ORNL/Sub-4269/14

MASTER

PROJECT SUMMARY REPORT RSI-0033

DESIGN ASPECTS OF THE ALPHA REPOSITORY:

VII. SUMMARY OF RESULTS FOR THE CONCEPTUAL FACILITY LAYOUT, ROOM STABILITY ANALYSIS, AND EQUIPMENT SELECTION

Submitted To

Oak Ridge National Laboratory
Oak Ridge, Tennessee

operated by

Union Carbide Corporation
Nuclear Division
for the
Department of Energy

by

Paul F. Gnirk
William H. Grams
Thomas J. Zeller

November 3, 1978

This report was prepared by RE/SPEC Inc., under Subcontract No. 4269 with Union Carbide Corporation, Nuclear Division, under Contract No. W-7405-eng-26 with the Department of Energy. The subcontract was administered by the Office of Waste Isolation, Union Carbide Corporation, Nuclear Division.

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RE/SPEC Inc.
P. O. Box 725
Rapid City, South Dakota

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(RSI-0033)

FOREWORD

This report was prepared under a subcontract with Union Carbide Corporation, Nuclear Division, a contractor for the Department of Energy. The subcontract was administered by the Oak Ridge National Laboratory. The principal objective of the ORNL Program is to provide facilities in various deep geologic formations at multiple locations in the United States which will safely dispose of commercial radioactive waste, which must be delivered to a Federal Repository for terminal storage. Some of the expected wastes produce both heat and radioactivity. This situation leads to many unique problems in design and rock mechanics. This report addresses particular design engineering aspects of low level waste disposal in bedded salt.

The study addressed herein originated from concerns relating to the potential for encountering unusual design and operational requirements in the disposal of low level radioactive wastes in bedded salt. Specifically, this investigation has examined various conceptual facility layouts, particular room stability situations, and the potential applicability of mining and drilling equipment.

The technical contents of this report have been reviewed by Messrs. Joe L. Ratigan and Gary D. Callahan. The report was typed by Ms. Julie S. Annicchiarico and Ms. Judy C. Hey.

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RE/SPEC INC.

P. O. Box 725 • Rapid City, S.D. 57709 • 605/343-7868

November 3, 1978

TECHNICAL MEMORANDUM REPORT RSI-0033

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FROM: Dr. Paul F. Gnirk
Mr. William H. Grams
Mr. Thomas J. Zeller
RE/SPEC Inc.
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Rapid City, SD 57709

SUBJECT: Design Aspects of the Alpha Repository: VII. Summary of Results for the Conceptual Facility Layout, Room Stability Analysis, and Mining Equipment Selection (Ref.: Union Carbide Corporation, Nuclear Division Subcontract No. 4269).

ABSTRACT. In 1975, RE/SPEC Inc. analyzed various design engineering aspects of an Alpha Repository for the disposal and isolation of packages of low-level solid waste and sealed metal canisters of spent fuel cladding waste. The proposed site was located in southeastern New Mexico, with candidate disposal horizons situated in massive bedded salt at depths of 580 to 825 m. The canisters would be emplaced in vertical drillholes in the floors of disposal rooms, and the packages of solid waste subsequently stacked on the floors. Consideration was given to various conceptual facility layouts, the structural stability of the disposal rooms, appropriate excavation/haulage systems, and equipment availability for drilling the canister emplacement holes. This report summarizes the results of the entire study.

