UMR-MEC Conference on Energy

12 Oct 1976

The National Waste Terminal Storage Program

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THE NATIONAL WASTE TERMINAL STORAGE PROGRAM

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Abstract

The National Waste Terminal Storage (NWTS) program has been established to provide facilities (federal repositories) in various deep geologic formations at multiple locations in the USA which will safely dispose of the commercial radioactive waste that must be delivered to a federal repository for terminal storage. This paper presents an overview of the NWTS program and describes the stepwise approach that is being taken in meeting the objective of the program.

I. INTRODUCTION

In the United States today, 60 nuclear power reactors are in operation, an additional 93 are being built, and 85 are in the planning stage. The current operating reactors generate 41 GWe, or about 8% of the total electrical power being produced. Between 1985 and 1990, when all the reactors are in operation, including those that are planned, the total nuclear electrical generating capacity will be 237 GWe, or about 25% of the total. While the predicted total power capacity will grow by a factor of 3, from 492 GWe in 1975 to 1,550 GWe in 2000, the electrical power produced by nuclear facilities will increase by a factor of 5, increasing from 8% of the total in 1975 to 40% of the total in 2000.(1) This is a significant increase, and it indicates the importance of nuclear power to this nation. During this period, most of the-nuclear-produced electricity will be produced by light-water reactors.

The steps in the nuclear fuel cycle for light-water reactors can be outlined as follows. Uranium from the mines is converted to UF_6, enriched in concentration of ^{235}U prior to conversion into a fuel, and then fabricated into a fuel element, which is used to generate power in a reactor. After the spent fuel element is removed from the reactor, it is placed in a storage pool until it is ready for reprocessing. In the reprocessing step, the uranium remaining in the spent fuel element is recovered and returned to the fuel cycle, and the plutonium produced in the fuel element while it was in the reactor is removed and converted into a fuel. The nuclear waste from reprocessing, which includes the fission products and fuel element cladding hulls as well as the low- and intermediate-level transuranic waste, is then disposed of as waste in a geologic disposal facility.

The nuclear fuel cycle is not as yet complete since no commercial reprocessing plant is in operation.

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

However, one plant is under construction at Barnwell, South Carolina, and one or more is being planned at other locations. In addition, no geologic disposal facility exists although there is an extensive program to develop such facilities under the NWTS program. The purpose of this paper is to provide a summary of that program.

2. HISTORY OF GEOLOGIC DISPOSAL EFFORTS

The geologic disposal of radioactive waste has been under study for many years. As early as 1957, the National Academy of Sciences—National Research Council Advisory Committee suggested burial of solid radioactive wastes in bedded salt deposits as the best of the many methods it had considered.(2) Since that time, this disposal method has been under continuous study and development, including an underground vault test in a bedded salt mine in Lyons, Kansas, in the late 1960s. Although further development of the Kansas vault test into a pilot plant facility was not pursued, work continued at a low level of effort toward identification of other rock units that could be acceptable for terminal storage of radioacfive waste.

In the early 1970s, the Atomic Energy Commission (AEC) authorized the Atlantic Richfield Hanford Company (ARHCO) to design a Retrievable Surface Storage Facility (RSSF) to receive and store high-level radioactive waste on a schedule compatible with the then-planned operating schedule of the commercial nuclear reprocessing industry. The RSSF was considered an interim solution for storage of waste until a permanent terminal storage facility could be developed. However, since the schedule for constructing the nuclear facilities has slipped, there is now time to implement a full-scale geologic terminal storage program. The RSSF approach has been placed in a standby status as another alternative if needed.

In early 1976, the Energy Research and Development Administration (ERDA) announced a greatly expanded program in the area of management of nuclear waste. At that time, they created the National Waste Terminal Storage program and placed the lead responsibility for the program with the ERDA Oak Ridge Operations Office. At the request of ERDA Oak Ridge Operations, Union Carbide Corporation's Nuclear Division established the Office of Waste Isolation (OWI), which has been assigned the responsibility for program management.

