored) is obligated to solidify the high-level liquid waste remaining from the fuel reprocessing operations of the Eurochemic plant at Mol, Belgium. They invested heavily in a calcination process (LOTES) and, in cooperation with the Gelsenberg Company in West Germany, in the development of the PAMELA process for making waste glass marbles and embedding them in a metal matrix. Eurochemic has now elected to build a French AVM-type vitrification plant at Mol, and their plans to build LOTES and PAMELA demonstration plants have been dropped. Since Eurochemic is to transfer ownership of all their facilities at Mol to Belgium by mid-1982, and since the Eurochemic AVM plant is not scheduled for startup before 1983-84, a Belgian company is to assume responsibility to vitrify the old Eurochemic plant waste (800 m^3). After the aged waste is treated, Belgium will use the plant to treat HLW from future Belgian fuel reprocessing operations. For details of the AVM process, see the France section.
5. Non-high-level waste treatment:
   - Bituminization: CEN/SCK operates a batch plant and Eurochemic has placed in service a continuous plant, "EUROBITUM," for cladding and other intermediate-level wastes. EUROBITUM capacity is 650 m^3/yr.

- Spent solvent treatment: Eurochemic is operating the "Eurowatt" solvent treatment plant (1 m^3/day) for conversion of used Purex solvent to forms suitable for disposal.

FUEL CYCLE AND WASTE TREATMENT R&D

CEN/SCK

Treatment of non-high-level wastes:

- Incineration: A high-temperature incinerator with a 150 kg/hr capacity has been installed for TRU wastes. The incinerator operates at a temperature high enough to convert the ashes to a basalt-like slag.
- Volume reduction of cladding hulls and other wastes.
- Control of airborne effluents from fuel cycle operations.

DWK

HLW solidification: DWK is designing a PAMELA process pilot vitrification plant for installation at Mol (see West Germany section).

Eurochemic

1. HLW solidification: Eurochemic developed two waste immobilization techniques at Mol:
   - LOTES: This process solidifies waste at low temperatures in a stirred-bed calciner. The phosphate waste granules can be consolidated by melting or can be incorporated in a metal matrix. The project was carried to the point that process tests had been started in a new, all-steel test unit rated at 10 ℓ/hr feed rate, when the decision was made to use French AVM technology for treatment of Eurochemic wastes.
   - A technique for embedding waste particles or glass beads in a low-melting alloy: This technique was demonstrated with LOTES product and with glass beads.
2. Other wastes:
   - Fuel assembly hardware: Eurochemic has developed a process for encapsulating fuel end pieces in a SiO_2-plastic matrix, under water.
   - Solid wastes: R&D includes studies of acid digestion, pyrolysis and molten-salt combustion for combustible alpha wastes.

WASTE DISPOSAL

Objective: Install a licensed repository for high-level and alpha-bearing wastes. Milestone: start operation in a test repository by 1980-1981. Participants: CEN/SCK (in charge) and Geological Survey.

Status: Evaluation of preliminary tests indicates that tunnels and underground facilities can be constructed in the Boom clay formations at Mol, at depths up to 250 m, and that a thermal load of about 15 kw per hectare can be tolerated. Heater experiments and the construction of a test chamber (350 m long by 30 m wide) under the Mol site are planned.

BRAZIL

NUCLEAR POWER POLICY

With a rapid annual increase in electric power consumption and with most of the easily accessible hydropower potential committed, Brazil has turned to nuclear power for much of its future expansion. Present investment is in LWR stations, but FBR research is planned. In pursuit of a national goal to achieve nuclear plant and fuel cycle independence by 1992, Brazil is installing a number of pilot- and demonstration-scale fuel cycle plants--with technology, plant design and hardware from West Germany. In late 1978 the reactor construction program was subjected to public criticism on grounds of excessive haste, poor site selection, and insufficient attention to safety.

SELECTED AGENCIES AND COMPANIES

- Commissaõ Nacional de Energia Nuclear (CNEN), Rio de Janeiro (National Nuclear Energy Commission)
- Nuclebrás, Rio de Janeiro

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1979--0.6 LWR; 2000--60 (35%).
2. Uranium mining and milling (MTU/yr): 1985--385.

FUEL CYCLE R&D

1. Uranium enrichment: A joint Brazil-West Germany pilot plant to demonstrate the Becker nozzle process is being built by Nuclei S.A. Capacity--250 MT SW/yr. Startup--1983-84.
2. Fuel reprocessing: Nuclebrás, the Brazilian fuel cycle company, is building a 10 kg U/day pilot reprocessing plant in the Rio de Janeiro area. Design and technical assistance have been provided by West Germany. Startup is planned for 1984.

CANADA

NUCLEAR POWER POLICY

Canada has been aggressive in developing a domestic nuclear power capability (particularly in Ontario Province) and a CANDU reactor export business. Thus far, spent CANDU fuels have been stored in waste pools at the power stations. Although Canada has no near-term plans for fuel reprocessing, AECL has now initiated a program to develop a thorium-burning CANDU system and the full thorium-^{233}U fuel cycle by the mid-1990's. This will require fuel reprocessing to allow ^{233}U recycle. Waste disposal plans are based on installation of a geologic repository, probably in crystalline rock formations in Ontario Province, by about the year 2000.

SELECTED AGENCIES, NUCLEAR RESEARCH CENTRES AND COMPANIES

- Atomic Energy of Canada, Ltd. (AECL), Ontario
- AECL Chalk River Nuclear Laboratories, Chalk River, Ontario
- AECL Whiteshell Nuclear Research Establishment, Pinawa, Manitoba
- Department of Energy, Mines and Resources (includes the Geological Survey of Canada), Ottawa, Ontario
- Ontario Hydro, Toronto, Ontario

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1978--4.5 PHWR, 0.25 LWR; 2000--75.
2. Uranium mining and milling (MTU/yr): 1978--6450; 1985--12,500.
3. Spent fuel storage: Ontario Hydro plans to build a centralized storage facility to allow storage in a water pool for 5 years and natural-draft storage in air for 50 years.
4. Management of reactor wastes: Ontario Hydro's Radioactive Waste Operations Site at the Bruce power station has facilities for waste incineration, compaction and in-ground storage.

FUEL CYCLE AND WASTE TREATMENT R&D

Chalk River

1. Spent fuels: Spent CANDU fuels have been stored in air in concrete-lined holes in the ground.
2. Reactor wastes: treatment and immobilization of reactor wastes (reverse osmosis, combustion, bituminization).
3. High-level wastes: AECL's Chalk River Laboratories studied the incorporation of fission products in aluminosilicate glasses about 20 years ago. In 1960, glass blocks containing high-level fission products were placed in swampy ground below the water table. Water samples taken since that time have shown almost negligible leach rates.

Whiteshell

1. Spent fuel handling:
    - develop canisters and storage techniques for interim storage or long-term isolation
    - test in-air storage.
2. Spent fuel reprocessing: A 300 g/d mini fuel reprocessing plant with six banks of mini mixer-settlers is being assembled. It is to be installed in Whiteshell hot cells and used for Thorex process studies and for preparation of Thorex HLW to be used in vitrification tests.
3. High-level wastes: Whiteshell Nuclear Research Establishment investigators are currently studying the incorporation of spent fuel wastes

into glasses and ceramic materials. Their objective is to develop an in-can melting process for high-activity wastes from reprocessing thorium fuels. Design and construction of a pilot-stage immobilization plant is expected to start in 1980. Whiteshell also has a waste-form characterization program underway.

4. Gaseous wastes from fuel reprocessing:
   - recovery of volatile radionuclides from fuel reprocessing operations
   - incorporation of noble gases in solids (e.g., krypton in zeolites).

Other Establishments

Management of mill tailings:
- radium control
- environmental impacts
- grout injections around tailings ponds.

WASTE DISPOSAL

Objective: Commission a commercial geologic repository for spent fuels and/or high-level and TRU wastes. Milestones: complete concept verification--1981; site selection for a repository--1984; start up a test repository--1989; commission a commercial repository--about 2000. Participants: Whiteshell (in charge) and Department of Energy, Mines and Resources (geological and geophysical studies).

Status: Many potential repository sites have been located. Most of them are in granite formations in the Precambrian shield of Ontario Province, with others in salt formations. Present efforts are directed towards 1) showing that geologic disposal is safe and viable and 2) narrowing the number of potential sites. A test site has been established in a small granitic body at White Lake to permit testing equipment and concepts.

R&D

Whiteshell

- repository site characterization
- radionuclide migration

- hydrology
- thermal and mechanical properties of rock formations.

CHINA

NUCLEAR POWER POLICY

Chinese officials appear to be shopping for nuclear power stations and technology. They have indicated the intent to have two nuclear reactors on-line by 1985. These might be PWR's or CANDU's.

COMMERCIAL NUCLEAR ACTIVITIES

1. Uranium mining and milling
2. Uranium enrichment: A 180 tonne SW/yr (94% enriched U) has been operating at Lanchou since the early 1960's.

NUCLEAR RESEARCH CENTRES

- Atomic Energy Research Institute of the Academy of Sciences

FUEL CYCLE R&D

Atomic Energy Research Institute: fuel fabrication and fuel reprocessing.

DENMARK

NUCLEAR POWER POLICY

In 1976, the Minister of Energy presented to Parliament an energy plan which called for five nuclear stations to be completed by 1995. Decision to implement the plan has been deferred, pending the resolution of waste disposal questions, because of public opposition. The future is unclear.

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Danish Energy Agency, Copenhagen
- Risø Research Establishment, Roskilde

COMMERCIAL NUCLEAR ACTIVITIES

Power production (GWe): Beyond 1990--5 (possible).

WASTE TREATMENT R&D

Risø Research Establishment, Roskilde: low-level waste treatment technology.

WASTE DISPOSAL

Objective: Evaluate the feasibility of a salt-dome waste repository in the Jutland area.

Status: Risk analysis and supporting R&D for geological waste disposal are being conducted at the Risø Research Establishment, while a French engineering company, Geostock, has a contract to design a salt-dome repository.

FINLAND

NUCLEAR POWER POLICY

Finland has purchased nuclear power stations (LWR's) from both Russia and Sweden. Spent fuel from the Russian- uilt reactors is returned to Russia for reprocessing and disposal of the wastes. Finland may purchase reprocessing service abroad for spent fuels from their Swedish-built reactors.

