MASTER

ADDENDUM NO. 1
CONCEPTUAL DESIGN CRITERIA
FOR
FACILITIES FOR GEOLOGIC DISPOSAL OF
RADIOACTIVE WASTES IN SALT FORMATIONS

UCC-ND Engineering
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OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

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IN SALT FORMATIONS

Prepared by

UCC-ND ENGINEERING

for the

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Date: 3/2/77

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Date:

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<u>No.</u>	<u>Section</u>	<u>Location</u>	<u>Remark</u>
1	1.4	4	"project cost data which should include projected operating costs <u>and decommissioning cost</u> in addition to construction data."
2	1.5.2	Last para., Fifth Line	Should read "ATMX-600" <u>not</u> AMTX-6000.
3	2.2.2	First two para.	Delete and substitute attached geologic descriptions "A Salt Dome Province and a Representative Salt Dome" and "A Bedded Salt Basin"
4	2.4.1	Fourth para.	Should read "counting room" <u>not</u> change room.
5	2.4.1	Last para.	Delete last two sentences.
6	2.4.3	Second para.	Delete plant phase and plant operation and substitute "initial phase" and "initial operation" respectively.
7	2.4.5	Second para.	Delete and substitute: "The inhabited nonradioactive and potentially radioactive zones of the building will be served by independent air conditioning, exhaust, and control systems. Before distribution, supply air will be filtered through pre-filters (8 to 30% NBS) and main filters (90% NBS), contained in positive seal, side loading retainers. The exhaust air from the potentially radioactive zones will be passed through, in series, 8 to 30% NBS filters, 90% NBS filters and HEPA filters contained in positive seal, side loading filter retainers. Auxiliary backup capabilities and standby power will be provided for this exhaust system."

<u>No.</u>	<u>Section</u>	<u>Location</u>	<u>Remark</u>
8	2.5	Fourth Line	Should read "if the canister is damaged" <u>not</u> the cask.
9	2.5.1	Sixth Line	Should read "of manipulators for maintenance; a shielded overpack cell;"
10	2.5.1	Para. Nine	Delete sentences two and three.
11	2.5.3	First Line	Should read "to accommodate half of the quantities"
12	2.5.4.1	Third & Fourth Para.	Delete and substitute: "Normally inhabited area of confinement zones will be air conditioned and ventilated with six to ten air changes per hour except for the cask unloading area, which will have a minimum of three changes per hour. Supply air to all confinement zones will flow through prefilters (30% NBS), main filters (90% NBS), HEPA filters contained in positive seal, side loading filter retainers, and a back-flow preventer before being distributed to these areas. Exhaust air from all confinement zones will be processed through 90% NBS filters, two banks of HEPA filters in series (separately DOP testable), in bag out side access housings, and then discharged through a stack to the atmosphere. A duplicate filter bank and exhaust fan installation will be provided to ensure reliability of operation, except for the high-level hoist house. Both fans will be tied into the stand-by power distribution system. Upon loss of normal power, the confinement zone ventilation supply system will automatically shut down, and the exhaust fan will automatically operate at half-speed.

The nonrestricted areas of the building, except the maintenance area, will be air conditioned with supply air filtered

<u>No.</u>	<u>Section</u>	<u>Location</u>	<u>Remark</u>
12	2.5.4.1	Fourth para. (cont'd.)	through 8 to 30% NBS and 90% NBS filters. The exhaust from nonrestricted areas, except the maintenance area and operations office, will be filtered through 30% NBS and 90% NBS filters and a single bank of HEPA filters, contained in positive seal, side loading filter retainers, before discharge to the atmosphere. The maintenance area and change room will be heated and ventilated. Ten air changes per hour will be supplied to the chemical laboratory, and health physics office. Outside design conditions for heating, ventilation, and air conditioning will be based on data published in the ASHRAE <u>Handbook of Fundamentals</u> ."
13	2.6.2	Second Line	Should read "automotive" <u>not</u> automative.
14	2.7.7	-	Add "Closed circuit television and combustible gas and temperature monitors will be strategically located throughout the facility."
15	2.7.8	-	Add this new subsection: "2.7.8 Environmental Control The administration building, offices in the maintenance shop building, offices in the warehouse building, and the security building will be air conditioned. The remaining areas of the maintenance shop and warehouse area will be heated in cold weather and ventilated in warm weather. Exhaust systems will be provided in the maintenance shop building to conform to OSHA standards.
16	Figures 4,5, and 6	P. 28, 29 and 30	Delete and substitute: Stratigraphy in geologic attachment referenced in comment number 3.
17	Tables 1-5	Pgs. 37, 38, 39, 40 and 41	Delete and substitute: information in "Updated Projections of Radioactive Wastes to be Generated by the U. S. Nuclear Power Industry" C. W. Kee, A. G. Croff, J. O. Blomeke, ORNL/TM-5427, December 1976.