The objective of the NWTS program is to provide facilities (federal repositories) in various deep geologic formations at multiple locations in the USA which will safely dispose of the commercial radioactive waste that must be delivered to a federal repository for terminal storage. The general scope and plan for the NWTS program will be outlined in this paper. In order to accomplish this program, OWI intends to seek the participation of a large number of organizations around the country. Approximately 85% of the OWI budget will be awarded to organizations outside the Oak Ridge area. During FY 1976 and the transition quarter, the program budget was \$5.1 million. In FY 1977 the budget will increase to \$38.2 million; this increase reflects the significance of the NWTS program.

3. FEDERAL REGULATIONS FOR COMMERCIAL WASTE DISPOSAL

Currently, the only regulations requiring delivery of commercial waste to a federal repository are contained in Title 10, Code of Federal Regulations (CFR), Part 50. 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 (1) a fuel reprocessing plant's inventory of high-level liquid radioactive waste* will be limited to that produced in the prior 5 years; (2) 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;

*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.

and (3) 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, 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 nanocuries 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 the federal repository as well as waste contaminated with some minimum level of transuranic waste. The present design plans for the repository provide for disposal of four types of containerized waste defined as follows:

High-level waste - 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 emitters at concentrations greater than 10 nanocuries per gram and have typical surface dose rates between 10 and 1000 millirems per hour 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 nanocuries per gram and yet have sufficiently low external radiation levels after packaging that they can be handled directly.

These definitions are taken from a paper by Blomeke and Kee.[3] For reference, the accumulated quantities of these wastes to be delivered to a federal repository through the year 2005 are presented below:

Waste type	Accumulated volume to the year 2005 ($1000\ ft^3$)
High level	221
Cladding	326
Intermediate-level transuranic	1,651
Low-level transuranic	4,940

If reprocessing is not approved and the throw-away cycle is implemented, then the federal repositories will still be built, but they will be designed to dispose of spent fuel elements.

4. DESCRIPTION OF A REPOSITORY

An artist's concept of a federal repository in a bedded salt formation is shown in Fig. 1. Typically, the facility would consist of a large number of excavated rooms located several hundred feet below the surface of the ground. On the surface would be located receiving and handling facilities for containerized waste, which would be delivered by truck or rail. Shafts would connect the receiving facilities to the mine for delivery of the containerized waste to transporter vehicles, which would move the waste to its point of disposal. In the case of waste with high levels of radiation, the canisters would be lowered into suitably prepared vertical holes in the floor of a room, and the hole would be plugged for radiation protection. In the case of low-level waste, the containers would be stacked for storage.

The surface facilities would occupy approximately 100 acres and would be the only visible evidence of the repository. The underground full-scale facility encompasses an area of about 2,000 acres. Surface areas above the mine, but outside the fence around the surface facilities, might be leased for general use. Surrounding the central 2,000-acre area would be an outer controlled area of approximately 16,000 acres in which mining operations and deep drilling would be controlled to avoid any compromise of the safe operation of the repository. Surface areas over the outer controlled area would not be restricted from normal activities.

5. GENERAL PLAN FOR GEOLOGIC TERMINAL STORAGE

At this time the plans of the NWTS program call for construction of six terminal storage facilities as shown in Fig. 2. The solid triangle indicates the time geologic field work starts, the objective being to identify pilot plant sites in the rock unit being investigated. Earlier work, which will be accomplished prior to the search for sites, is not shown on this schedule.

The general plan for the NWTS program calls for the eventual construction of facilities for terminal storage in various geologic formations at multiple locations in the United States. The concept of placing terminal storage facilities at multiple geographic locations incorporates a number of advantages into the program, which include the following:

(1) Feasibility of a timely operation of a terminal storage facility is increased because of the simultaneous and parallel activities.

(2) A retrievability concept for storage of 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) It will be possible for more than one site to serve the country as a terminal storage facility so that no one location need bear the burden for the entire United States.

(4) Reduced waste transportation costs are possible if more than one facility is used since the facilities will be dispersed around the country.