SELECTED RESEARCH CENTRES

- Technical Research Centre of Finland, Espoo.

COMMERCIAL NUCLEAR ACTIVITIES

Power production (GWe): 1979--1.5 LWR; 1980--2.16 LWR (35%); 1985--7.

WASTE TREATMENT R&D

Espoo: encapsulation of reactor wastes in bitumen and concrete.

WASTE DISPOSAL

Since Finland may have to take back solidified HLW from foreign reprocessors of Finnish spent fuel, the feasibility of a crystalline rock repository is being evaluated. Supporting R&D includes:

- risk assessment studies
- migration of radionuclides
- economic evaluation of alternatives.

FRANCE

NUCLEAR POWER POLICY

France is very aggressive in developing nuclear power capability and in exporting equipment, plants and technology. Present emphasis is on: installation of PWR power stations; expansion of LMFBR capacity (to 25 GWe by the year 2000); expansion of uranium enrichment and fuel reprocessing capacity, to satisfy foreign and domestic requirements; development of industrial waste treatment technology and plants; and establishment of a licensed repository for TRU wastes.

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Cadarache Centre d'Etudes Nucléaires, St. Paul-les-Durance
  (Cadarache Nuclear Research Centre)
- Compagnie Generale des Matières Nucléaires (COGEMA), Chatillon
  (Nuclear Materials Company)
- Commissariat à l'Energie Atomique (CEA), Paris
  (Atomic Energy Commission)

- Fontenay-aux-Roses Centre d'Etudes Nucléaires (F-a-R), Paris (Fontenay-aux-Roses Nuclear Research Centre)
- Grenoble Centre d'Etudes Nucléaires, Grenoble (Grenoble Nuclear Research Centre)
- La Hague Centre, near Cherbourg
- Marcoule Centre, Bagnols-sur-Ceze
- Saclay Centre d'Etudes Nucléaires, Gif-sur-Yvette (Saclay Nuclear Research Centre)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1986--40 LWR, GCR, AND FBR (52%)
2. Uranium enrichment:
   - Pierrelatte and Eurodif gaseous diffusion plants. (Eurodif is a multinational project owned by Belgium, France, Iran, Italy and Spain.)
   - A CEA pilot plant (50-100 MT SW/yr) is to be built to demonstrate a new French chemical exchange process which operates efficiently only for low enrichments. Startup--1983.
3. Fuel fabrication: The Cadarache MOX plant makes fuels for the French LMFBR's. Capacity: 15 MT/yr for LWR fuels; 5 MT/yr for FBR fuels.
4. Spent fuel reprocessing:
   - UP-1 (COGEMA, Marcoule): designed for natural uranium, gas-graphite reactor fuels. Capacity--900 to 1200 MTHM/yr.
   - PURR (COGEMA, Marcoule): a new plant, designed for MOX fuels from fast breeder reactors. Design capacity--100 MTHM/yr. Startup--1989-90.
   - SAP (CEA, Marcoule): a pilot plant used for process development. Current effort supports France's FBR fuel cycle program. Capacity--25 kg/day.
   - UP-2 (COGEMA, La Hague): Designed and constructed for natural-uranium, gas-graphite reactor fuels, UP-2 now has a chop/leach head end to allow treatment of LWR oxide fuels. Present capacities are 1000 MTHM/yr for natural uranium metal fuels, 400 MTHM/yr for oxide fuels. Expansion of the oxide head end to 800 MTHM/yr capacity is planned. COGEMA intends to reprocess gas-graphite fuels only at Marcoule in the future, leaving UP-1 for LWR fuels.

- UP-3 (COGEMA, La Hague): a twin-line plant being built to handle LWR oxide fuels. The first line, UP-3A, is to start up in 1986 and is to service foreign customers. UP-3B, to come on line in 1989-90, will handle domestic French fuels. Each line is sized at 800 MTHM/yr.
- AT-1 (COGEMA, La Hague): a pilot-scale plant (200 kg/yr) used to reprocess Rapsodie (LMFBR) spent fuels.

5. High-level waste solidification--AVM Plant (Marcoule):

   AVM uses a rotary-kiln calciner coupled with a semi-continuous metallic melter to produce borosilicate glass blocks. Capacity--150 m^3 HLW/yr; one canister of glass (150 ℓ; 350 kg) per day. Waste canisters are stored in air-cooled pits in underground concrete vaults.

   The AVM has been operating successfully with Marcoule UP-1 waste since June 1978. The French fuel cycle company, COGEMA, plans to install scaled-up AVM-type plants (capacity--50 ℓ liquid feed/hr per line vs AVM's 36 ℓ/hr) at La Hague to treat high-level wastes from La Hague's UP-2 and UP-3 fuel reprocessing plants.

   France has also sold AVM technology to other nations. Eurochemic is installing an AVM-type plant at Mol, Belgium; West Germany plans to install an AVM-type plant at their WAK fuel reprocessing pilot plant at Karlsruhe, and will probably use the AVM process at their new fuel cycle and waste management center at Gorleben; and other countries are considering using the AVM process.

6. Management of non-high-level wastes: A number of nuclear energy centres are operating waste incinerators and pilot plants for incorporating non-high-level wastes in bitumen, concrete or resins.

FUEL CYCLE AND WASTE TREATMENT R&D

Cadarache

1. MOX fuels: development of fabrication technology
2. Reactor wastes: pilot plant operation
   - bituminization
   - cryogenic crushing.

Fontenay-aux-Roses

1. Mill tailings: control of tailings piles by growth of vegetation
2. Fuel reprocessing:

- FBR fuel reprocessing R&D
- control of volatile radionuclides (noble gas cryogenics)

3. TRU wastes: partitioning.

Grenoble

1. Incorporation of non-HLW in thermosetting resins
2. Recovery of volatile radionuclides.

Marcoule

1. Fuel reprocessing: The SAP pilot plant (25 kg/day HM) is used for process development for FBR spent fuels.
2. HLW vitrification:
   - PIVER pilot plant: PIVER was used for early vitrification process development and now serves for special studies.
   - ceramic melter development
   - waste form characterization.
3. Meltdown of fuel cladding hulls
4. Treatment of non-high-level wastes
   - incineration of solid wastes
   - bituminization (twin-screw extruder).

WASTE DISPOSAL

Objective: Commission waste repositories for alpha-bearing wastes. Milestone: have the first pilot-plant repository, for alpha-bearing waste only, operational by 1985.

Status: The planned disposal method for alpha-bearing wastes is emplacement in deep geological formations. For fission products, either geologic disposal or long-term storage in engineered facilities is a possible solution. The formations presently being studied for geologic disposal are rock salt and crystalline rocks. The reconnaissance of salt formations in France has indicated the existence of several promising areas. However, present plans are to devote a significantly greater effort to crystalline rocks. The possibility of disposal in granite has been evaluated for the site of La Hague, and plans are underway for a large program that will evaluate many other crystalline-rock formations.

R&D

F-a-R Nuclear Research Centre and Paris School of Mines

1. Radionuclide migration (laboratory and in situ experiments)
2. Use of natural mineral barriers against migration of radionuclides through the ground.

DEMOCRATIC REPUBLIC OF GERMANY

NUCLEAR POWER POLICY

As with the other Soviet Bloc nations, East Germany is developing a strong nuclear power energy base.

COMMERCIAL NUCLEAR ACTIVITIES

Power production (GWe): 1978--1.8 LWR; 1993--10 LWR.

WASTE DISPOSAL

The country is establishing an industrial-scale waste repository in an abandoned salt mine at Bartensleben, near the border with West Germany.

FEDERAL REPUBLIC OF GERMANY

NUCLEAR POWER POLICY

Major West German resources are being applied to the installation of LWR power stations, closure of the LWR and THTR fuel cycles, and demonstration of THTR and LMFBR technology. Present work on the LWR fuel cycle is focused on design, construction, and licensing of a spent fuel disposal centre (the NEZ at Gorleben) to service the German nuclear industry. The NEZ is to include spent fuel storage and reprocessing facilities, a recycle fuel fabrication plant, waste treatment plants, and waste repositories.

The programs have been retarded significantly by public opposition, expressed in demonstrations and legal actions.

SELECTED NUCLEAR AGENCIES AND FUEL CYCLE COMPANIES

- ALKEM GmbH, Hanau
- Bundesministerium für Forschung und Technologie (BMFT), Bonn (Federal Ministry for Science and Technology)
- Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH (DWK), Hannover (German Fuel Reprocessing Company)
- European Transuranium Institute, Karlsruhe (A CEC laboratory)
- Institut für Tieflagerung der GSF (GSF/IfT), Clausthal Zellerfeld (Underground Storage Institute, Society for Radioactive and Environmental Research)
- Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH (GWK), Leopoldshafen (near Karlsruhe) (Fuel Reprocessing Company, operator of WAK reprocessing pilot plant)
- Hahn-Meitner Institut für Kernforschung Berlin, GmbH (HMI), Berlin
- Kernforschungsanlage Jülich GmbH (KFA), Jülich (Julich Nuclear Research Centre)
- Kernforschungszentrum Karlsruhe (KfK), Karlsruhe (Karlsruhe Nuclear Research Centre)
- NUKEM GmbH, Hanau
- Physikalisch-Technische Bundesanstalt (PTB), Braunschweig (Federal Physical-Technical Bureau)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1984--27 LWR, FBR, and LMFBR; 1990--40.
2. Uranium mining and milling: 100 MTU/yr.
3. Uranium enrichment: Uranit mbH, a partner with British and Dutch companies in the URENCO consortium, plans to build a 1000 MT SW/yr gas centrifuge plant at Gronau. Start of construction is expected in 1981.
4. Fuel reprocessing: WAK Plant (DWK, Karlsruhe)--a 40 MTHM/yr pilot plant, used for routine reprocessing of spent fuels and as a test facility for new processes and components.
5. Spent fuel disposal: The Nukleares Entsorgungs Zentrum (NEZ), Germany's spent fuel disposal center, is to include all facilities to recycle U and Pu from spent LWR fuels and to manage the wastes. It is located on a 12 km^2 site near the village of Gorleben, close to the East German

border. DWK (German fuel cycle company) is responsible for design and construction of all facilities except the waste repository, which is assigned by law to PTB, a federal institute similar to the U.S. Bureau of Standards. The NEZ is to include the following facilities:

- Spent fuel storage pool (3000 MT). Startup--1985.
- Fuel reprocessing plant. A 1400 MT/yr commercial plant for LWR fuels, the plant is to use a chop-leach head end and Purex-type solvent extraction system with pulse columns and mixer-settlers. Required capacity is to be provided by two or more parallel process lines. Startup--1992.
- Uranium storage and conversion plant. Startup--1991.
- Plant for plutonium storage and conversion and for MOX fuel fabrication (500 MT/yr fuel; 14 MT/yr Pu). The MOX plant, designed and operated by ALKEM, is to have multiple glove-box lines, each with 25 MT/yr capacity. Startup--1992.
- Non-HLW conditioning plant. Startup--1990.
- HLW vitrification plant: DWK has selected the French AVM waste vitrification process for installation at the WAK reprocessing pilot plant at Karlsruhe. The company has also based its license application for the waste treatment facility at the Gorleben spent fuel disposal centre upon the AVM process. The Gorleben plant will need the capacity to handle about 600 m^3/yr of HLW and is to be sized to produce four or five 70-liter canisters of glass per day. The waste canisters are to be stored in air-cooled, underground interim storage facilities until they have cooled sufficiently to allow placement in the salt-dome repository. Startup--mid-1990's.
- Salt-dome repository (see Waste Disposal section).