A SALT DOME PROVINCE AND A REPRESENTATIVE SALT DOME

One region of the United States ranks among the most significant areas in the World for the development of salt diapirs or salt domes. The latter are extensive masses of rock salt (which contains varying amounts of anhydrite) which have upwardly intruded through and into the overlying sedimentary sequence under a form of deformation called halokinesis. This latter term refers to the overburden-induced movement under conditions of plastic deformation to the salt, which originally was deposited as one or more thick strata of bedded salt in a basin experiencing appreciable post-salt subsidence and sedimentation. Where the overlying sediments were deposited to a thickness that could exert enough of a static loading effect on the deeply buried "mother salt" to induce plastic deformation, salt movement into either salt ridges (anticlines) or actual diapirs or piercement domes resulted.

As a regional tectonic-depositional feature, this basin, or geosyncline as it is also called, is complicated both as to its origin and the structural features which border it or are included within it. Developed initially sometime in the early Mesozoic (Triassic-Jurassic, although open to some debate), the geosyncline consists of a seaward thickening wedge of sediments which ranges upward to 60,000 feet in thickness within several so-called depocenters that lie in the present-day offshore portion. Although the exact mechanism responsible for the formation of this subsiding basin is not clearly understood, the onshore extent of this feature is marked by a series of regional border faults. These are referred to as fault systems, because each is represented by a series of faults as opposed to one major

fault. In addition to these fault systems and the salt domes, the region is structurally characterized by several local to semi-regional uplifts, posiments (as opposed to uplifted areas, these are structural features which remained stable while adjacent basins subsided), major growth faults within the basin where faulting-displacement was contemporaneous with and accentuated by rapid sedimentation, various other faults as well as numerous anticlines and synclines. Many of these structural complexities are either directly associated with salt domes or have been developed wholly or partly in response to the various modes of salt movement and migration. Based upon geophysical examination, many anticlines, typically low in their overall relief, are known to be supported at depth by ridges or rolls of deformed salt.

The regional stratigraphic succession consists of from 15,000 to upwards of 60,000 feet (the latter figure is inferred from seismic data) of Jurassic, Cretaceous and Tertiary sedimentary strata. Most observers consider the "mother salt" to be a deep salt formation, which by extrapolation and projection is viewed as being Jurassic in age. In terms of regional stratigraphic position, this "mother salt" generally rests upon deformed and eroded deposits that vary in age and rock type depending upon position within the region. This underlying complex varies from either structurally deformed Paleozoic sedimentary rocks (locally intruded by igneous rocks) or metamorphic rocks of several different geologic ages to even other Mesozoic sedimentary rocks. Overlying the salt are several other Jurassic-age sedimentary units, including at least one evaporite sequence which some investigators feel could also be a source of some salt for the regions's salt

domes. Because the deep salt formation is rarely penetrated by wellbores, its exact distribution and lithologic character on a region basis is very poorly understood.

The Lower and Upper Cretaceous sequence contains shales, sands and sandstones, various limestones, including several chalk intervals, and some evaporite units. Tertiary-age sediments regionally become progressively younger in a seaward direction, and include sequences of Paleocene, Eocene, Miocene and Plio-Pleistocene age. The rock lithologies are dominated by shales and poorly consolidated sands, many of the latter representing reservoirs for petroleum production. Sedimentation for most of the Tertiary and Pleistocene strata was by a series of prograding delta systems which deposited vast volumes of sediments in the actively subsiding geosyncline.

It is convenient to subdivide the salt-dome province into two sub-provinces because there are several centers of salt dome formation. Each of the subprovinces further consists of one or more salt dome basins to reflect even more localized clusters of domes. The first subprovince contains two major salt-dome basins. One basin contains only a few known domes, most of which are too deep for consideration. The other basin, which embraces a sizeable number of offshore domes (all of which are not being evaluated further due to their position in the marine area), contains a large number of onshore salt domes. Based upon a variety of conflicting uses (petroleum development, cavern storage), excessive depth, and the fact that many coastal domes may still be involved in halokinetic-tectonic movement, the vast

majority of these domes are not being considered further. The elimination of most these domes is based upon an analysis of such factors by a previous study.