I. INTRODUCTORY REMARKS

The disposal and isolation of radioactive waste in mined cavities in geological formations involves design engineering considerations that are unique to the waste emplacement concept. In 1975, under the direction of the Oak Ridge National Laboratory, RE/SPEC Inc. performed an analysis of certain design engineering aspects of an Alpha repository facility in bedded salt (1). At that time, the Alpha repository was a conceptual facility for the underground disposal of packages of low-level solid waste and sealed metal canisters of spent fuel cladding waste. The designated site area was located in southeastern New Mexico, approximately 45 km east of the city of Carlsbad. The subsurface stratigraphy at the site is characterized by thick beds of salt-bearing evaporite, with candidate disposal horizons situated in massive salt at depths of 580, 640, and 825 m. The operational life of the repository was established as 20 years, with a disposal capacity of approximately 380,220 cu m of alpha solid waste and 17,825 cu m of spent fuel cladding waste. It was anticipated that the cladding waste would be contained in canisters fabricated from schedule 40 steel pipe, with diameters of either 0.25 or 0.3 m and an overall length of 3 m. The canisters would be emplaced in vertical drillholes in the floors of the disposal rooms, with the annulus between the canister and drillhole walls, as well as the upper portion of the drillhole, being backfilled with dry sand. The low-level bulk waste would be contained in packages (about 2.8 cu m of waste volume) and stacked on the floors of the disposal rooms after emplacement of the canisters.

2. GEOTECHNICAL ASPECTS OF THE REPOSITORY SITE

Geologically speaking, the proposed site was located within the northern end of the Delaware Basin, which is contained within the much larger Permian Basin, and is characterized by thick salt-bearing evaporite beds in the lower part (Castile, Salado, and Rustler formations) of the Late Permian Ochoan Series and a thin bed of silt-stone and sandstone in the upper part (Dewey Lake Redbeds) (2). A columnar section through the formations, as derived from the logs of two drillholes in the general site area, is presented in Fig. 1. The upper two candidate disposal horizons were situated in massive salt in the central section of the Salado formation at depths of 580 and 640 m. This section of the formation is characterized by alternating stringers of anhydrite and polyhalite, with the base of the anhydrite stringers commonly being either clay or shale. The third candidate horizon was situated at a depth of 825 m in the bottom portion of the Salado formation. This section is also characterized as massive salt, with occasional stringers of anhydrite.

In order to obtain the mechanical properties of the site rock, 75 specimens of anhydrite, polyhalite, and rock salt of nominal ten-cm diameter field core were tested in the laboratory to determine the uniaxial compressive strength, indirect tensile strength, Young's modulus of elasticity, and Poisson's ratio (3). The test specimens were selected over a depth interval of 577 to 1176 m. As indicated in Table I, the compressive strength of the rock salt ranges from about 17 to 26 MPa, depending upon the inclusion of clay and/or polyhalite impurities. The compressive strength of the anhydrite is of the order of twice that of the rock salt, even with inclusions of halite. Four specimens of rock salt from the 580 and 825 m horizons were tested in uniaxial compression to determine the creep parameters. As illustrated in Fig. 2, the curves of axial strain as a function of time are approximately linear when plotted logarithmically. For a creep law of the form $\varepsilon = Kt^n$, n and K are of the order of 0.22 and 10^{-4}, respectively, where t has units of sec. Although the data are somewhat limited, strain appears to be a nonlinear function of the deviatoric stress. Neither steady-state nor tertiary creep were achieved during any of the tests.