FUEL CYCLE AND WASTE TREATMENT R&D

ALKEM

MOX fuels fabrication technology: ALKEM's Hanau pilot plant has an 18 MT/yr capacity.

DWK

Waste Solidification: Although DWK has referenced French AVM (vitrification) technology in the NEZ license application, the company plans to demonstrate a German backup process. For this purpose, DWK has chosen the PAMELA process and plans to build a PAMELA pilot plant on Eurochemic land at Mol, Belgium, and run a process demonstration with Eurochemic high-level waste.

As originally developed by Gelsenberg A.G. and Eurochemic investigators, PAMELA was intended to produce phosphate waste glass beads and embed them in a low-melting metal matrix to form "Vitromet." As conceived by DWK, the PAMELA pilot plant is to be able to produce borosilicate glass in either block or bead form and to make Vitromet from the beads. Two ceramic melters are to be used, one for blocks and one for beads. Capacity of the PAMELA pilot plant--30-40 ℓ/hr feed. Startup--after 1983.

Hahn-Meitner Institut

HLW solidification:

- development of improved HLW waste forms (glasses and glass ceramics)
- characterization of waste forms.

Jülich Nuclear Research Centre (KFA)

1. HTGR fuel cycle development: KFA has overall responsibility to develop HTGR technology and the associated fuel cycle.
   - ThO_2-UO_2 fuel fabrication technology
   - ThO_2-UO_2 fuel reprocessing. KFA is building JUPITER, a 2 kg/day pilot plant. Process operations include a grind-burn-leach head-end to remove the graphite matrix and dissolve (continuously) the ThO_2-UO_2 fuel particles; a Thorex flowsheet for the fertile particles; a Purex system for the fissile particles; and a fabrication plant for the ^{233}U product. Startup--after 1981.
   - Waste vitrification: KFA is building a 10 kg glass/hr hot pilot plant to demonstrate the solidification of HLW from the thorium fuel cycle by the FIPS process. FIPS uses a drum dryer coupled with a rising-level, in-pot melter to produce a borosilicate glass or ceramic.
2. Incineration of combustible solids.

3. Recovery of volatile radionuclides from Jupiter off-gases: Kryosep cryogenic process for noble gas recovery.

Karlsruhe Nuclear Research Centre (KfK)

1. Uranium enrichment: Becker nozzle process.
2. Fuel reprocessing: process development for LWR and FBR fuels:
   - Milli facility (KfK, Karlsruhe): a miniature fuel reprocessing plant using mini mixer-settlers in a hot cell.
   - TEKO Hall (KfK, Karlsruhe): a nonradioactive facility which is equipped for large-scale tests of components and unit operations.
3. HLW solidification:
   - VERA process: spray calciner and ceramic melter. The VERA process was tested extensively in laboratory and cold pilot plant runs, then dropped in favor of ceramic melter development.
   - Ceramic melter: spray-calciner coupled with a ceramic melter; or a liquid-fed ceramic melter. Karlsruhe investigators made extensive tests of this concept before their effort was diverted to support the PAMELA process demonstration program.
   - Other techniques: KfK and HMI have also looked at a number of alternate techniques for solidifying high-level wastes, including preparation of glass ceramics by devitrification of a waste glass and use of a thermite reaction to yield a glass-ceramic material.
   - Packaging and characterization of HLW solids and waste glasses containing alpha-emitters.
4. Non-HLW treatment and solidification:
   - volume reduction of liquid wastes
   - incorporation in bitumen or concrete (including in situ solidification in concrete in a geologic repository).
5. Partitioning and immobilization of alpha-bearing wastes.
6. Handling and packaging of cladding hulls:
   - properties of hulls (e.g., heat generation, tritium release)
   - immobilization of hulls in concrete.
7. Incineration and mechanical volume reduction of solids.
8. Management of airborne effluents:
   - in-plant control and storage

- cryogenic processes for noble gas recovery
- ion implantation of noble gases in a metal matrix.

9. Transportation.

WAK Reprocessing Pilot Plant, Karlsruhe

1. Spent fuel reprocessing: The WAK pilot plant, with a 40 MT/yr capacity, is used for routine reprocessing of spent fuels and as a test facility for new processes and components.
2. HLW vitrification: An AVM-type vitrification plant is planned for WAK, to treat stored and future HLW.
3. Volatile radionuclide control: in-plant control of iodine and tritium.

European Transuranium Institute (a CEC establishment located at Karlsruhe)

Properties of transuranics.

WASTE DISPOSAL

Objectives:

1. License the NEZ salt-dome repository for high- and low-level waste disposal. Goal capacities: 20,000 drums/yr of non-HLW; 1600 canisters/yr of HLW glass. Milestones: start disposal of non-HLW drums--1991; start disposal of HLW canisters--late 1990's. Project participants: PTB, Braunschweig (in charge), DBE (prime contractor for construction and operation), and GSF/IfT and KfK (R&D).
2. Convert the Konrad iron mine (at Salzgitter, 45 km from Asse) into an industrial repository for non-alpha-bearing wastes. Startup--1985. Project participants: KSF/IfT and KfK.

R&D

GSF/IfT, Clausthal-Zellerfeld

Since 1965, IfT has been using an abandoned salt mine, Asse II (near Wolfenbüttel) for disposal of low- and intermediate-level wastes and to develop salt repository technology. In December 1978, the operating permit for the site expired, and the government of Lower Saxony is requiring compliance with new regulations before operations can be resumed. Getting a new license may require 2-5 years. R&D activities (partly sponsored by CEC) include development and testing of various techniques for placing waste containers in repositories, rock mechanics studies, in situ measurements of parameters of interest, and safety analyses.

KfK, Karlsruhe

KfK and GSF/IfT are cooperating in a program to develop technology for the in situ solidification (in a cement matrix) of low- and intermediate-level wastes in a shaped salt cavern. KfK is also studying radionuclide migration and disposal of tritium by injection into deep wells.

HMI, Berlin

HMI has the lead in a major West German program ($12 million spread over four years) to assess the safety of the post-reactor fuel cycle, including final disposal of wastes in salt.

INDIA

NUCLEAR POWER POLICY

India is reaching for complete nuclear self-sufficiency. The country started with LWR's, switched to installation of PHWR's (to avoid enrichment), and plans to convert to a ^{233}U-Th FBR system which will allow use of India's plentiful thorium resources. Because of transportation problems, India has adopted a policy of setting up low-capacity fuel cycle complexes near major power stations, rather than a centralized plant.

SELECTED AGENCIES AND NUCLEAR CENTRES

- Atomic Energy Commission, Bombay
- Bhabha Atomic Energy Centre (BARC), Trombay, Bombay
- Madras Atomic Power Project, Kalpakkam
- Tarapur Atomic Power Project, Tarapur

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1984--1.7 LWR and PHWR; 1991--6 (7%).
2. Uranium mining and milling: 200 MTU/yr.
3. Fuel reprocessing: India has installed two fuel reprocessing plants and is planning a third, at the following locations:
   - Trombay (BARC): A 60 MTHM/yr pilot plant for LWR fuels, Trombay produced the plutonium used in India's nuclear weapon test.
   - Tarapur: A 100 MTHM/yr plant for LWR and PHWR (CANDU) fuels.
   - Madras: An "industrial" scale plant to handle PHWR and FBR spent fuels from Madras-area power stations.
4. HLLW solidification: A waste immobilization plant is under construction at Tarapur, scheduled for startup in 1979-1980. It is based on a semi-continuous pot process developed at Trombay. The HLLW feed is pre-concentrated, then calcined in the calciner-melter pot. When the pot is 75% full of calcine, the waste is melted and drained into a waste canister.
5. Non-HLW treatment: BARC has a liquid-waste treatment plant.

WASTE TREATMENT R&D

BARC

1. TRU waste management
   - partitioning of TRU wastes
   - conversion of TRU wastes into insoluble alumino-silicates by a hydrothermal process.
2. Bituminization of non-high-level wastes.
3. Storage and treatment of fuel hulls.

WASTE DISPOSAL

Objective: Develop a repository for high-level and TRU wastes.

Status: India has conducted a geological survey for potential repository sites and has supporting R&D underway at BARC, Trombay. Igneous rock and sedimentary formations currently show the best potential.

IRAN

NUCLEAR POWER POLICY

Prior to the recent (January 1979) change in government, Iran had been investing heavily in various energy-producing projects, including nuclear power stations. It now appears that the only reactors which will be built are two 1200-MWe units currently under construction. The country has a share of the Eurodif enrichment plant in France, and aspired to develop complete fuel cycle capability. To date, Iran has depended heavily on other nations for technology and has employed UKAEA (England) to evaluate the problems associated with the storage and management of spent fuel and radioactive wastes from Iran's nuclear power plants.