Designated subdivisions in the second subprovince include three basins. There are over a hundred known or suspected domes in these three basins. Attention within this discussion will be focused from this point forth on one of these basins in the second subprovince because various followup studies have provided more data to date on this area. This basin lies between two posiments (incorrectly referred to as uplifts) on the east and the west. The northern boundary of the basin merges to the north with a general sedimentary sequence while the southern margin is designated as the regional flexure or hinge zone which marks the north edge of the much thicker Miocene sedimentary sequence to the south. Due to the presence of a persistent east-west structure, the basin can be divided into a smaller subbasin on the north and a counterpart to the south. The former contains five salt domes while the latter possesses fourteen domes.

Because of the influence on these two subbasins by the adjacent posiment, the regional dip of the Eocene strata is toward the east. The youngest unit, however, is nearly flatlying, indicating a relatively early point within the Tertiary for a halt to basin subsidence in relation to the structural control to the west.

Studies have also suggested, but not yet proven, that it may be possible to establish the rate of salt movement in dome formation. Evidence strongly suggests that salt dome formation was ongoing by mid Cretaceous in the basin.

One method has been to compare the degree of structural dip (in degrees) against the geologic age of the strata to discover whether any relationship exists between these parameters. In the case of some of the domes in the basin, early (100-120 million years ago) salt-dome growth rates were followed by two pulsatory increases and subsequent declines according to this dip/geologic age method. By Paleocene time, a major decline in growth rate has been noted, and is believed to signal the end of salt movement in this basin's domes. This observation tends to agree with the view that these interior domes are presently inactive due to lack of surface indications of diapirism, undeformed Tertiary (Miocene-age) strata that overlies several of the domes and the relatively shallower (15,000 feet) source of salt from which these domes arose as compared to the 40 to 60,000-foot depths in the coastal province.

Because there are several ongoing studies being conducted on one of the domes, a diagram of this dome is included here to illustrate certain features of interest. This dome is the southernmost salt dome in one of the basins and is approximately 2 miles across in a north-south direction at a depth of 2000 feet. It is elongated in plan view. Depending on the exact point of penetration, wellbores have encountered the top of the salt along the crest at between 777 and 799 feet. Overlying the salt mass is some 90 to 120 feet of caprock, which consists of porous limestone and irregularly bedded anhydrite. This caprock, like that found on many salt domes, is believed to be the cemented residue from salt dissolution active during dome formation. Evidence here suggests that this caprock extends as much as 1600 feet down the flanks of the dome.

This dome has uplifted Upper Cretaceous, Paleocene and Eocene sedimentary units, and the magnitude of uplift may be as great as 500 feet. The diagram purposely does not show several faults originally proposed in the vicinity of the dome from the records of the four wells shown. It also does not illustrate the relative positions of the various stratigraphic units encountered by the other wells. Thus, the sequence penetrated in the general area of the reference well (well #2) will be different from that encountered in the other three wells, or even in the other crestal well shown.

An expected, yet restricted, sequence that might be penetrated on the crest of the dome would include a variable thickness of Quaternary terrace deposits (mainly sands, gravels with minor silts and clays), underlain by one or more units consisting of silts, clays and sands, several of which are fresh-water aquifers elsewhere. Although not shown on this diagram, a sand lies adjacent to the dome and appears hydrologically uncontaminated by saline water from the dome. A saline plume does exist in an aquifer as uplifted over the dome to the east, but appears to be less concentrated than earlier studies indicated. The lower part of the section overlying the dome, as depicted in the illustration, consists entirely of clays and shales, and while only 300 feet thick here, generally reaches 500 feet in thickness in this basin. Slightly more than 100 feet in caprock could be expected at this locality.

Due to differences in uplift by this (or any) dome, variable effects due to dome-influenced faulting, the exact position (for a test borehole) on the dome's crest versus its flanks, variations in caprock, and differing degrees

of erosion over domes, it must be emphasized that considerable differences in anticipated sequence can occur over relatively short lateral distances.

A BEDDED SALT BASIN

Bedded rock salt or halite (NaCl) has been formed in a number of different sedimentary basins by the natural evaporation of seawater. In parts of the United States, major salt deposits of Silurian age occur in these sedimentary basins.