(5) It eliminates concern regarding possible federal government reluctance to abandon potential sites after significant expenditure since other facilities will be available.

In the general program plan, the first two facilities will be located in salt formations, and the remaining facilities will be in other rock formations. All of these facilities will be dispersed around the country. The schedule in Fig. 2 shows the first two plants receiving waste in the middle of 1985. The next set of two facilities will start operation two years later, with the remaining two following at intervals of two years. Not shown in this schedule are the dates when the facilities will be licensed for operation by the Nuclear Regulatory Commission (NRC). This is under study at this time; however, it will be the objective of the program to seek a license for each facility at the earliest possible time.

6. DETAILED PLAN FOR PILOT PLANTS 1 AND 2

A more detailed plan for the first two pilot facilities is presented in Fig. 3. These will be located in salt formations. The first phase shows that identification of acceptable sites for the first two pilot plants will not occur until near the end of FY 1978. In the second phase, although purchase of land rights and long lead items are shown, it should be noted that land negotiations will not start until the entire review process for site selection has been completed for salt formations. Phase 5 shows that hot operation of pilot plants 1 and 2 with actual radioactive waste will not occur until mid-1985 — almost nine years from the present time. The last phase shows that safety studies and environmental studies will be continuing through the whole pilot plant program.

7. DEVELOPMENT STEPS FOR A FEDERAL REPOSITORY

Although the sequence for developing a federal repository may differ slightly from one geologic formation to another, the generalized sequence can be characterized as having seven distinct steps, as follows:

(1) Identification of formations of interest
(2) Reconnaissance surveys
(3) In situ tests
(4) Area studies
(5) Detailed confirmation studies
(6) Pilot plant operations
(7) Conversion of the pilot plant into a federal repository

Although the seven steps are distinct, it is not necessary that they all occur in sequence. For example, the in situ tests could proceed in parallel with other geologic studies. A brief description of the steps is given below.

7.1 IDENTIFICATION OF FORMATIONS OF INTEREST

In the process of identifying formations of interest, a review is made first which is based solely on the general knowledge of the geologic properties and/or fundamental properties of the rock type involved. If the review is promising, a reconnaissance survey would be undertaken. This step has already led to the identification of salt, argillaceous, crystalline rock, and carbonate rock formations as formations of interest. However, others may also be identified in the future.

At present, a number of formations are of interest in the NWTS program. Many of these are shown in Figs. 4, 5, and 6. Figure 4 shows the rock salt formations in the United States. Of these, the Salina salt formation, the interior province of the Gulf Coast dome region, and the Permian Basin are all considered to be formations of high potential for location of terminal storage facilities. Figure 5 shows the argillaceous (shale and clay) formations in the United States, and Fig. 6 shows the crystalline rock formations in the United States.

7.2 RECONNAISSANCE SURVEYS

The purpose of the reconnaissance survey is to collect all the available data on those properties and characteristics of a formation which must be considered in making a regional evaluation of the potential for utilization of the formation for waste disposal. These properties and characteristics may include (1) structure, stratigraphy, depth, and thickness; (2) hydrology; (3) mineralogy/petrology; (4) natural resources; and (5) general surface characteristics. Based on the information compiled at this stage, the prospects for the formation are evaluated and reviewed, and a number of smaller regions are identified for further geologic area studies.

7.3 IN SITU TESTS

Once the formation is identified as a possible candidate for waste disposal, a set of in situ experiments will be conducted in parallel with other geologic studies. These in situ experiments range from simple electrical heaters placed in holes in exposed surface outcrops of the formation to extensively instrumented vault tests in excavations especially constructed at the expected depth of the pilot plant. In general, the vault tests are constructed to permit tests with both electric heaters and/or canisters of simulated waste which are removed at the conclusion of the experiment. They provide extensive information on the physical behavior of the rock and the waste canister, as well as the stability of the underground layout. Preliminary in situ tests have already been completed for salt formations but still have to be completed for other formations of interest.