ITALY

NUCLEAR POWER POLICY

Italy has defined an ambitious nuclear power program: the installation of many LWR's; participation in the Eurodif enrichment plant project in France; partnership in LMFBR demonstration plants in France and West Germany, hopefully leading to a domestic FBR system; and development of fuel cycle self-sufficiency. Accomplishment of these objectives is questionable at present because of economic problems, plant siting difficulties, and public opposition.

SELECTED AGENCIES, NUCLEAR RESEARCH CENTRES, AND COMPANIES

- AGIP Nucleare SpA, Milan
- Casaccia Nuclear Studies Centre (CSN Casaccia), Rome
- Comitato Nazionale per l'Energia Nucleare (CNEN), Rome (National Nuclear Energy Committee)
- Joint Research Centre, Euratom (CCR Euratom), Ispra (Varese)
- Saluggia Centre, Saluggia (Vercelli)
- Trisaia Centre, Policoro (Matera)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1985--3.4 LWR, GCR, and LWCHW.
2. Uranium Mining and Milling (MTU/yr): 1985--120
3. MOX fuel fabrication: AGIP Nucleare is building a 14 MT/yr plant at Rotondella to fabricate fast breeder PuO_2/UO_2 fuels for the Superphenix FBR core. Startup--1982.
4. Spent fuel reprocessing: Italy has two pilot-scale reprocessing plants (see R&D--CNEN), and the construction of an industrial-scale plant is being evaluated by CNEN and AGIP Nucleare. Probable capacity--1200 MTHM/yr. Location--near EUREX (Torino area) or ITREC (Rotondella area).

FUEL CYCLE AND WASTE TREATMENT R&D

AGIP Nucleare, Milan

- MOX fuel fabrication
- Combustion of solid wastes in molten salts.

CNEN, Rome

1. Fuel reprocessing: The CNEN sponsors fuel reprocessing R&D (LWR and FBR fuels) at its Saluggia and Trisaia Centres:
   - EUREX (CNEN--Saluggia Centre, near Torino): Initially designed for MTR fuels, Eurex now has a chop-leach head-end and capability for LWR oxide fuels. Capacity--MTR fuels, 30 kg/day; LWR oxides, 50-100 kg/day.
   - ITREC (CNEN--Trisaia Centre, Rotondella): ITREC was built for thorium fuel reprocessing and has a chop-leach head-end. The plant's current assignment is FBR fuel reprocessing R&D.
2. HLW solidification: CNEN and AGIP Nucleare are collaborating on plans to build two vitrification demonstration plants based on a batch process: IVET-1, a cold plant to be built at CSN-Casaccia; and IVET-2, a hot plant to be coupled with one of CNEN's small reprocessing plants. IVET-3, a cold demonstration plant for a continuous process (perhaps a French AVM plant), is also under consideration.

CSN, Cassacia

1. HLW vitrification: development of ESTER, a multistage pot-calcination-vitrification process that may produce either a phosphate or a borosilicate glass. ESTER has been tested in hot-cell runs at Ispra.
2. Non-HLW treatment:
   - immobilization in polymer-impregnated cement
   - characterization of waste forms.
3. TRU wastes: partitioning and transmutation.

Joint Research Centre, Ispra (CEC)

TRU wastes:
- partitioning and transmutation
- immobilization in bitumen.

WASTE DISPOSAL

Objective: Install a repository for high-level and TRU wastes. Milestone: start operations in a test repository by the mid-1980's.

Status: CNEN is evaluating the argillaceous sediments near the Trisaia Centre in Southern Italy. Supporting R&D includes in situ tests of thermal and radiation effects, engineering development, and risk assessment. CNEN-Casaccia (Rome) and the CEC Joint Research Centre at Ispra are contributing to geologic isolation safety assessments.

JAPAN

NUCLEAR POWER POLICY

With Japan dependent upon other nations for 90% of its energy supplies (1973), the country is placing heavy emphasis on the growth of nuclear power, with commitment to developing a variety of reactor systems: LWR, HWR, and LMFBR. Japan is also seeking to become self-sufficient in all phases of the fuel cycle including uranium enrichment and plutonium recycle. A major problem is finding sites for future nuclear power plants.

SELECTED AGENCIES, NUCLEAR RESEARCH CENTRES, AND COMPANIES

- Japan Atomic Energy Commission (JAEC), Tokyo
- Japan Atomic Energy Research Institute (JAERI), Tokyo
- Oarai Research Establishment (JAERI-Oari), Oarai-Machi
- Power Reactor and Nuclear Fuel Development Corporation (PNC), Tokyo
- Tokai Works (PNC-Tokai), Tokai Mura
- Tokai Research Establishment (JAERI-Tokai), Tokai Mura

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1985--18.5 LWR, GCR, PHWR and LMFBR: 1990: 60.
2. Uranium mining and milling (MTU/yr): 30
3. Uranium enrichment: gas centrifuge pilot plant at Ningyo-toge mine site. Full operation (75 MT SW)--1981.
4. MOX fuels: Japan relies on private industry to fabricate uranium fuels and on PNC for development and fabrication of MOX fuels. PNC's Plutonium Fuel Fabrication Facility (PFFF) has two fabrication lines--an FBR fuel line with a capacity of 15 kg MOX/d, and an HWR fuel line with a 50 kg MOX/d capacity.
5. Fuel reprocessing: Japan has contracts in place with COGEMA (France) and BNFL (UK) for them to provide fuel reprocessing service until Japan's domestic plants can carry the load. Present Japanese facilities and activities include:
   - Tokai Mura plant (PNC), a 210 MTHM/yr Purex plant for LWR oxide fuels which started operations in late 1977. The process includes a chop-leach head-end and a mixer-settler solvent extraction system.
   - Planning for an industrial, two-line, 6 MTU/day reprocessing plant, which may be built and operated by private industry.
6. HLW solidification: Japan's stated intent is to have a demonstration vitrification plant operating by 1987, to support the Tokai Mura reprocessing plant. PNC, Japan's fuel cycle company, is considering several types of technology: fluid-bed calcination, followed by sintering, melting, or hot-pressing; and the ceramic melter. Supporting R&D is being done by PNC and Japan's Atomic Energy Research Institute.

7. Non-HLW management:
   - bituminization: JAERI has a 30 ℓ/hr plant at Oarai, and PNC plans to build a 200 ℓ/hr plant
   - incineration: ombustible solids incinerators are in service at Tokai and Oarai.

FUEL CYCLE AND WASTE TREATMENT R&D

1. Uranium enrichment:
   - gas centrifuge technology
   - gaseous diffusion and ion exchange chromatography (JAERI).
2. Fuel fabrication:
   - development of fabrication technology for LWR, HWR and FBR fuels (PNC)
   - development of coated-particle (UO_2) fuels for JAERI's experimental HTR (PNC).
3. Fuel reprocessing: PNC is building three research facilities for FBR fuels at the Tokai Works:
   - Technological Test Facility (cold engineering). Construction complete--1982
   - Chemical Processing Research Facility (1 kg/batch, hot operation). Cold test runs--1979; hot equipment tests--1982
   - Reprocessing Research Facility (150 kg/day, hot engineering). Installation complete--1987.

   Present PNC R&D activities include:
   - equipment development (FBR fuel disassembly and shearing apparatus; dissolver; feed clarifier equipment; centrifugal contactor; pulse column)
   - process studies (voloxidation; electrolytic Pu reduction; solvent treatment).
   - airborne effluent control.
4. HLW solidification: Japanese agencies which have conducted waste solidification R&D projects include:
   - PNC: fluidized bed calcination of high-sodium HLLW, calcine converted to glass or ceramic

- JAERI-Tokai: rotary kiln calcination and vitrification of waste-loaded zeolite ion exchangers
- Government Research Institute, Osaka: sintering or hot-pressing (with Pyrex glass and Cu powder additives) of calcined wastes; devitrification of waste glasses.

Present PNC emphasis is reportedly on:

- development of a rising-level pot melter for FBR wastes
- testing of a joule-heated ceramic melter and engineering tests on an integrated calciner-melter-packaging system. Capacity--250 kg/d. Test program duration--1978 to 1981.

5. Non-HLW solidification:
   - immobilization in bitumen and polyethylene (JAERI)
   - use of plastic-impregnated concrete containers (JAERI).
6. TRU wastes:
   - incineration and acid digestion of combustibles (PNC)
   - TRU waste partitioning (JAERI).
7. Gaseous wastes:
   - cryogenic recovery and separation of noble gases (PNC, Hitachi Research Laboratory, Toshiba R&D Centre). By 1982, the Tokai Mura reprocessing plant is to be equipped with a cryogenic plant for ^{85}Kr recovery.
   - thermal diffusion for Kr-Ar separation (Tokyo Institute of Technology).
8. Packaging and Transportation: Several agencies, working under STA sponsorship, are studying the effect on waste and spent fuel packages of drop impact, fire, and immersion in deep water.

WASTE DISPOSAL

Objective: To have a licensed, industrial-scale repository for high-level and TRU wastes ready for operation by the year 2000.

Status: A survey by Mitsubishi Metals identified granite and zeolite rock formations as potential sites and suggested further consideration be given to limestone, diatomite and shale formations. In further work, PNC is to conduct physical and chemical tests on different rocks; JAERI is to conduct the safety studies, and the Atomic Energy Bureau is to develop the disposal system.

R&D (JAERI and PNC)

- Planning for a facility to study waste-rock interactions--1981.
- Studies of seismic activity in an instrumented borehole 300-500 meters deep.

MEXICO

NUCLEAR POWER POLICY

Mexico plans major nuclear power capability. The emphasis to date is on installation of power stations and exploration of what may be extensive uranium resources. The country also plans to develop fuel cycle technical capability, with construction of pilot and laboratory facilities.

SELECTED AGENCIES AND RESEARCH CENTRES

- Instituto Nacional de Energia Nuclear, Mexico City
  (National Nuclear Energy Institute)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1983--1.3 LWR; long range--14.
2. Uranium mining and milling (MTU/yr): 1978--20; 1985--550.

FUEL CYCLE R&D

National Nuclear Energy Institute

- Fuel reprocessing pilot plant.
- MOX fuel fabrication.

THE NETHERLANDS

NUCLEAR POWER POLICY

Dutch planners have forecast the need for up to 20,000 MWe nuclear power by the year 2000, but construction of additional power stations has been delayed for several years because of public opposition and the unsettled political situation. Present emphasis is on expanding uranium enrichment capability and development of waste isolation technology.