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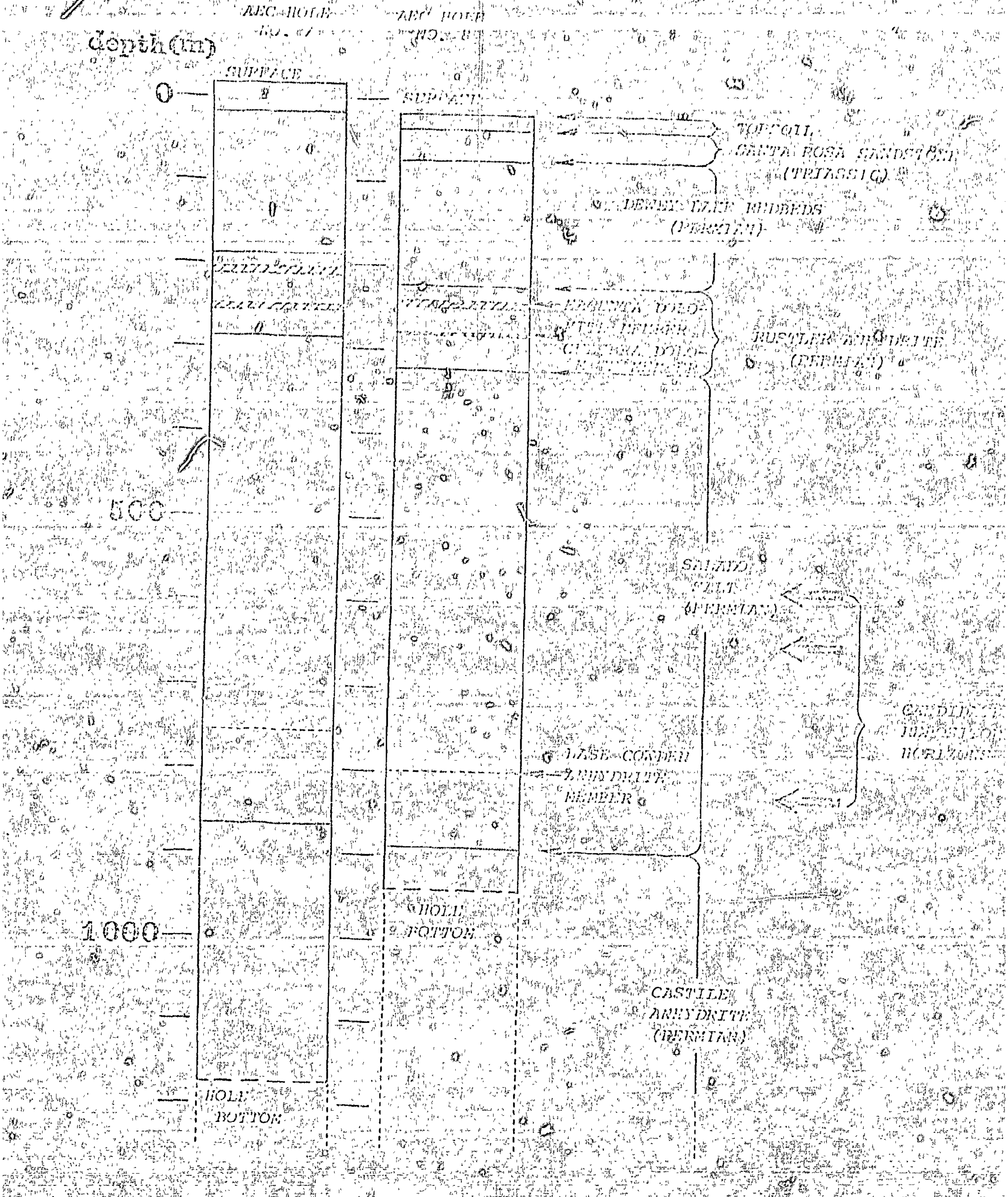


FIG. 1 — STRATIGRAPHY OF PROPOSED ALPHA REPOSITORY SITE (2).

TABLE 1

QUASI-STATIC STRENGTH AND ELASTIC PROPERTIES OF SALT, ANHYDRITE, AND POLYHALITE FROM THE SALADO AND CASTILE FORMATIONS (3)

DEPTH INTERVAL (METERS)	ROCK TYPE	SPECIFIC GRAVITY	COMPRESSIVE STRENGTH (MPa)			TENSILE STRENGTH (MPa)			YOUNG'S MODULUS (MPa)			POISSON'S RATIO		
			C_0	S	N	T_0	S	N	E	S	N	ν	S	N
577.3 to 600.[illegible]	ROCK SALT, WITH CLAY AND/OR POLYHALITE IMPURITIES	2.17	16.9	3.4	8	1.4	0.3	12	23375	4775	8	0.33	0.09	8
623.0 to 652.2	ROCK SALT	2.11	25.7	4.4	11	1.7	[illegible]	15	13375	9120	12	0.34	0.06	12
719.9 to 720.2	POLYHALITE	2.16	34.0		1	3.4		2	75105		1	0.29		1
624.[illegible]	ANHYDRITE, W/HALITE	2.65	41.6		1				47365		1	0.33		1
777.0 to 776.[illegible]	ANHYDRITE, W/HALITE	2.72	51.7		1	1.7		1	75755		1	[illegible]		1
901.3 to 1171.2	ANHYDRITE	2.86	90.2	11.2	6	5.7		16	76125	10550	6	0.35	0.04	6