7.4 AREA STUDIES

The geologic area studies that follow the reconnaissance survey are designed to develop new and specific data in the areas of interest. These studies include (1) core drilling at a density of perhaps 6 to 10 holes per 1000 square miles to obtain adequate definition of the important subsurface characteristics of the formation, (2) field geologic mapping, (3) hydrologic studies, (4) geophysical surveys, and (5) other geologic studies. It is appropriate to note that environmental assessments are usually required by each state in order to obtain drilling permits. In the NWTS program, an environmental assessment for each drilling operation will, of course, be prepared. This is in compliance with ERDA regulations, which conform to the National Environmental Policy Act of 1969. Upon completion of the area studies, the suitability of the area is again reviewed, and if it still appears promising, a few specific locations will be identified for even more detailed confirmation investigations. At this point, there will be extensive reviews involving all review groups that have been established. The selection by OWI and ERDA of specific locations for more detailed confirmation investigations and the final selection of pilot plant sites will be firmly based on all these reviews, as well as on public comments obtained during public progress reports.

7.5 DETAILED CONFIRMATION STUDIES

The detailed confirmation studies are directed toward specific locations of perhaps 5 to 10 square miles each. The investigations involve primarily the drilling and testing of four or more core holes at each location, plus the continuation of any specific geologic studies for which the previous results were inadequate to evaluate the suitability of the location. The results of this phase of the investigation would be used to determine which locations fully qualify for consideration as pilot plant sites.

7.6 PILOT PLANT OPERATIONS

After adequate review, a pilot plant site will be selected and a pilot plant constructed to evaluate handling and storage operations, using actual canisters of high-level and other types of waste, and to confirm all design calculations. The initial pilot plant would involve the excavation of only a small part of the ultimately available mine area and would handle relatively small amounts of each of the waste types. Surface facilities would, however, be approximately full scale. Experiments would be performed to test retrievability devices and emplacement concepts and, in general, to evaluate the stability of the underground workings. The data obtained during the initial pilot plant operation will be used to design the expanded pilot plant, which will be operated until it has successfully been demonstrated that (1) it can safely receive, emplace, and store high-level waste at the design rate and (2) no anomalies in the geologic formation have been found.

7.7 CONVERSION TO A FEDERAL REPOSITORY

The conversion of the facility to a federal repository will occur when sufficient data have been gathered to obtain the required licenses from the NRC. This will be done at the earliest opportunity. At some point in this sequence, the retrievability concept will also be abandoned when sufficient data are available to warrant such action. At that time the storage rooms will be backfilled and sealed.

It is planned that a number of review groups will also be created to help in the decision-making process during the sequence leading to creation of the operating repositories. These review groups will include:

(1) A Geologic Review Group reporting to the Director of OWI, consisting of senior geologists, hydrologists, and other appropriate experts to review the entire geologic program on a continuing basis

(2) Basin or Regional Review Groups consisting of experts knowledgeable about each particular basin or region in which field operations are expected

(3) Federal-State Review Groups consisting of representatives of agencies of the federal and state governments and other organizations who would have responsibility for or interest in some aspect of the NWTS program

In addition, the public will also be involved in the reviews during public information meetings that will be held periodically in the regions where operations will be under way.

REFERENCES

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2. Disposal of Radioactive Waste on Land, Publication 519, National Academy of Sciences—National Research Council, Washington, D.C., 1957.

3. J. O. Blomeke and C. W. Kee, "Projections of Wastes to Be Generated," pp. 96-117 in Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, CONF-76-0701, October 1976.

BIOGRAPHY

Clayton D. Zerby has been with Union Carbide Corporation since 1950, originally joining the staff of Oak Ridge National Laboratory as an engineer. Since that time, he has held positions of increasing responsibility, including president of two subsidiaries of Union Carbide. He was appointed Director of the Office of Waste Isolation early in 1976.

He received the Ph.D degree in physics from the University of Tennessee in 1960. He is a registered Professional Engineer in Ohio and Tennessee.