SELECTED AGENCIES, RESEARCH CENTRES, AND COMPANIES

- Energy Centrum Nederland (ECN), The Hague
  (Energy Centre of the Netherlands)
- Petten Research Center, Petten
- KEMA, Arnhem

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1978--0.5 LWR; long-term--3.5.
2. Uranium enrichment (MTSW): 1978--200; future--1250.

WASTE TREATMENT R&D

Energy Centre of the Netherlands, Petten

1. Treatment of non-HLW.
2. Volume reduction of solid wastes.

WASTE DISPOSAL

Objective: Establish the feasibility of a salt-dome waste repository for high-level and TRU wastes.

Status: Preliminary design parameters have been defined, and sites for exploratory drilling (on State-owned land) have been selected.

R&D

- Theoretical and experimental studies of thermal effects, nuclide migration, and geology.
- Safety assessment.
- Cataloging of suitable formations.

PAKISTAN

NUCLEAR POWER POLICY

Pakistan imports 85 to 90% of its fuel, and is looking to nuclear power for a future major energy supply. The country will probably develop mining and milling capability, and is trying to develop general fuel cycle capability including construction of a 300 kg U/d fuel processing plant. France agreed to provide such a plant to Pakistan, and has delivered most of the design, but is now seeking to convert the plant to a coprocessing system. Pakistan has rejected the change, and the future is in doubt.

COMMERCIAL NUCLEAR ACTIVITIES

Power Production (GWe): 1978--0.12 PHWR; 2000--16 (49%).

SPAIN

NUCLEAR POWER POLICY

Spain has long planned for extensive nuclear power, but in recent years has been forced to reduce forecasts of capacity significantly. Present emphasis is on LWR construction. The country is attempting to develop complete fuel cycle self-sufficiency with an interest in Eurodif (uranium enrichment) and with plans to develop fuel fabrication, fuel reprocessing and waste management capability.

SELECTED AGENCIES AND RESEARCH CENTRES

- Centro de Energia Nuclear de Soria, Soria (about 110 miles from Madrid) (Soria Nuclear Energy Centre)
- Centro Nacional de Energia Nuclear Juan Vigon, Madrid (Juan Vigon National Nuclear Energy Centre)
- Empresa Nacional del Uranio SA (ENUSA), Madrid (National Uranium Company)
- Junta de Energia Nuclear (JEN), Madrid (Atomic Energy Commission)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production(GWe): 1982--10.2 LWR and GCR; 1987--10 (60%).
2. Uranium mining and milling (MTU/yr): 1978--190; 1985--1270.

FUEL CYCLE AND WASTE TREATMENT R&D

Juan Vigon

1. Fuel development.
2. Fuel reprocessing: JEN operated a small pilot plant at the Juan Vigon Centre (Madrid) a few years ago, and plans to build a 2 MT/yr pilot plant at the new Soria Nuclear Energy Centre.
3. HLW solidification: The Juan Vigon Centre has done limited lab-scale R&D on a variety of techniques for high-level waste solidification.
4. Non-HLW treatment:
   - decontamination of liquid wastes
   - immobilization in asphalt or cement.

WASTE ISOLATION

Objective: Commission a repository for high-level and other wastes.
Milestone: start up a pilot repository--late 1980's.

Status: For several years, Spain has stored non-HLW drums in an abandoned iron mine located in the Sierra Morena. A search is being made for other repository sites, and supporting R&D is in progress.

SWEDEN

NUCLEAR POWER POLICY

With a lack of coal and oil resources, Sweden embarked on a major nuclear power program during the 1950's, with emphasis upon LWR's. In 1977, public opposition and a new government produced a new law which required a reactor operator, before any new reactor can be fueled, to 1) provide assurance that the spent fuel can be reprocessed and the waste can be stored safely, or 2) prove that safe terminal storage of spent fuel can be effected. In a crash program, the Swedish utilities established a project which satisfied these requirements. Public opinion changed somewhat, and in early 1979 a new government approved a nuclear power station system of up to 11 reactors.

SELECTED AGENCIES AND RESEARCH CENTRES

- ASEA-ATOM AB, Västerås
- Chalmers University, Göteborg
- Kärnbränslesäkerhet (KBS), Stockholm (Nuclear Fuel Project)
- Program-Rådet för Radioaktivet Avfall (PRAV), Stockholm (Program Council for Radioactive Waste)
- Royal Institute of Technology, Stockholm
- Studsvik Energiteknik AB, Nyköping (Studsvik Energy Centre)
- Svensk Kärnbränsleförsörjning AB (SKBF), Stockholm (Swedish Nuclear Fuel Supply Company)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1978--5.5 LWR (25%); 1985--9.4.
2. Uranium mining and milling: potential--1500 MTU/yr.
3. Fuel reprocessing: SKBF has signed a contract with COGEMA (France) for French reprocessing of Swedish fuels.

WASTE TREATMENT R&D

1. High-level wastes: The present Swedish plan for managing their high-level wastes calls for overpacking waste glass canisters (prepared by France at La Hague) in stainless steel and either copper or lead and titanium cans. As a backup, a Royal Institute of Technology team is studying a concept similar to the Sandia process for absorbing fission products on an inorganic ion exchange material and using the ASEA-Atom hot isostatic pressing (HIP) method to embed the saturated ion exchanger in a stable aluminum oxide matrix. The HIP technique can also be used to encapsulate spent fuel rods or solid wastes in thick-walled aluminum oxide cylinders which are highly resistant to chemical attack. The encapsulation process has been tested with spent fuel rods.
2. Canister development for storage of spent fuels (Studsvik).
3. Partitioning of TRU wastes (Chalmers University).
4. Combustion of solid wastes (Studsvik).
5. Waste form characterization:
    - leach rates for spent fuels
    - leach rates for HLW waste forms.

WASTE DISPOSAL

Objective: Commission a repository for spent fuel or high-level waste.
Milestone: Have a pilot plant ready for operation by the mid-1980's.

Status: In 1978, the Swedish Nuclear Fuel Safety Project (KBS), established in early 1977 by four nuclear power utilities, issued a report recommending the following HLLW management scheme:

- interim storage of spent fuels in a central storage facility
- reprocessing at La Hague in France and return of vitrified wastes to Sweden
- thirty-year storage in air, in an underground rock formation
- application of a lead plus titanium overpack and emplacement in granite formations 500 m underground.

The proposal has been evaluated extensively and accepted by the Swedish government as adequate to satisfy the law and permit fuel loading in new reactors. Extensive work is continuing to qualify a repository site and to complete the development of needed technology.

R&D

- Stripa Test Station (KBS): Shafts and tunnels in an exhausted iron mine at Stripa have been used to demonstrate mining techniques and to study parameters such as rock permeability, hydrologic and mechanical properties, and thermal effects. The U.S. has participated in some of these tests.
- Studsvik Energy Centre: In situ radionuclide migration.
- Chalmers University: Nuclide transport by groundwater.

SWITZERLAND

NUCLEAR POWER POLICY

Switzerland's plans for a strong nuclear power system have run into extensive public opposition but were sustained by the public in a referendum held in February 1979. Much of the public discussion centers on spent fuel disposal. Swiss plans are to have spent fuels reprocessed at the La Hague plant (France), to take back the HLW glass, and to develop a HLW repository, probably in a deep granite formation.

SELECTED AGENCIES AND RESEARCH CENTRES

- Nationalen Genossenschaft für de Lagerung Radioaktiver Abfälle (NAGRA), Baden
  (National Association for the Storage of Radioactive Waste)
- Eidg. Institut für Reaktorforschung (EIR), Würenlingen
  (Federal Institute for Reactor Research)

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1986--3.8 LWR.
2. Spent fuel disposal: Switzerland has a contract with COGEMA (France) for French reprocessing of Swiss spent fuels through 1989.

WASTE DISPOSAL

Objective: Evaluate the feasibility of a waste repository in Switzerland.

Status: NAGRA, a private company formed to develop a repository, has located a potential disposal site in deep granite beds in the area of Olten. Characterization of the deposits is to start in 1979. Supporting R&D is conducted at the Würenlingen Institute for Reactor Research.

UNITED KINGDOM

NUCLEAR POWER POLICY

The United Kingdom nuclear power program is based upon 1) a first generation of gas-cooled, graphite-moderated reactors (GCR: Magnox-clad, natural-uranium-metal fuels); 2) a second generation of advanced gas-cooled reactors (AGR: SS-clad UO_2 fuels); 3) a third generation of power reactors which might be LWR's or AGR's; 4) development and demonstration of FBR's; 5) development of comprehensive fuel cycle and waste management capability for all domestic reactor systems; and 6) provision of fuel cycle services to foreign customers.

SELECTED AGENCIES, RESEARCH CENTRES, AND COMPANIES

- BNFL Risley, Warrington
- BNFL Windscale and Calder Works, Sellafield
- National Radiological Protection Board (NRPB), Harwell
- UKAEA (United Kingdom Atomic Energy Authority), London
- UKAEA Atomic Energy Research Establishment (AERE), Harwell
- UKAEA Dounreay Experimental Reactor Establishment (DERE), Thurso
- UKAEA Reactor Development Laboratory, Windscale Works, Windscale, Sellafield

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1981--11.8 GCR, HWR, and LMFBR; 2000--25 to 40 (up to 75%).
2. Uranium enrichment: BNFL has a 500 MT SW/yr gaseous diffusion plant at Capenhurst and a URENCO gas centrifuge plant. Expansion of the URENCO facility from its present 200 MT SW/yr to 400-600 MT SW/yr is planned.

