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THE NATIONAL WASTE TERMINAL STORAGE PROGRAM

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THE NATIONAL WASTE TERMINAL STORAGE PROGRAM

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At present, one of the most controversial subjects involving the production of electricity by nuclear reactors is the management of radioactive fission wastes generated by the nuclear fuel cycle. The subject is one which is amenable to a rational solution and well within present-day technologies. The unpopularity of the task stems from the obvious natural reluctance of the public to consider living near large amounts of radioactivity which will persist for hundreds of years. This paper provides, in capsule form, the plans of the Energy Research and Development Administration (ERDA), through the Office of Waste Isolation (OWI), for the safe and rational terminal storage in deep geologic formations of radioactive wastes from the commercial light-water reactor nuclear fuel cycle.

The original concept for deep geologic disposal was first advanced in 1957 when a National Research Council Advisory Committee of the National Academy of Sciences suggested the burial of solid radioactive wastes in salt deposits.¹ Since that time, the former Atomic Energy Commission (AEC) has supported modest programs in this area, including very successful underground tests in an abandoned bedded salt mine at Lyons, Kansas, in the late 1960s. This work was conducted by Oak Ridge National Laboratory (ORNL), which is operated by Union Carbide Corporation-Nuclear Division (UCC-ND). Some further work involving conceptual design for a repository was done, but the main ORNL effort was directed toward a variety of geologic formations, with emphasis on bedded and domed salt.

In the early 1970s, the AEC also sponsored designs carried out by Atlantic Richfield Hanford Company (ARHCO) for a Retrievable Surface Storage Facility (RSSF). This facility was, in essence, a well-shielded and -constructed surface building that would store radioactive waste from the commercial fuel cycle for approximately 100 years. Because of a slippage in the schedule for the construction of nuclear reactors, additional time has become available for development of the geologic storage concept, and the RSSF concept has been deferred.

Although in the past 15 to 20 years the AEC supported many modest programs involving the storage or disposal of waste, only recently has ERDA made a substantial effort to resolve this vital and challenging disposal problem.

In February of 1976, ERDA announced a greatly expanded program for the management of nuclear waste from ERDA facilities and from commercial power plants. A major portion of this program was the escalated program for the disposal of commercial wastes in suitable geologic formations. This new program is called the National Waste Terminal Storage (NWTs) program, and its objective is as follows:

*Operated by Union Carbide Corporation-Nuclear Division for the Energy Research and Development Administration.

Superior numbers refer to similarly-numbered references at the end of this paper.

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To provide facilities in various deep geologic formations at multiple locations in the USA which will safely dispose of the commercial radioactive waste, which must be delivered to a Federal Repository for terminal storage.

The organizations responsible for the overall management of the NWTS program and their areas of responsibility are as follows:

ERDA Division of Nuclear Fuel Cycle and Production Washington, D.C.	Policy Formulation Program Objectives and Definition Overall Direction for Program Management Approving Key Technical Decisions Final Determination of Budget
ERDA Oak Ridge Operations Office Oak Ridge, Tennessee	Program Coordination Federal Interagency Agreement Participation of ERDA Field Organizations Facility Design and Construction Contracts Administration of UCC-ND Contract
Office of Waste Isolation Union Carbide Corporation- Nuclear Division Oak Ridge, Tennessee	Program Contracting and Technical Management Technical Coordination of ERDA Contractors Developing and Presentation of Overall Budget Accounting for All Funds Other Management Activities Deemed Necessary

The Office of Waste Isolation is presently expanding its staff and within six months should be staffed to about 50 to 60 people experienced in various technical disciplines, but primarily with technical program management expertise. Most of the actual program work will be performed by organizations outside OWI, e.g., commercial firms, private consultants, ERDA laboratories, universities, and state and government agencies.

An indication of the tremendous effort under way to resolve this program can best be illustrated by the OWI fiscal budgets: 1976, \$5.1 million; 1977, \$38.2 million (approximate). The program planned for FY 1978 will require a substantial increase of from \$25 to \$50 million over FY 1977. Approximately 85% of the budget will be expended in program activities outside OWI by the organizations indicated above.

The sequence of steps that must be taken to carry out the objective of the NWTS program is generally as follows:

1. Selection of geologic formations of interest.
2. Preparation of conceptual designs.
3. Geological reconnaissance surveys.
4. In situ experiments.
5. Geological area studies.
6. Plant design.
7. Detailed site confirmation studies.