S = STANDARD DEVIATION; N = NUMBER OF TESTS

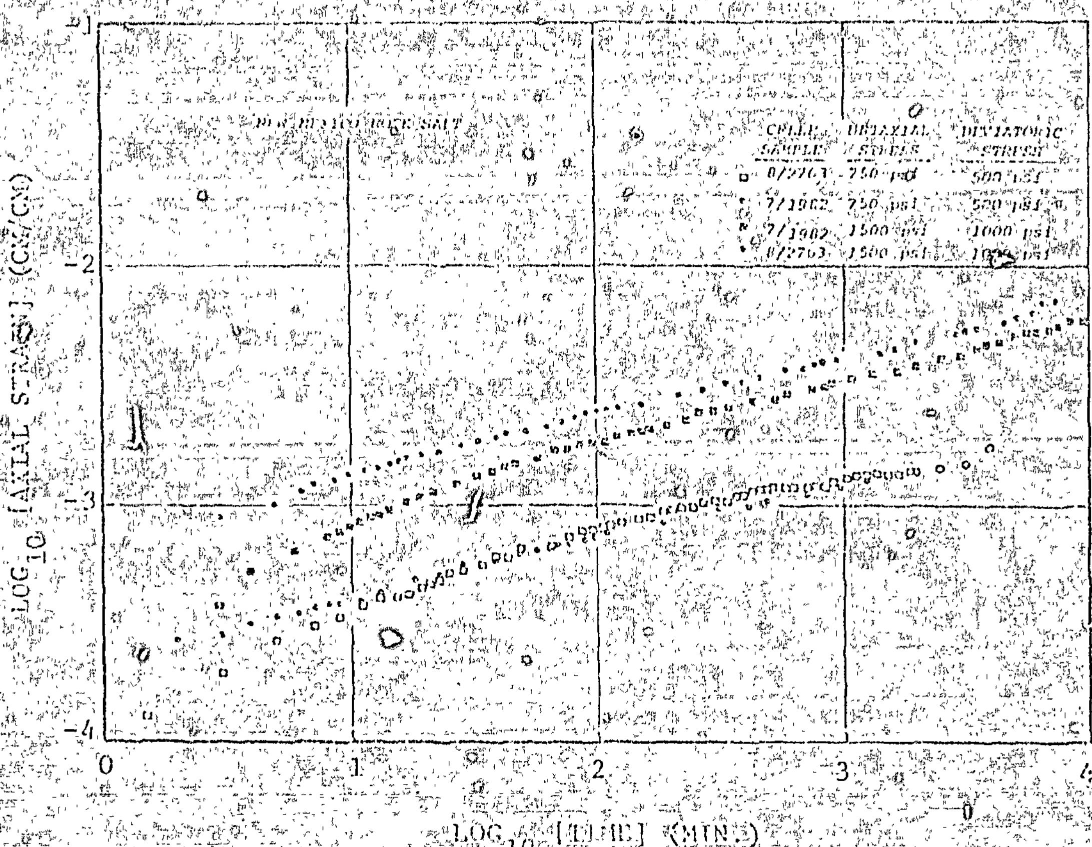


FIG. 2 — CREEP CURVES AT ROOM TEMPERATURE FOR SALT FROM THE SALADO FORMATION (3).

3. SUMMARY OF DESIGN CONSTRAINTS

The disposal capacity of the repository facility must be sufficient to accommodate 17,825 cu m of spent fuel cladding waste, which amounts to about 144,305 canisters with diameters of 0.25 m or 100,227 canisters with diameters of 0.3 m. The canisters were to be emplaced in drillholes in the floors of disposal rooms, with either one or two canisters per hole. After the canister capacity of a disposal room was achieved, and the holes were backfilled, packages of low-level solid waste would be stacked on the floor. The 380,220 cu m of solid waste amounts to approximately 134,000 packages, with packaged dimensions of 1.22 by 1.83 by 1.83 m. Fig. 3 illustrates the estimated accumulations of alpha solid waste and spent fuel cladding waste through the year 2003 (1).