He has served on the USAEC's Cross Section Advisory Group and the Ad Hoc Committee of the USAF's Scientific Advisory Board on Space Radiation Effects.

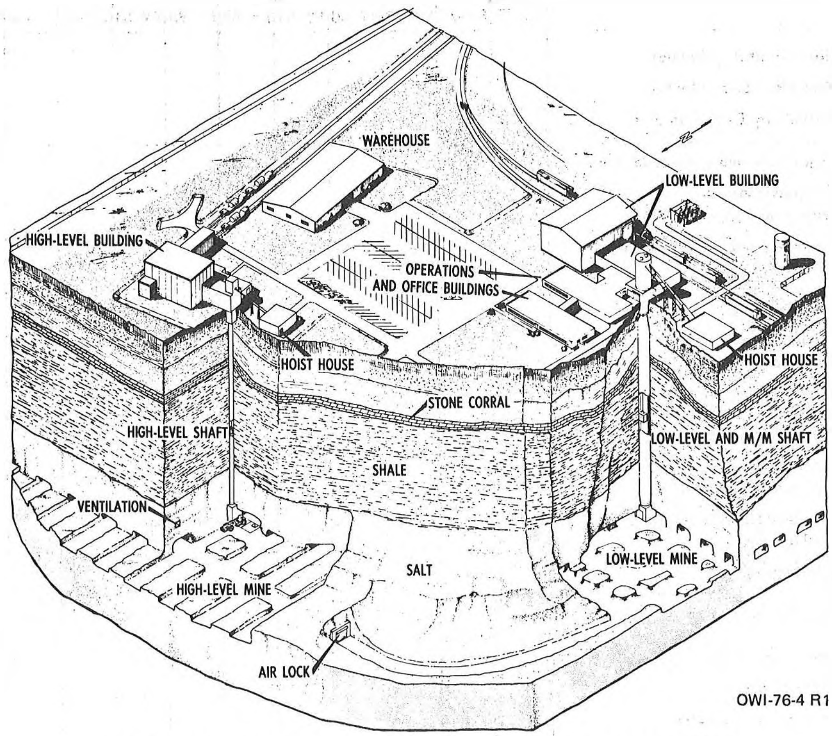

FIGURE I. ARTIST'S CONCEPT OF A FEDERAL REPOSITORY.