These Silurian deposits constitute some of the greatest accumulations of salt in the world. Thick, high purity salt units occur within one formation which underlies a total area of approximately 100,000 square miles throughout two adjacent basins. In the central portion of one of the basins, the salt reaches an aggregate thickness in excess of 2000 feet. Both individual salt beds and the entire salt-bearing sequence thin toward the edge of the basin and become more shallow. The top of the salt ranges in depth from about 6000 feet in the center of the basin to less than 1000 feet along the margins.

This basin, as both a sedimentary and structural basin, includes all or portions of several states. This tectonically stable feature is surrounded by gently uplifted or domed areas. In plan view, the basin is nearly circular with a slight north-south elongation.

Essentially flat-lying sedimentary strata that are folded or faulted in only a few places characterize the basin's regional structural picture. Rock units dip gently toward the center of the basin from the surrounding arches and shield area at generally less than $1/2$ degree. An anticline, a northwest-trending flexure-fold in the southeast portion of the basin, is probably the most significant, individual structural feature. In the central part of the basin, several northwest-trending anticlines with salt-filled cores have been developed. These features resulted from the draping

of younger strata over elongated masses of salts that remained following subsurface salt dissolution in adjacent areas. Dissolution and removal of Silurian-age salt shortly after deposition has also caused some overlying rock units to become brecciated as the latter collapsed into the solutioned cavities. This phenomenon has affected a sizeable stratigraphic interval and has been referred to as a "breccia." The latter is more extensively developed throughout the northern portion of the basin.

Faulting within the basin appears to be slight. A significant fault is associated with the previously mentioned anticline, but other examples are either of small displacements or their existence is based upon inconclusive evidence. Although there are undoubtedly other faults in the basin, their exact detection would require additional investigation.

The entire region was extensively glaciated during the Pleistocene; as a result, glacial-drift deposits which average between 200 and 300 feet in thickness overlie the sedimentary sequence throughout much of the basin. Eventually relieved of the great weight of glacial ice, the basin has also undergone glacial (elastic) rebound. This relatively small amount of vertical uplift is however not considered a significant structural feature.

Reflecting a long history of tectonic stability, the basin exhibits a very low incidence of seismic activity. Only two events of Modified Mercalli Intensity V or greater have ever been recorded in that portion of the basin underlain by the Silurian salt sequence. Although adjacent areas have experienced somewhat more numerous seismic events, the latter have locally been slight in intensity (less than Modified Mercalli Intensity VIII) and posed no threat to the salt sequence within the basin.

Inasmuch as the stratigraphic sequence contains several carbonate units, sinkholes and other karst-like features have been locally developed in certain limestones and dolostones. In the northeast portion of the basin, one stratigraphic group has been so affected. In addition to the development of the breccia and several salt-cored anticlines, other evidence supports the past dissolution of salt in the basin. Principal here is the abrupt thinning and actual termination of certain salt units near the periphery of the basin. Where salt units currently lie near to the land surface and dynamic, non-saturated (with reference to NaCl) ground water can come in contact with the salts, dissolution may be active at the present time.

The stratigraphic succession in the basin consists of sedimentary strata which include carbonates (limestones and dolostones), shales, sandstones and evaporites (salt and anhydrite) which overlie a Precambrian-age basement complex dominated by igneous and metamorphic rock types. A maximum thickness of nearly 15,000 feet of sedimentary rocks is thought to be present within the central part of the basin. Rocks of Cambrian, Ordovician, Silurian, Devonian, Mississippian and Pennsylvanian age are present. A thin sequence of Jurassic-age shale and sandstone also is present in the central part of the basin, but is entirely overlain by Pleistocene-age glacial deposits.

Salt and anhydrite units also are present in the Devonian-age sequence. This evaporitic sequence however is considerably thinner and more restricted than that of the Silurian. Maximum thickness of the younger salts exceeds

500 feet only within a small area, and the entire salt-bearing interval is confined to the northern half of the basin. Like several of the Silurian-age salts, individual salt beds in this formation thin toward the margins of the basin. These Devonian-age salt beds range from 20 to 80 feet in individual thickness, although the uppermost salt unit attains a thickness slightly greater than 100 feet in one local area.

The Silurian therefore contains the major bedded salt deposits within the basin, and consists of a number of stratigraphic divisions that are based upon subsurface information (well cuttings, cores and mechanical well logs) and are essentially equivalent to formations. Work in both basins has clearly shown that several of these salt units exhibit a similar lithologic (rock character) expression over this wide geographic area. Very distinctive mechanical-log curves recorded from these units has enabled reliable correlation or assignment of equivalence over fairly extensive distances.