8. Pilot plant construction and operation.
9. Expanded pilot plant operation.
10. Conversion of pilot plant to a Federal Repository.

The selection of suitable areas for siting of the plants encompasses studies involving geology, hydrology, seismicity, tectonics, erosion, denudation, solutioning, etc.

Concurrent with the geological area selection activities, efforts will be under way on safety analyses, environmental impact statements, heat transfer, rock mechanics, waste/rock interactions, borehole plugging, in situ tests, salt handling, waste canister envelopes, transportation, economic analyses, and socioeconomic studies.

One of the most pressing problems will be that of obtaining acceptance both by the public and by local, county, state, and federal legislative officials. For example, a partial list of state agencies that may become involved would include (a) the Governor's office, (b) the State legislative body, (c) the Geologic Survey, (d) the Department of Conservation, (e) the Department of Environmental Control, (f) the Department of Public Health, (g) the Department of Labor, etc. ERDA and OWI intend to undertake a substantial effort to inform and involve the public in the interest of gaining public acceptance and support of the NWTS program.

Several government agencies will, of course, be involved in the approval and decision-making chain. It is almost certain that the facilities will require licensing by the Nuclear Regulatory Commission (NRC), probably under 10 CFR 70, Special Nuclear Materials.

Although disposal in deep geologic formations is only one of several proposals being considered for the safe disposal of radioactive wastes, it is the one about which we are most knowledgeable. Fortunately, this concept does not rely on man for its workability, but only on a predictable Nature.

The initial task in any construction project is to find a suitable location. The OWI and its predecessors have been engaged in reviewing and identifying formations of interest for several years, with most of the effort directed toward salt (halite) formations. Other formations of interest include argillaceous, crystalline rock and carbonate formations. Most of the states contain one or more formations that may possess the desired geologic features. Salt (Fig. 1) is extremely desirable as the host media for the retention of wastes because: (1) It underlies portions of 23 states and encompasses an area estimated at 500,000 square miles. (2) It has good thermal conductivity properties (compared to other rock). (3) It has radiation shielding properties approximately equivalent to concrete. (4) The mining of it is a well-understood process and is supported by a well-developed technology. (5) It has been around for many millions of years and has been totally isolated from circulating water. (6) It has unique properties of ductility and plasticity. However, salt has disadvantages, which include the following: (1) It is soluble in water. (2) It is frequently found in association with oil and gas. At present, the areas of interest involving rock salt

formations are in the Salina Basin, the interior of the Gulf Coast Dome region, and the Paradox Basin (Fig. 1).

The regulations requiring delivery of commercial waste to a Federal Repository are contained in Title 10, *Code of Federal Regulations* (CFR), Part 50, Appendix F. These regulations refer to licensing of production and utilization facilities, and Appendix F refers to siting reprocessing and related waste management facilities. In brief, Appendix F requires that (a) a fuel reprocessing plant's inventory of high-level liquid radioactive wastes* will be limited to that produced in the prior five years; (b) high-level liquid radioactive waste shall be converted to a dry solid and placed in a sealed container prior to transfer to a Federal Repository; and (c) all high-level wastes shall be transferred to a Federal Repository no later than 10 years following separation of fission products from the irradiated fuel.

Other requirements for shipment of waste to a Federal Repository may be included in changes to Title 10 CFR, Part 20. Regulations in 10 CFR 20 pertain to standards for protection against radiation. Current proposed changes relate to transuranic waste disposal and will require that waste with contamination levels as low as 10 nCi of transuranic elements per gram of waste must be transferred to ERDA for storage as soon as practicable but within five years after its generation. These regulations imply that if reprocessing plants are put into operation, then high-level waste will be delivered to a Federal Repository and very probably low-level transuranic waste also. In this event, a Federal Repository would be designed to receive both types of waste. However, if reprocessing plants are not put into operation, then the repository will be built to dispose of spent fuel elements.

The types of commercial reactor fuel wastes to be handled by a repository have been tentatively classified in the following manner:

High-level wastes - solidified composites of all the liquid waste streams arising from the reprocessing of spent fuels. These wastes contain more than 99.9% of the nonvolatile fission products, 0.5% of the uranium and plutonium, and all the other actinides formed by transmutation of the uranium and plutonium in the reactor.

Cladding wastes and hardware - solid fragments of Zircaloy and stainless steel cladding and other structural components of the fuel assemblies which remain after the fuel cores have been dissolved. These fragments are compacted to 70% of theoretical density. In addition to neutron-induced radioactivity, the cladding waste contains 0.05% of the actinides and 0.05% of the nonvolatile fission products in the spent fuel.