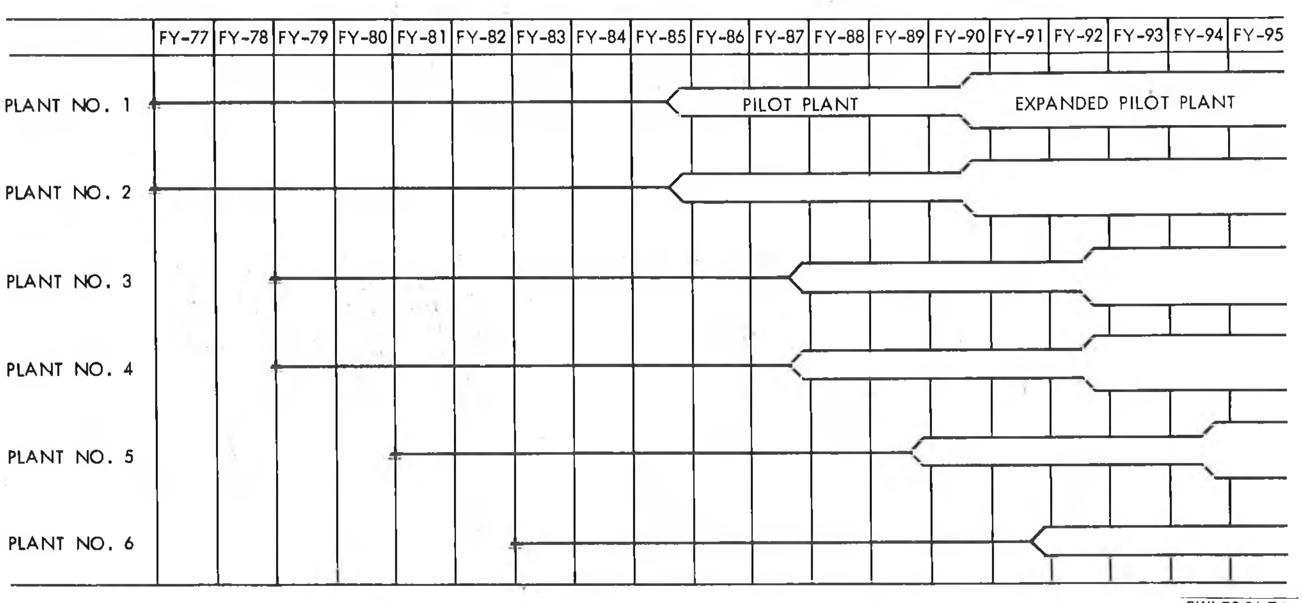

FIGURE 2. GENERAL PLAN FOR GEOLOGIC TERMINAL STORAGE.

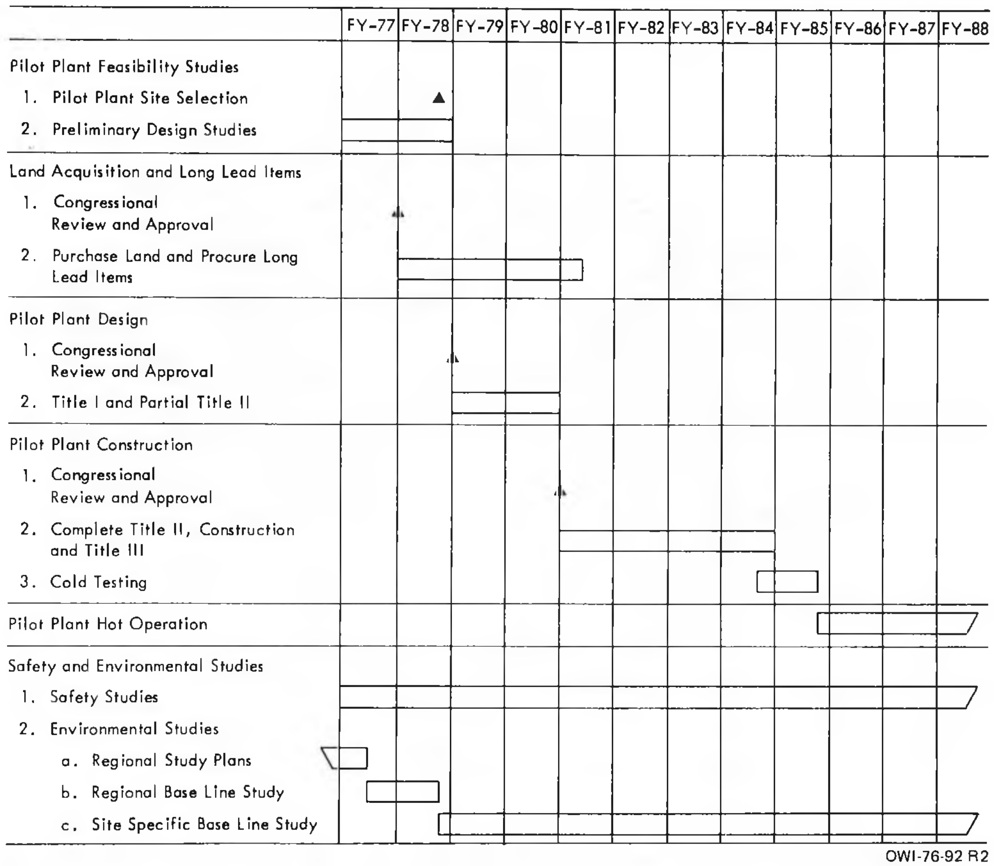

FIGURE 3. DESIGN AND CONSTRUCTION SCHEDULE FOR PILOT PLANTS 1 AND 2 FOR GEOLOGIC TERMINAL STORAGE.