The present stratigraphic nomenclature defines the stratigraphic units of interest as all those strata, dominated by evaporites with lesser amounts of carbonates and shales, which lie above the older carbonate interval and below the younger dolostones. This part of the geologic section is, for the purposes of this project, divisible into a series of lettered intervals, designated A through G from oldest to youngest. In turn, the oldest unit (A) is further subdivided into the basal A-1 salt, which is overlain by the A-1 carbonate (limestone), which is succeeded by the A-2 salt overlain by the A-2 carbonate (limestone and dolostone).

The basalmost portion of the A-1 salt consists of a thin interval of anhydrite, but the salt is relatively pure throughout the basin. This salt

unit does however contain some thin zones of potash in the deeper parts of the basin. The A-1 salt is never shallower than 3000 feet below the land surface and reaches a depth in excess of 8000 feet toward the center of the basin. Within most areas, the A-1 salt exceeds 200 feet in thickness, with a maximum thickness of 475 feet attained in the east-central portion of the basin. Toward the edges of the basin, the unit thins rapidly as well as grading into an anhydrite phase along both the northern and southern margins of its extent.

The most massive and thickest salt unit in most portions of the basin is the A-2 interval. The latter contains clean salt throughout the interior of the basin, but similar to the A-1 salt, grades laterally into anhydrite along its southern margin and toward the northwest. Average thickness of the A-2 salt is slightly greater than 300 feet, but the unit exceeds 475 feet in the deeper part of the basin. Depth to the top of A-2 salt ranges from 3000 feet along the margins of the basin to more than 7000 feet in the center.

The B salt contains relatively pure salt in the lower half and less pure salt interbedded with shale and dolostone in the upper half. It too laterally changes into anhydrite toward both the southwest and north, but extends throughout more of the basin than any of the other salts. Clean salt comprises approximately 50 percent of the total lithology of the B salt, which ranges between 300 and 500 feet in thickness. Along the basin margins, the B salt varies in depth from 2000 to 3000 feet, but is also found below 6000 feet in much of the central part of the basin.

No salt is developed in either the next youngest interval designated the C zone, or within the E or G units. These are represented by shale interbedded with dolostone. Salt development in the D zone is minimal as only two thin salt beds separated by a thin dolostone are present.

The youngest, salt-bearing division is the F salt, which consists of both clean and impure (shale and anhydrite impurities) salt interstratified with shales and dolostones. Being the youngest interval, the F salt is less than 3000 feet in depth along both the southern and northern tiers of the basin. Although many of the individual salt beds in this unit are less than 20 feet thick, the two deepest salts as well as the uppermost salt bed vary between 30 and 60 feet in thickness, and locally may reach 100 feet in thickness.

The relationships to the overlying stratigraphic intervals and the characteristics of these lettered divisions are depicted on the accompanying diagram. The latter illustrates a projected cross section between two boreholes in the northeastern portion of the basin. At this locality, the succession from youngest to oldest can be expected to consist of a thin veneer of glacial drift overlying a Devonian-age sequence which begins in a shale unit and extends through dolomite and anhydrite, and thereupon into the Silurian-age rocks of interest. The asterisked location on the diagram indicates the projected position of and depths to the F and B salts, whose thicknesses and lithologic expression in this sector of the basin make them worthy of further evaluation in terms of their potential for radioactive-waste isolation. The stratigraphic column on the right side of

the diagram illustrates the basic rock types which can be anticipated to be present in this area. Because the A-2 and A-1 salts lie fairly well below 3000 feet here, they would not be considered to be as prime a set of units as the lower F and B salts for any contemplated exploratory evaluation in the future.

Although the depicted cross section is representative of the rocks of interest as well as the overlying sequence that can be found in several areas throughout the northeastern portion of the basin, certain additional variables were considered in using this section as an illustration. In addition to the favorable depth, thickness and salt-lithology characteristics present here, these other factors included: (1) a relatively thin development of glacial drift; (2) the presence of the shale as the shallowest bedrock unit as opposed to the limestones in which there occurs appreciable sinkhole development; (3) absence of any known, major structural features; and, (4) a reasonable distance of separation from oil and gas activities whose principal exploration target has been small, pinnacle reefs developed in the underlying deeper and older carbonate interval.

PROJECTED CROSS SECTION THROUGH SILURIAN AND DEVONIAN
SEQUENCE
PRINCIPAL EVAPORITE-CARBONATE UNITS