The minimum cross-sectional dimensions of a disposal room were specified as 4.9 m in height by 6.4 m in width. The minimum diameter of a drillhole was specified as 50.8 cm, with minimum and maximum depths of 7.6 and 9.1 m, respectively. The minimum spacing between centerlines of the drillholes was established as 1.2 m, with a clearance between the rib of a room and the centerline of a drillhole being at least 0.9 m. The drillhole pitch could be either triangular (offset) or square, depending upon equipment constraints. In all instances, at least 1.5 m of the upper part of a drillhole would be filled with either crushed salt or dry sand.

By employing these constraints, the upper limit size of the repository was defined as that corresponding to the emplacement of one 0.25 m diameter canister per drillhole. By utilizing the drillhole specifications and the minimum cross-sectional dimensions of a disposal room, this upper limit case would require a total excavation of the order of 4.1 million metric tons of salt. This is equivalent to an average mining rate of 680 metric tons per day, 250 days per year for 24 years. This facility size would accommodate all of the packaged solid waste with a space utilization of 50%.

The lower limit of the repository excavation was based on 0.3 m diameter canisters with two canisters per emplacement drillhole. This would require a minimum excavation of approximately 1.7 million metric tons of salt, which is equivalent to an average mining rate of 285 metric tons per day. The packages of solid waste were actually the governing factor for a lower limit; however, for the purposes of this study, the lower limit was defined as canister governed, since canisters are more critical as regards disposal. Utilizing 50% of the volume of the rooms, approximately 35% of the solid waste packages could be disposed of in the repository facility.