Intermediate-level transuranic wastes - those solid or solidified materials (other than high-level and cladding wastes) which contain long-lived alpha

*High-level liquid wastes means those aqueous wastes resulting from the operation of the first-cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for processing irradiated reactor fuels.

emitters at concentrations greater than 10 nCi/g and which have typical surface dose rates between 10 and 1000 millirems/hr after packaging due to fission-product contamination.

Low-level transuranic wastes - those solid or solidified materials that contain plutonium or other long-lived alpha emitters in known or suspected concentrations greater than 10 nCi/g and yet have sufficiently low external radiation levels after packaging that they can be handled directly.

Unreprocessed spent fuel assemblies - In the highly unlikely event that reprocessing of spent fuel elements does not take place, these elements would be stored in the repository once they had been properly placed in high-level waste canisters.

The general plan for the NWTS program (Fig. 2) calls for the eventual construction of several waste repositories in geologic formations. The multiapproach offers the following advantages: (1) Feasibility of a timely operation of a terminal storage facility is increased because of the multiplicity of facilities. (2) A retrievability concept for stored waste becomes practical because other facilities are available to receive the waste should it be necessary to remove it from one of the facilities for any reason. (3) More than one site could serve the country as a terminal storage facility. (4) Reduced waste transportation costs are possible if more than one facility is used.

A detailed planning schedule for the first two pilot plants now planned for construction in salt is shown in Fig. 3. Conceptual design studies for the pilot plants, one in bedded salt and one in domed salt, are planned to start early in FY 1977. These studies will be carried out concurrently with the geologic search for suitable sites at two locations. OWI is requesting capital construction funds for the leasing or procurement of land in the latter part of FY 1978. In reality, such land acquisitions will not start until the entire review process has been completed for the two salt formation sites. As noted in the figure, design and long-lead procurement of specialized mining machinery will begin during this same period. Starting in FY 1979, two architect-engineering firms will be selected to do preliminary and final design of the plants. The nature of the projects requires that several specialized disciplines such as rock mechanics, mining, and sophisticated heat transfer be involved in the designs in addition to the customary routine services provided by an architect-engineer. The actual construction of the plants will commence in FY 1981, with physical construction to be completed at the end of FY 1984, followed by a cold shakedown period of about a year prior to hot operation. The pilot plants will therefore be ready for receipt of wastes by the end of FY 1985.

All wastes stored in the pilot plant are planned to be in retrievable form, i.e., they can be easily and safely removed should the need ever arise.

Since NRC licensing will probably be a requirement, all the design and construction activities will be carried out such that the quality assurance and other regulations required for licensing can be met.

During operation of the pilot plant, the surface handling equipment will be evaluated, and the adequacy of the specialized canister handling equipment and storage concepts in the mine proper will be determined. Design confirmation

experiments involving rock mechanics, heat transfer, retrievability devices, and mining operational concepts will be carried out. The data obtained during this pilot plant phase will be used to aid in the design of the expanded facility, which will be operated until sufficient information is gathered to confirm that the facility can safely receive, handle, and store the radioactive wastes. A close check will be maintained on the geology, hydrology, and other geotechnical aspects of the mine. When all the approval chains, including licensing, have been satisfied, the facility will be converted to a Federal Repository.

Tentative design parameters for preliminary design of the repositories are shown in Fig. 4. Although firm decisions have not been made on definitions of types of wastes or on the size of the canisters, for tentative planning purposes, we are assuming those shown in Fig. 4. The high-level wastes (HLW) are the only wastes in which we have a high heat generation problem. In this case, we have assumed an average of 1.8 kW per can. Most of this heat is due to ^{90}Sr and ^{137}Ce , with half-lives of approximately 30 years each. All the waste types except low-level TRU would be in cans 1 ft in diameter by 10 ft long, each containing 8 ft of wastes, giving a volume of 6.28 ft³. The low-level TRU wastes would be contained in 55-gal drums. Assuming the waste projections as shown, the total acreage required for a repository in which waste is maintained in a retrievable fashion would be 2000 acres, accommodating wastes produced through the year 2005.