3. MOX fuels fabrication (BNFL-Windscale):
   - A 5-10 MTHM/yr plant--in operation.
   - A 1 MTHM/yr pilot plant for FBR fuels production--in operation.
   - A 20 MTHM/yr plant. Startup--1984.
   - A 50 MTHM/yr plant. Startup--1987.
4. Spent fuels reprocessing:
   - Windscale (BNFL, Seascale): A 2000 MTHM/yr Purex-type plant used for Magnox (natural uranium metal) fuels from UK's gas-cooled reactors. A 400 MT/yr chop-leach head-end for LWR oxide fuels was added in 1969 and operated until 1973. Revision of the oxide head-end is planned, with startup scheduled for 1981. The main role of the oxide head-end will be to test new processes for THORP.
   - Thermal Oxide Reprocessing Plant (THORP, BNFL): A new plant to reprocess LWR oxide fuels for domestic and foreign customers is planned. With nominal capacity of 1200 MTHM/yr, it is to be built at Windscale. Startup--1987.
   - A cold pilot plant (BNFL): This is being installed to test equipment and train operators for THORP. Nominal capacity--1200 MT/yr. Startup--1979.
   - PFR Reprocessing Plant (DERE, Dounreay): The Dounreay plant, with a capacity of 9-10 MT/yr, was installed to treat spent fuels from the Dounreay fast reactors. After a number of years' service, it was decontaminated and remodelled and now reprocesses spent fuels from the Dounreay 250 MW Prototype Fast Reactor.
5. HLW solidification:
   - HARVEST Demonstration Plant: The HARVEST process uses rising-level in-pot calcination and melting to produce a borosilicate glass. The hot demonstration plant is to be built at Windscale to treat reprocessing HLW. Completion date--1987.
   - DERE Waste Vitrification Plant: The UKAEA plans to build a plant at Dounreay to treat HLW from the FBR fuels reprocessing plant. Capacity--30 ℓ/hr feed. Startup--late 1980's.

FUEL CYCLE AND WASTE TREATMENT R&D

UKAEA-Harwell

1. HLW solidification:
   - process development--FINGAL/HARVEST process (rising-level, in-pot calciner/melter). The Harwell pilot plant has a capacity of 240 kg glass per run.
   - waste form characterization
   - immobilization of fission products on TiO_2.
2. Other wastes:
   - treatment of spent solvent
   - combustion of solid wastes
   - TRU wastes treatment and partitioning
   - immobilization of cladding hulls
   - control and storage of volatile radionuclides.

BNFL-Windscale

1. HLW solidification: Present effort is mainly directed to construction and startup of the following Windscale test and demonstration facilities:
   - A hot (radioactive) pilot plant. Capacity--1 ℓ feed per hour; one waste canister per month. Scheduled to start up in 1978.
   - HARVEST prototype. A full-scale mockup, built for cold demonstration of operations and equipment. Scheduled completion date--1980.
   - HARVEST demonstration plant.

   Windscale is also involved in process development and waste form characterization studies.
2. Other wastes:
   - treatment of cladding hulls
   - combustion of solid wastes
   - effluents control.

DERE-Dounreay

Fuels reprocessing:
- Use of lasers to cut fuel assembly sheaths.
- Solvent extraction systems.
- Construction of mini-pilot FRP (pulse columns). Startup--1980-81.

WASTE DISPOSAL

Objective: Provide a waste repository for high-level and alpha-bearing wastes. (UK is also doing exploratory R&D on seabed disposal.) Milestones: select the site for a repository--1984; start a pilot disposal operation with radioactive glass--1992; have the repository operational--2000. Project participants: Department of the Environment (in charge and R&D); Institute of Geologic Sciences and AERE-Harwell (supporting R&D).

Status: A number of sites (crystalline rock, argillaceous, and evaporite formations) have been selected for exploratory drilling and in situ investigations, and a conceptual design for a repository in hard rock has been prepared.

R&D

- Installation of a high-pressure/high-temperature geochemical laboratory. Startup--February 1979.
- Migration of radionuclides.
- Thermal properties and effects (including heater tests in a granite formation).
- Properties of granite.

UNITED STATES

NUCLEAR POWER POLICY

Until the 1976-1977 period, the United States was pressing for full development of a commercial LWR fuel cycle based upon recycle of plutonium to LWR power stations or to breeder reactors. Major radioactive waste management R&D programs were directed to the treatment and safe isolation of commercial wastes, including high-level and TRU wastes from fuel reprocessing operations. In the spring of 1977, the government decided to defer indefinitely the commercial reprocessing of nuclear fuels, and the direction of the national fuel cycle and waste management efforts changed significantly. At the present time, U.S. nuclear policy is based on the following assumptions:

1. Light-water reactor stations will continue to be an important source of energy into the early part of the 21st century, but recycle of uranium and plutonium from spent LWR fuel back into the LWR power system is unnecessary.
2. The primary objective of waste management planning is to provide assurance that existing and future nuclear waste from military and civilian activities (including discarded spent fuel from the once-through fuel cycle) can be isolated from the biosphere and pose no significant threat to public health and safety.
3. Reprocessing is not required to assure safe disposal of commercial spent fuel.
4. Unreprocessed spent fuels, HLW and TRU wastes can be safely isolated from the biosphere in geologic repositories. Short-lived radioactive wastes can be safely disposed of in shallow land burial grounds.

Major elements in the national fuel cycle and waste management program include:

1. Assessment of alternate fuel cycles to define those systems which offer the greatest security against nuclear weapons proliferation; development and demonstration of the technology required to implement the most promising alternatives.
2. Development and demonstration of waste treatment processes for defense wastes, existing commercial fuel reprocessing wastes, and reactor wastes.
3. Development and demonstration of shallow land burial and geologic isolation technology.
4. Installation of licensed geologic repositories for either spent fuels or solidified high-level and TRU wastes.

SELECTED AGENCIES, NUCLEAR RESEARCH CENTRES AND GOVERNMENT CONTRACTORS

- Allied Chemical Corporation
  Idaho Falls, ID
- Argonne National Laboratory (ANL)
  Argonne, IL

- Brookhaven National Laboratory (BNL)
  Upton, NY
- U.S. Department of Energy (DOE)
  Washington, D.C.
- Hanford Engineering Development Laboratories (HEDL)
  Richland, WA
- Idaho National Engineering Laboratory (INEL)
  Idaho Falls, ID
- Lawrence Livermore Laboratory (LLL)
  Livermore, CA
- Los Alamos Scientific Laboratory (LASL)
  Los Alamos, NM
- U.S. Nuclear Regulatory Commission (NRC)
  Washington, D.C.
- Oak Ridge National Laboratory (ORNL)
  Oak Ridge, TN
- Office of Nuclear Waste Isolation (ONWI)
  Columbus, OH
- Pacific Northwest Laboratory (PNL)
  Richland, WA
- Rockwell-Hanford International (RHI)
  Richland, WA
- Rocky Flats Plant (RFP)
  Golden, CO
- Sandia Laboratories
  Albuquerque, NM
- Savannah River Laboratory (SRL)
  Aiken, SC
- United Nuclear Industries
  Richland, WA

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1992--184 LWR and HTGR; 2000--up to 380.
2. Uranium mining and milling (MTU/yr): 1978--19,300; 1985--36,000.
3. Uranium enrichment:
   - Gaseous diffusion plants at Oak Ridge, Portsmouth, and Paducah--17,000 MT SW/yr.
   - Gas centrifuge: development facility, startup--1982; commercial scale plant, 8750 MT SW--1984.

4. Fuel reprocessing:*

   Nuclear Fuel Services Plant, West Valley, NY. Capacity--300 MT/yr LWR fuels. The plant operated from 1956-1972 and is now to be decommissioned.

   Morris Fuel Reprocessing Plant, Morris, IL. Capacity--300 MT/yr LWR fuels. Because of technical problems, the plant was not licensed.

   Allied-General Nuclear Services Plant, Barnwell, SC. Capacity--1500 MT/yr LWR fuels. The U.S. moratorium on commercial fuel reprocessing has prevented plant startup.

5. High-level waste solidification
   - Calcination. Allied Chemical operates a waste calcination facility for high-level waste from the Idaho Chemical Process Plant (ICPP).
   - Vitrification. Consideration is being given to installation of waste vitrification facilities at the Hanford and Savannah River plants to solidify defense wastes.

FUEL CYCLE AND WASTE TREATMENT R&D

Allied Chemical (Idaho)

1. Fuel reprocessing:
   - flowsheet improvements for the Idaho Chemical Process Plant
   - HTGR fuels.
2. HLW calcination:
   - mechnical support and process development
   - long-term management of HLW calcine.
3. Treatment of gaseous effluents.

Argonne National Laboratory

1. Fuel recycle:
   - advanced solvent extraction techniques for Purex processes
   - pyrochemical and dry processing of fuels from alternate fuel cycles (carbide and thorium-uranium fuels).
2. Metal matrix encapsulation of HLW beads, calcine particles, etc.
3. Criteria for handling and disposal of cladding hulls.

---

*Allied Chemical at INEL operates a small reprocessing plant for fuels from naval and other specialty reactors.

Brookhaven National Laboratory

1. Removal of tritium from effluents and conversion to a solid form for disposal.
2. Fixation of reactor wastes in cement and bitumen.

Hanford Engineering Development Laboratory

1. Solidification of non-HLW.
2. Acid digestion of solid wastes for volume reduction.

Idaho National Engineering Laboratory

1. Retrieval of TRU wastes from burial grounds (EG&G).
2. Long-term management of TRU wastes (EG&G).

Los Alamos Scientific Laboratory

1. TRU waste:
    - incineration and other volume reduction techniques
    - evaluation of TRU waste burial grounds
    - degradation of TRU waste forms.
2. Shallow land burial ground technology (for LLW).

Mound Laboratory

1. Ultrafiltration of non-high-level liquid wastes.
2. Incineration of TRU waste and fixation of incinerator ash.
3. Management of tritiated liquid wastes.

Oak Ridge National Laboratory

1. Fuel cycle studies:
    - advanced fuel recycle and alternate fuel cycle technologies
    - HTGR fuel recycle and fuel technology
    - projection of radioactive wastes from the nuclear fuel cycle.
2. TRU wastes partitioning and transmutation.
3. HLW: cermet waste process.

4. Non-HLW:
   - decontamination of liquid wastes by biological agents
   - fixation in concrete.

Pacific Northwest Laboratory

1. Fuel cycle development: processes for fabricating pellet and particle fuels containing U, Pu or Th.
2. HLW solidification:
   - vitrification
   - alternate waste forms
   - characterization of waste forms.
3. Criteria for TRU waste treatment and disposal.
4. Fixation of radioactive krypton, carbon and iodine.
5. Shallow land burial ground technology.
6. Decontamination and decommissioning.
7. Waste management supporting studies:
   - risk assessment
   - systems studies
   - international program support.
8. Mill tailings stabilization.
9. Environmental impact studies.