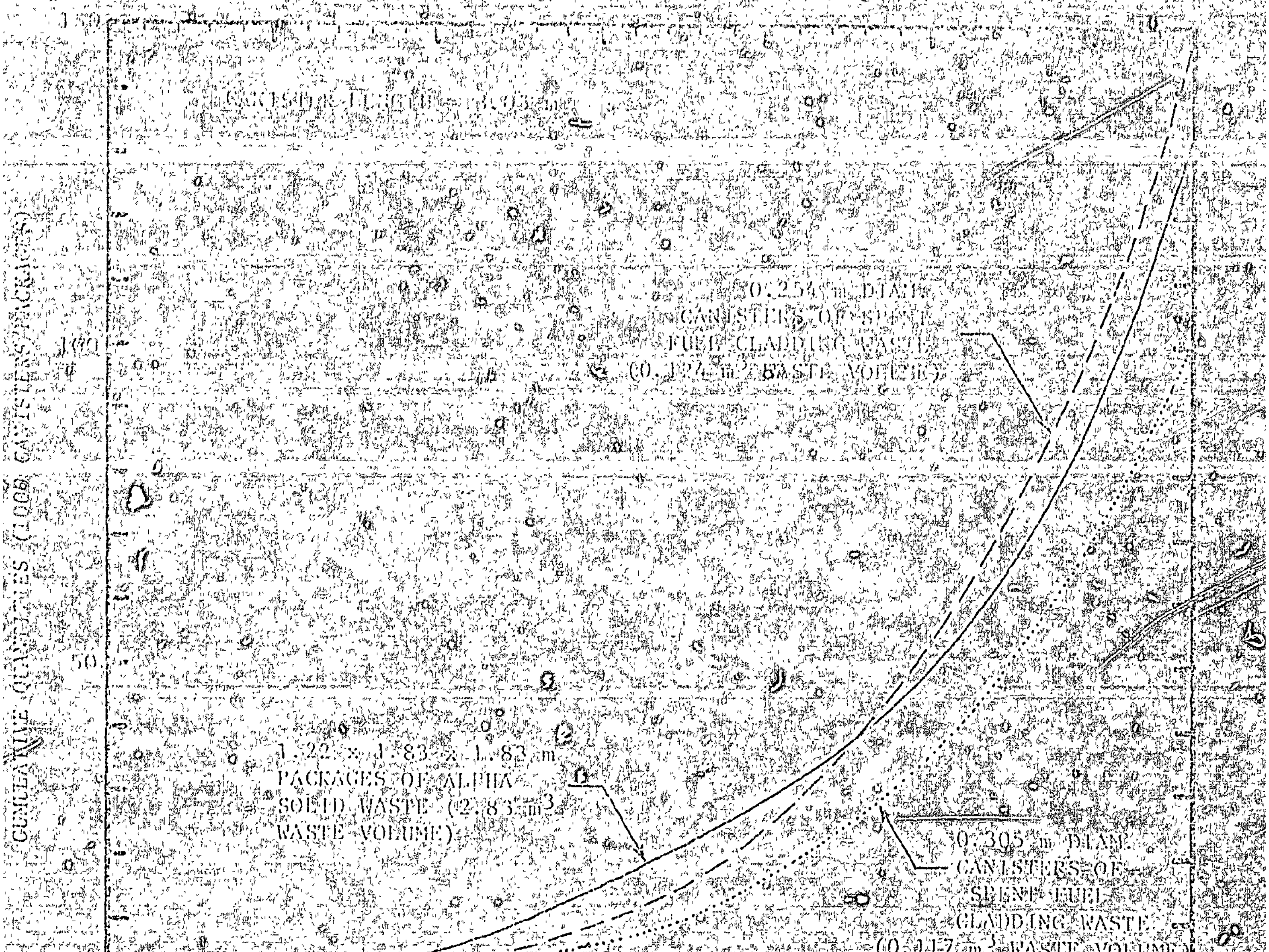


FIG. 3 — ESTIMATED ACCUMULATIONS OF PACKAGES OF SOLID ALPHA WASTE AND CANISTERS OF SPENT FUEL CLADDING (1).

4. CONCEPTUAL LAYOUT OF THE REPOSITORY FACILITIES

A variety of conceptual layouts of a repository facility were developed to establish a basis for evaluations of the excavation/haulage and large hole drilling equipment needs (4). The layouts were established by use of a building block principle with the disposal room being the basic component. Consideration was given to room widths of 6.7 and 9.1 m, corresponding to 5 and 7 canister emplacement holes across the width of a room, respectively. The emplacement holes can be drilled on either a square or triangular (offset) pattern. However, the square pattern appears to offer more advantages as regards the number of emplacement holes in a room and equipment convenience. Accessways with merging sections connect the disposal room to the haulage and ventilation drifts. The length of the disposal room, including the ventilation and haulage accessways, is approximately 116 m. For a square drill-hole pattern, 518 holes can be drilled in each disposal room.

As illustrated in Fig. 4, a panel consists of a sequence of disposal rooms positioned on either side of a dual sub-main haulageway. The submain haulageways are in turn connected to a dual entry main haulageway. The cross-sectional dimensions of the haulageways are 6.1 by 4.9 m, with the entries separated by a pillar width of 15.2 m. Ventilation drifts, with cross-sectional dimensions of 4.6 by 4.6 m, are situated along the periphery of the panel, and in turn connect into a ventilation collector drift of the same cross-section. The ventilation collector drift leads to the main ventilation shaft. Disposal rooms with a width of 6.7 m are separated by pillars with widths of 18.3 m, which gives an extraction ratio of 27%; the rooms with a width of 9.1 m are separated by pillars with widths of 21.3 m, for an extraction ratio of 30%.