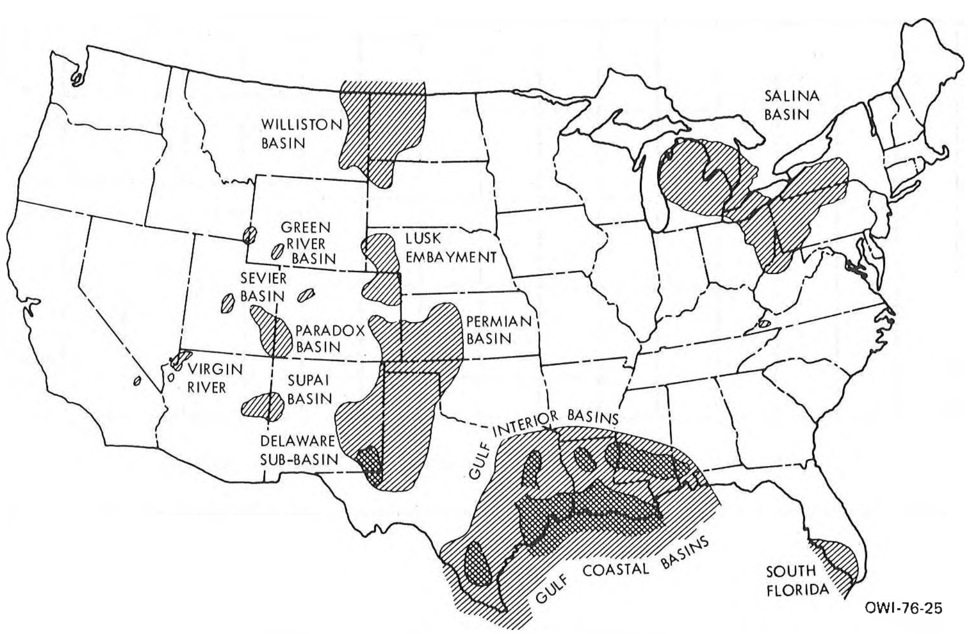

FIGURE 4. ROCK SALT DEPOSITS IN THE UNITED STATES (AFTER PIERCE AND RICH, U.S. GEOL. SURV. BULL. 1148).