Rockwell-Hanford

1. Treatment and isolation of Hanford's high-level defense wastes.
2. Long-term management of Hanford contaminated soils and sediments.
3. Decommissioning of retired Hanford facilities.

Rocky Flats Plant

Fluidized-bed incineration of TRU wastes.

Sandia Laboratories

1. Evaluation of ^{85}Kr storage concepts.
2. Transportation of radioactive materials.
3. Seabed disposal.

Savannah River Laboratory

1. Reprocessing technology--proliferation resistant fuel cycles.
2. Spent fuel storage technology.
3. Solidification of SRP's high-level defense waste.
   - calcination; ceramic melter.
4. Incinceration of combustible solids.
5. Shallow land burial ground technology.

United Nuclear Industries, Richland, WA

Decommissioning of retired nuclear facilities.

WASTE DISPOSAL

Objective: Develop one or more national waste repositories (NWR) for the permanent disposal of commercial HLW and other TRU wastes or spent fuel. Milestones: initial operation of an intermediate-scale repository--1986; initial operation of NWR--1988 to 1992, depending on the approach.

Status: Extensive work to identify potential sites for geologic waste repositories in the United States, develop the required technology, and prepare a generic environmental impact statement for commercial waste management has been under way for several years. Although current plans emphasize the use of salt beds for commercial wastes, other deep formations (granite, shale and basalt) are also being considered. Present major projects include the evaluation of three sites:

1. WIPP, a waste isolation pilot plant, is planned for construction in a salt formation near Carlsbad, New Mexico. It is intended as a final disposal site for defense TRU wastes and as a place to conduct R&D with other materials such as spent fuels. Project management--Sandia Labs. Startup--1986.
2. Basalt beds under the DOE reservation at Hanford. Rockwell Hanford plans to evaluate the disposal of HLW and spent fuel in a near-surface test facility, with test operations starting in August 1979.

3. The DOE Nevada Test Site. A major objective of the evaluation is to determine if disposal of nuclear wastes in rock formations there would be compatible with future weapons testing. Project management--Sandia Labs.

R&D

R&D supporting repository design is being done at many of the national laboratories and at several universities:

1. Heat transfer and thermal analysis programs.
2. Waste-rock interaction studies.
3. Rock mechanics studies.
4. Borehole plugging studies.
5. Waste isolation safety assessment.

USSR

NUCLEAR POWER POLICY

The Soviet Union plans extensive use of nuclear power, with emphasis on: 1) PWR's; 2) a pressure-tube reactor which uses enriched uranium, boiling light water as a coolant, and a graphite moderator; and 3) commercial fast breeders. The USSR plans to reprocess spent fuels from its reactors and from those supplied to other countries (Finland and the CMEA nations).

SELECTED AGENCIES AND NUCLEAR RESEARCH CENTRES

- Institute of Physical Chemistry, Academy of Sciences of the USSR, Moscow
- Ministry of Power and Electrification
- Chemical Plant Research Institute, Sverdlovsk
- USSR State Committee on the Utilization of Atomic Energy, Moscow
- Khlopin Radium Institute, Leningrad

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production (GWe): 1980--21 LWR and HTGR.
2. Uranium enrichment: 7-10 MT SW/yr.
3. Fuel reprocessing: The USSR is reportedly building a commercial-scale (5 MT/d) plant.

FUEL CYCLE AND WASTE TREATMENT R&D

1. Spent fuel reprocessing: A 3 kg U/d pilot plant has operated at the Khlopin Radium Institute since 1973.
2. HLW solidification: The Russians have described two waste vitrification pilot plants, both nonradioactive--the KS-KT-100 plant, which uses a 2-stage process (fluid bed calcination followed by melting in a concrete-refractory storage pot); and a single-stage continuous process using a ceramic-type melter. The product in both cases is a phosphate glass. Capacities--20 kg/hr glass from KS-KT-100; 100 ℓ/hr HLLW feed to the ceramic melter.
3. Treatment of other wastes:
   - chemical treatment
   - immobilization-bitumen
   - TRU waste partitioning
   - melt-down of cladding hulls.
4. Transportation: development of shipping containers.

WASTE DISPOSAL

For a number of years, the Soviet Union has practiced disposal of non-HLW by injection of liquids into deep, porous strata. The nation is also evaluating geologic disposal of solid wastes in salt formations.

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

A major IAEA program is in the field of nuclear safety and environmental protection. Its purpose is to ensure the safe operation of nuclear installations and the protection of man and his environment from the harmful effects of nuclear radiation and radioactive or nonradioactive releases from nuclear installations.

In the waste management area, the IAEA provides a multinational focus for investigation and development in problem areas which ultimately may be handled satisfactorily only through international solutions.

The IAEA's waste management activities include:

- development of mutually agreed-upon safety standards and criteria for the management and disposal of radioactive waste arising from all stages of the nuclear fuel cycle
- promotion of information exchanges in the radioactive waste management area via international conferences and symposia, technical committees and advisory groups for selected areas of technology, and specialized training courses and seminars
- coordination of research programs in specific technical areas
- issuance of publications in the field of waste management including the annual "Waste Management Research Abstracts."

Limited IAEA funds (generally $150,000 to $200,000 annually) are provided for research and development in selected areas of radioactive waste management and environmental assessment, usually for coordinated research programs involving participation by member states.

COMMISSION OF THE EUROPEAN COMMUNITIES (CEC)

Member States are:

Belgium	Italy
Denmark	Luxembourg
France	The Netherlands
West Germany (FRG)	United Kingdom
Ireland	

CEC sponsors and funds nuclear R&D at the research establishments of the CEC (formerly Euratom) Joint Research Centre and in the laboratories of the Member States. Funds for the national laboratories of the Member States are generally provided on a matching basis. In 1975, CEC budgeted $26M for a 5-yr radioactive waste management program, with about $16M devoted to geologic disposal. Sponsored activities and participating countries include these fields:

- treatment of low- and medium-level waste (France and FRG)
- decontamination and consolidation of irradiated fuel element cladding (Belgium, FRG, Italy)
- incineration (Belgium, FRG, Italy)
- properties of high-level waste forms (France, FRG, UK)
- engineered storage for solidified HLW (Belgium, FRG, Italy)
- geologic waste storage (salt domes-FRG; crystalline rock formation-France and UK; clay-Belgium)
- separation and transmutation of actinides (UK and The Netherlands).

OECD NUCLEAR ENERGY AGENCY (NEA)

The NEA is a specialized agency of the OECD, set up to promote international cooperation among the OECD countries for the development and application of nuclear power for peaceful purposes through international research and development projects and exchange of scientific and technical experience and information.

In 1975, at the request of the OECD, and building upon previous efforts of the IEA Working Group on Radioactive Waste Management, the NEA established a Radioactive Waste Management Committee (RWMC). Its purpose is to initiate, encourage and coordinate cooperative R&D activities in the field of radioactive waste management, particularly within NEA member states. RWMC has held a series of meetings and established a number of permanent and ad hoc committees and study groups to deal with specific technical areas.

Current NEA waste management activities are focused on the definition of cooperative programs to develop geologic waste isolation technology.

Member states are:

Australia	Iceland	Portugal
Austria	Ireland	Spain
Belgium	Italy	Sweden
Canada	Japan	Switzerland
Denmark	Luxembourg	Turkey
Finland	The Netherlands	United Kingdom
France	New Zealand[a]	United States
Germany, Federal Republic of	Norway	Yugoslavia[a]

(a) Special status

The Eurochemic Company, sponsored by a number of OECD/NEA countries, operated the 60 tonne/yr Eurochemic fuel reprocessing plant at Mol from 1968 to 1974. Present Eurochemic activities are described in the data sheets for Belgium.

COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE (CMEA)

CMEA is the counterpart of OECD for the countries with centrally controlled economies. The organization has a standing commission concerned with the use of atomic energy for peaceful purposes that holds periodic conferences and meetings of national specialists on radioactive waste management technology.

In 1971, CMEA set up a coordinating scientific and technical council concerned with radioactive waste management. The council meets semiannually and has given high priority to the development of safe disposal methods for radioactive wastes.

Member states are:

Bulgaria	Mongolia
Cuba	Poland
Czechoslovakia	Romania
East Germany	USSR
Hungary	Yugoslavia[a]

(a) Special status

DISTRIBUTION

No. of Copies	
OFFSITE	
2	Brookhaven National Laboratory Reference Section Research Library Upton, NY 11973
	G. H. Vineyard, Director Brookhaven National Laboratory Associated Universities, Inc. Upton, NY 11973
	P. W. Levy Physics Department Brookhaven National Laboratory Upton, NY 11973
	J. L. Larocca, Chairman Engineering Research and Development Authority Empire State Plaza Albany, NY 12223
	R. Chaturvedi Department of Physics State University of New York Cortland, NY 13045
	J. P. Duckworth, Plant Manager Nuclear Fuel Services, Inc. P.O. Box 124 West Valley, NY 14171
	Deputy Director for Fuels and Materials NRC Directorate of Licensing for Fuels and Materials 4915 St. Elmo Avenue Bethesda, MD 20014
	John Pomeroy, Technical Secretary National Academy of Sciences Committee on Radioactive Waste Management National Research Council 2101 Constitution Avenue Washington, DC 20418
2	Dave Smith Technology Assessment Division Environmental Protection Agency Washington, DC 20460
	Dixon Hoyle Nuclear Technology Section Bureau of Oceanic, International & Environmental Science Affairs Department of State Washington, DC 20520
	George Cunningham Counselor for Atomic Energy Affairs M/IAEA Vienna U.S. Department of State Washington, DC 20520
	Don Booher DOE Representative American Embassy (OECD) APO NY 09777
	Theodore Beresovski c/o U.S. Mission, OECD Department of State Washington, DC 20521

No. of Copies

Billy Hill
U.S. Department of Energy
Tokyo Office - American Embassy
c/o Department of State
Washington, DC 20521

Robert Purple
U.S. Department of Energy
Brussels Office - USEC
c/o U.S. European Communities Mission
Department of State
Washington, DC 20521

Raymond E. Vener
U.S. Department of Energy
Bonn Office - American Embassy
c/o Department of State
Washington, DC 20521