A conceptual drawing of what a repository in a geologic formation might look like is shown in Fig. 5. The surface facilities would consist of separate high-level and low-level facilities for receiving containers of waste canisters or drums which would be delivered by rail or truck. The appropriate high-level canister remote handling equipment for decontaminating, cooling, and overpacking, if necessary, would be provided as part of the surface facilities. Similar facilities would be provided for low-level waste drums except that the remote handling feature would be eliminated since these drums can be handled with "hands-on" techniques. The appropriately sized shafts for man, materials, salt removal, and waste handling would also be provided. Underground facilities would consist of a radioactive waste transporter, drilling equipment, salt mining equipment, ventilation equipment, and maintenance facilities as necessary.

Since there will be two pilot plants, each mine would be sized initially as a pilot plant capable of handling one-half the wastes through the year 1990. A decision has yet to be made on whether the surface facilities would be sized for a full-scale repository or just for a pilot plant; but, in any event, sufficient mine space will be planned to allow expansion to a full repository. The initial salt removal mining would be for the pilot plant only.

A possible design for storing the wastes in retrievable form is shown in Fig. 6. A hole is drilled in the mine floor into which a steel sleeve of the appropriate dimensions is inserted. The outside surface of the sleeve is in contact with the salt. The high-level waste canister is then lowered into the sleeve using remote handling equipment. A concrete or steel shielding plug is then installed on top of the can, as shown. With this configuration, retrievability can be achieved at will simply by removing the plug and retrieving the waste canister using the same equipment used for emplacement.

During the initial period of pilot plant operation, several of the waste canisters and sleeves will be appropriately instrumented in order to obtain verification of the design concepts. In fact, many verification-type experiments will be under way, including rock mechanics, heat removal, waste/rock interactions, and, of course, refinements in waste canister operational handling techniques.

Following an unspecified period of testing and verification, it is expected that the readily retrievable feature will be abandoned. This, of course, will not be a unilateral decision but will involve all parties appropriate to the decision-making process. At this time, all filled storage rooms will be backfilled; thus, eventually the corridors will no longer be needed. Any further waste canister burial will be directly in salt without benefit of a sleeve.

When the mine is completely filled, the shaft will be plugged, the surface facilities removed, and the terrain returned to its original appearance. Appropriate markers will be placed, and necessary monitoring practices will be instituted.

In closing, it should be pointed out that the requirement for the safe and sensible terminal storage of radioactive wastes already exists and that we do not have a choice since commercial, and especially military, wastes exist in copious quantities. We believe that the terminal storage of wastes in deep geologic formations offers us a practical present-day solution, which will not be "passing the buck" to future generations.

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ROCK SALT DEPOSITS IN THE UNITED STATES
(AFTER PIERCE AND RICH, U.S.G.S. BULL. 1148)

Figure 1

OWI-76-25

GEOLOGIC TERMINAL STORAGE
GENERAL PLAN

Figure 2

GEOLOGIC TERMINAL STORAGE
PILOT PLANTS NO. 1 AND 2, DESIGN AND CONSTRUCTION SCHEDULE

Figure 3

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TENTATIVE DESIGN PARAMETERS FOR PRELIMINARY DESIGN OF REPOSITORY IN SALT

WASTE TYPE	BLOMEKE & KEE TABLE*	PHYSICAL FORM	HEAT GENERATED (W/UNIT)	UNITS IN PILOT PLANT(1)	ACRES IN PILOT FACILITY(1)	UNITS IN FULL FACILITY(2)	ACRES IN FULL FACILITY(2)
HLW	2	CANISTERS	1,800	1,000	32	35,300	1,100
CLADDING HULLS	3	CANISTERS	55	3,100	4	52,200	70
LOW-LEVEL TRU	9	55-GAL DRUMS	2.2×10^{-1}	53,000	8	674,000	100
ILW-TRU	10	CANISTERS	1.3×10^{-1}	26,000	33	265,000	330
					77		1,600
		SHAFTS, CORRIDORS, AND BULKHEADS			58		400
					135		2,000

(1) CAPACITY OF PILOT PLANT ALLOWS FOR RETRIEVABLE STORAGE OF HALF OF ALL WASTES GENERATED THROUGH THE YEAR 1990.

(2) CAPACITY OF REPOSITORY ALLOWS FOR RETRIEVABLE STORAGE OF ALL WASTES GENERATED THROUGH THE YEAR 2005.

*J. G. Blomeke and C. W. Kee, "Projections of Wastes to Be Generated," in *Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle*, CONF-760701, October 1976.

OWI-76-132 R1

Figure 4

ARTIST'S CONCEPT FEDERAL REPOSITORY

Figure 5.

Figure 6

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