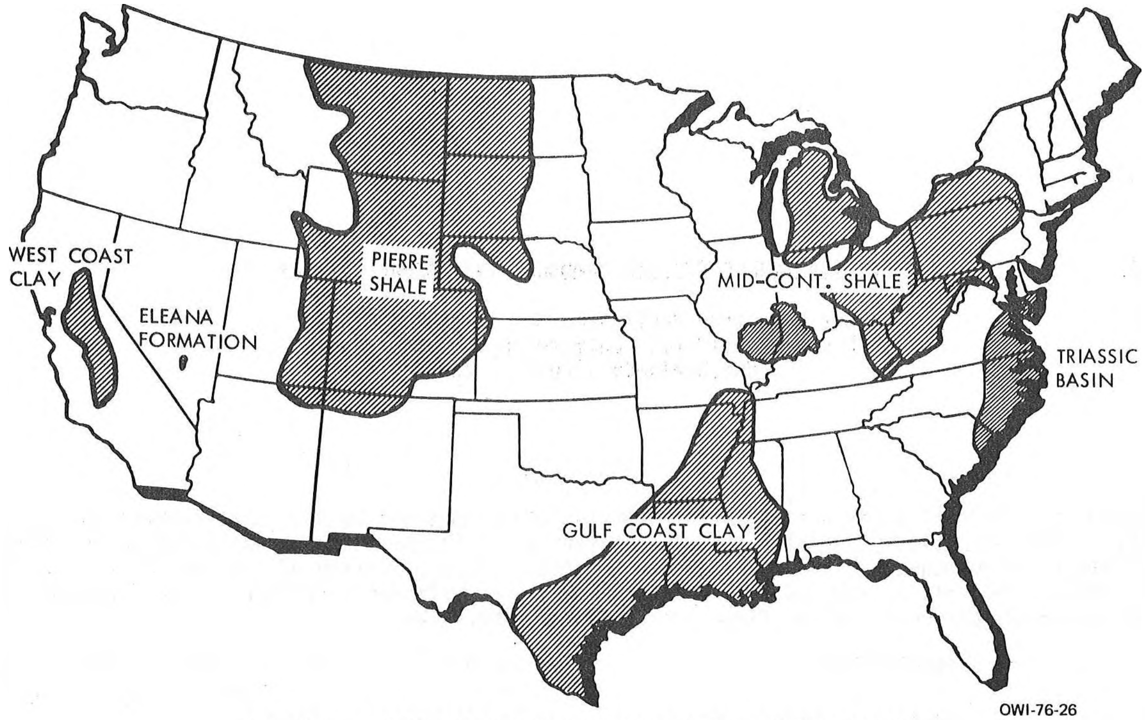

FIGURE 5. ARGILLACEOUS FORMATIONS IN THE UNITED STATES.

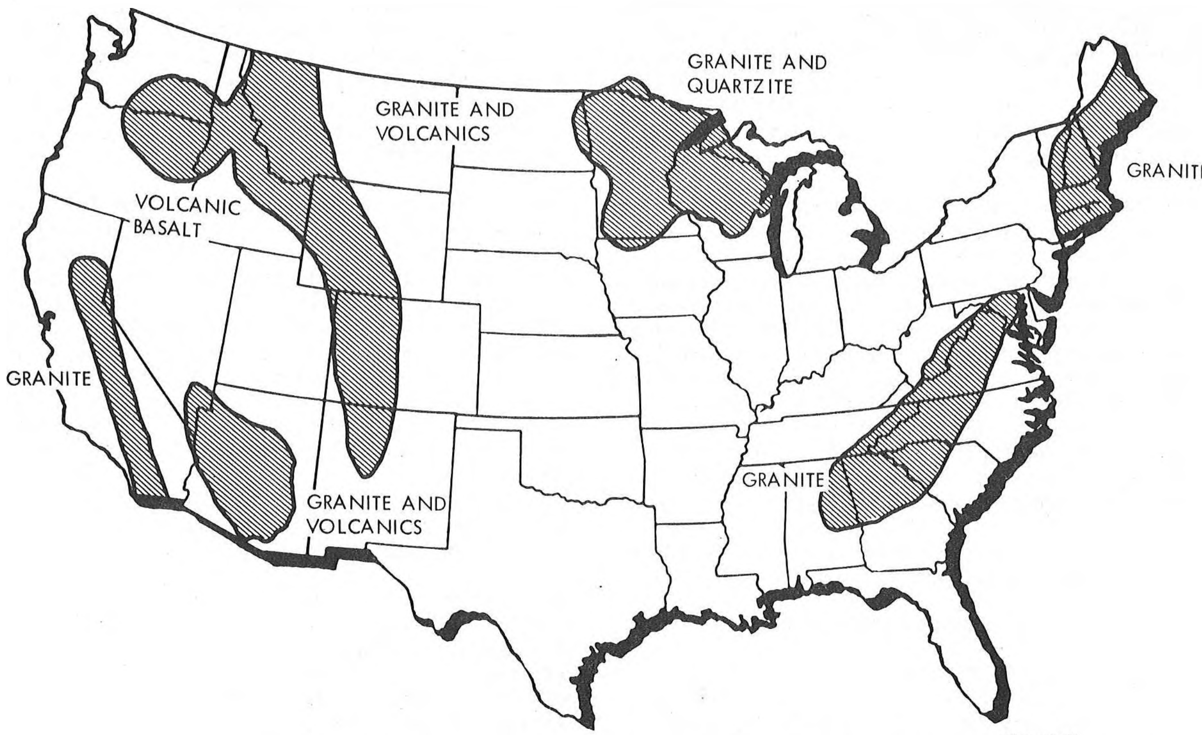

FIGURE 6. CRYSTALLINE FORMATIONS IN THE UNITED STATES.