Vernon Adler
Science Representative
Teheran (Iran) Office - U.S. Embassy
c/o Department of State
Washington, DC 20521

2 A. F. Perge
ETW, B-107, HQ
U.S. Department of Energy
Washington, DC 20545

J. M. Deutch
Energy Technology
U.S. Department of Energy
Washington, DC 20545

J. A. Leary
Energy Technology
U.S. Department of Energy
Washington, DC 20545

R. W. Ramsey
ECT Division
U.S. Department of Energy
Washington, DC 20545

No. of Copies

H. Jaffe
AIA Division
U.S. Department of Energy
Washington, DC 20545

M. D. McDonough
AIA Division
U.S. Department of Energy
Washington, DC 20545

C. W. Kuhlman
ETW, B-107, HQ
U.S. Department of Energy
Washington, DC 20545

W. Ballard
NPD, B-107, HQ
U.S. Department of Energy
Washington, DC 20545

C. R. Cooley
ETW, B-107, HQ
U.S. Department of Energy
Washington, DC 20545

W. G. Belter
Division of Biomedical and Environmental Research
Earth Sciences Branch
U.S. Department of Energy
Washington, DC 20545

W. A. Brobst
Division of Environmental Control Technology
U.S. Department of Energy
Washington, DC 20545

W. E. Mott
Division of Environmental Control Technology
U.S. Department of Energy
Washington, DC 20545

No. of
Copies

R. B. Chitwood
Division of Nuclear Power
Development
U.S. Department of Energy
Washington, DC 20545

C. H. George
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

C. A. Heath
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

G. Oertel
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

J. M. Taub
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

D. L. Vieth
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

R. D. Walton
Division of Waste Management
U.S. Department of Energy
Washington, DC 20545

2 John Martin
U.S. Nuclear Regulatory
Commission
Washington, DC 20555

David M. Rohrer
U.S. Nuclear Regulatory
Commission
Mail Stop 687
Washington, DC 20555

No. of
Copies

Margaret Conyngham
Reference Libraries
U.S. Nuclear Regulatory
Commission
Washington, DC 20555

C. H. Ice, Director
Savannah River Laboratory
Aiken, SC 29801

Leon Meyer
Savannah River Laboratory
Aiken, SC 29801

N. Stetson, Manager
Savannah River Operations Office
U.S. Department of Energy
P.O. Box A
Aiken, SC 29801

M. D. Boersma
duPont Company, Aiken (DOE)
E.I. duPont DeNemours & Co.
Savannah River Laboratory
Aiken, SC 29801

A. S. Jennings
duPont Company, Aiken (DOE)
E.I. duPont DeNemours & Co.
Savannah River Laboratory
Aiken, SC 29801

P. H. Permar
duPont Company, Aiken (DOE)
E.I. duPont DeNemours & Co.
Savannah River Laboratory
Aiken, SC 29801

J. A. Buckham
Allied-General Nuclear Services
P.O. Box 847
Barnwell, SC 29812

A. Williams
Allied-General Nuclear Services
P.O. Box 847
Barnwell, SC 29812

No. of
Copies

R. J. Hart, Manager
Oak Ridge Operations Office
Department of Energy
P.O. Box E
Oak Ridge, TN 37830

D. B. Trauger,
Associate Director
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

J. J. Schreiber
Oak Ridge Operations Office
U.S. Department of Energy
P.O. Box X
Oak Ridge, TN 37830

2 Reference Section
Central Research Library
Room 175-B, Bldg. 4500N
Union Carbide Corporation
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

Ray E. Blanco
Union Carbide Corporation
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

W. C. McClain
Union Carbide Corporation
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

John E. Van Cleve, Jr.
Bldg. 7601
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

No. of
Copies

27 DOE Technical Information Center

J. O. Blomeke
Union Carbide Corporation
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

2 D. E. Ferguson
Union Carbide Corporation
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

J. M. Batch
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

H. C. Burkholder
Battelle Memorial Institute
505 King Street
Columbus, OH 43201

J. R. McClain, Director
Monsanto Research Facility
Mound Laboratory
P.O. Box 32
Miamisburg, OH 45342

C. J. Kershner
Monsanto Research Facility
Mound Laboratory
P.O. Box 32
Miamisburg, OH 45342

R. H. Bauer, Manager
Chicago Operations Office
U.S. Department of Energy
9800 South Cass Avenue
Argonne, IL 60439

No. of Copies	
	A. A. Churm Chicago Patent Group U.S. Department of Energy 9800 South Cass Avenue Argonne, IL 60439
	R. G. Sachs, Director Argonne National Laboratory 9700 South Cass Avenue Argonne, IL 60439
	L. Burris Argonne National Laboratory 9700 South Cass Avenue Argonne, IL 60439
	M. J. Steindler Argonne National Laboratory 9700 South Cass Avenue Argonne, IL 60439
	W. M. Lamb, Manager Rocky Flats Area Office U.S. Department of Energy Golden, CO 80401
	R. O. Williams, General Manager Atomics International Division Rockwell International Rocky Flats Plant P.O. Box 464 Golden, CO 80401
2	M. A. Thompson Rockwell International Rocky Flats Plant Golden, CO 80401
	C. E. Williams, Manager Idaho Operations Office U.S. Department of Energy 550 2nd Street Idaho Falls, ID 83401

No. of Copies	
	F. H. Anderson, General Manager Allied Chemical Corporation Idaho Chemical Programs 550 2nd Street Idaho Falls, ID 83401
	B. C. Musgrave Allied Chemical Corporation Idaho Chemical Programs 550 2nd Street Idaho Falls, ID 83401
	T. R. Thomas Allied Chemical Corporation Idaho Chemical Programs 550 2nd Street Idaho Falls, ID 83401
	A. P. Roeh, Manager Process Evaluation Branch Allied Chemical Corporation 550 2nd Street Idaho Falls, ID 83401
	R. A. Brown Allied Chemical Corporation 550 2nd Street Idaho Falls, ID 83401
	C. A. Hawley Allied Chemical Corporation 550 2nd Street Idaho Falls, ID 83401
	D. A. Knecht Allied Chemical Corporation 550 2nd Street Idaho Falls, ID 83401
	Allied Chemical Corporation (File Copy) 550 2nd Street Idaho Falls, ID 83401

No. of
Copies

R. W. Kiehn, Manager
EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, ID 83401

R. G. Post
College of Engineering
University of Arizona
Tucson, AZ 85721

D. R. Anderson
Sandia Laboratories
Albuquerque, NM 87107

W. Weart
Division 1140
Sandia Laboratories
Albuquerque, NM 87107

H. D. Sivinski
Sandia Laboratories
Albuquerque, NM 87107

Morgan Sparks, President
Sandia Laboratories
P.O. Box 5800
Albuquerque, NM 87115

Jerry Freedman
Sandia Laboratories
P.O. Box 5800
Albuquerque, NM 87115

Jane Lord
Technical Library
Sandia Laboratories
P.O. Box 5800
Albuquerque, NM 87115

Delacroix Davis, Jr., Manager
WIPP Project Office
P.O. Box 6400
Albuquerque, NM 87115

No. of
Copies

S. E. Logan
University of New Mexico
Albuquerque, NM 87131

K. R. Braziel, Manager
Los Alamos Area Office
U.S. Department of Energy
Los Alamos, NM 87544

Director
Los Alamos Scientific Laboratory
Los Alamos, NM 87544

T. K. Keenan
Group Leader, Waste Management
University of California LASL
Los Alamos, NM 87544

M. E. Gates, Manager
Nevada Operations Office
U.S. Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

L. H. Brooks
Gulf Energy and Environmental
Systems
P.O. Box 81608
San Diego, CA 92138

R. F. Williams
Electric Power Research
Institute
P.O. Box 10412
Palo Alto, CA 94304

L. Henning
Electric Power Research
Institute
P.O. Box 10412
Palo Alto, CA 94304

R. E. Batzel, Director
Lawrence Livermore Laboratory
P.O. Box 808
Livermore, CA 94550

No. of
Copies

T. B. Cook, Jr., Vice President
Sandia Laboratories
Livermore, CA 94550

J. LaGroone, Acting Manager
Attn: J. Muhlestein,
Nuclear Energy Division
San Francisco Operations Office
U.S. Department of Energy
1333 Broadway
Oakland, CA 94612

A. M. Sessler, Director
Lawrence Berkeley Laboratory
Berkeley, CA 94720

R. G. Barnes
General Electric Company
175 Curtner Avenue
(M/C 160)
San Jose, CA 95125

R. A. Beall
U.S. Department of Interior
Bureau of Mines
Albany Research Center
1450 W. Queen Avenue
Albany, OR 97321

C. R. Schuller
Human Affairs Research Centers
40000 N.E. 41st Street
Seattle, WA 98105

ONSITE

5 DOE Richland Operations Office

E. A. Bracken
O. J. Elgert
A. G. Fremling
R. B. Goranson
H. E. Ransom

No. of
Copies

1 Exxon

S. J. Beard

1 Joint Center for Graduate Study

J. Cooper

10 Rockwell Hanford Operations

H. Babad
D. J. Cockeram
R. A. Deju
R. J. Gimara
E. J. Kosiancic
C. M. Manry
J. H. Roecker
M. J. Smith
D. D. Wodrich
File Copy

2 United Nuclear Industries, Inc.

T. E. Dabrowski
A. E. Engler

3 Westinghouse Hanford Company

A. G. Blasewitz
E. A. Evans
A. Squire

51 Pacific Northwest Laboratory

T. W. Ambrose
W. F. Bonner
A. Brandstetter
L. L. Burger
D. B. Cearlock
T. D. Chikalla
J. M. Davidson
R. L. Dillon
J. W. Finnigan

No. of
Copies

Pacific Northwest Laboratory (cont'd)

J. J. Fuquay
K. M. Harmon (20)
A. J. Haverfield
E. R. Irish
J. H. Jarrett
M. R. Kreiter
L. T. Lakey
R. P. Marshall
J. L. McElroy
R. E. Nightingale
D. E. Olesen
A. M. Platt
J. V. Robinson
K. J. Schneider
C. M. Unruh
H. H. Van Tuyl
L. D. Williams
Technical Information (5)
Publishing Coordination (2)