As illustrated in Fig. 5, five conceptual repository layouts were established by use of the disposal panel concept, with the panel designs differing by only the number of rooms in each panel. Each of the facility layouts have a man-material-salt hoisting shaft, a solid waste hoisting shaft, a canister hoisting shaft, and at least one ventilation shaft. The excavation and haulage distance requirements for each of the conceptual facility layouts are summarized in Table 2. The excavation requirements do not include the tonnage of the salt resulting from shaft sinking, shaft facilities excavation, and drilling canister emplacement holes. For the upper limit, involving 0.25 m diameter canisters with one

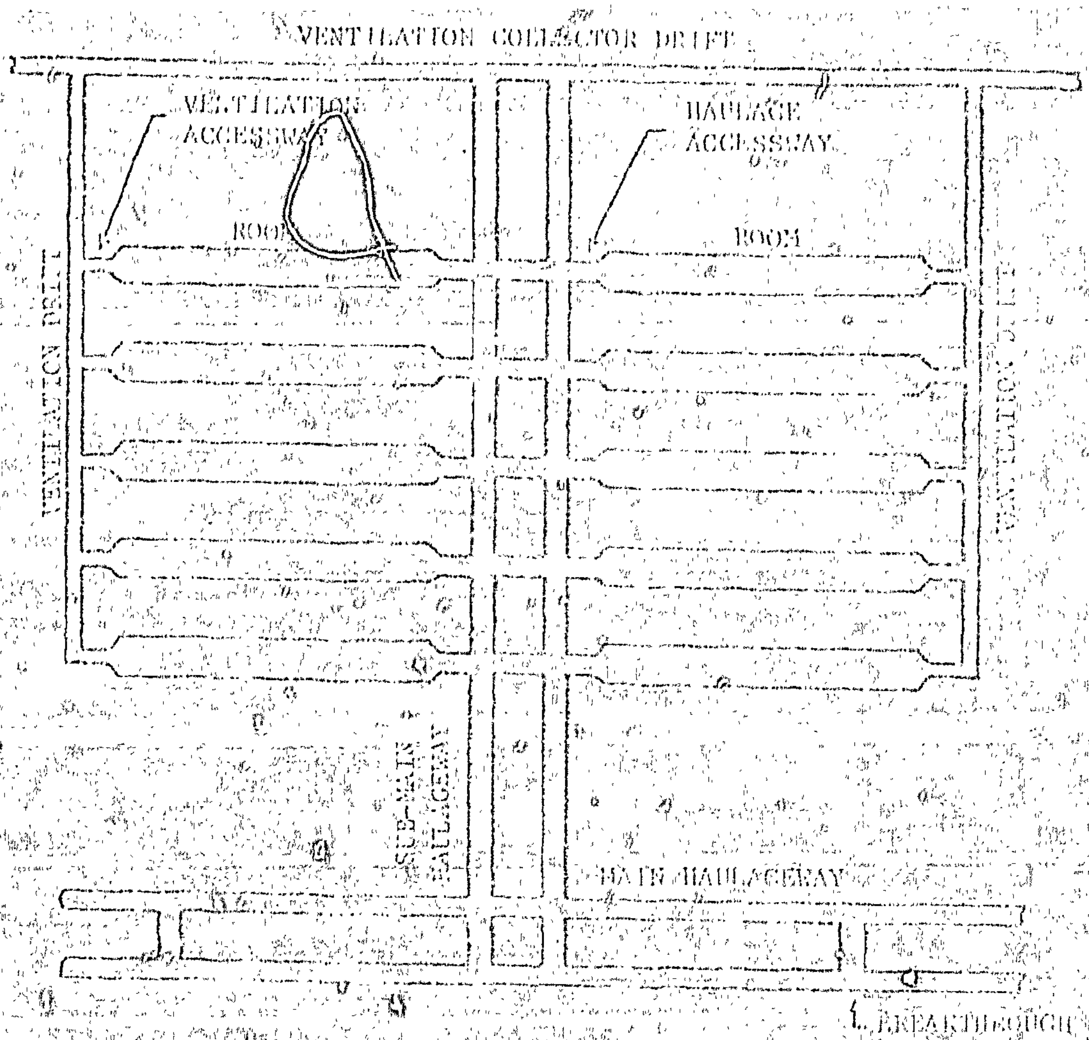


FIG. 4 — PLAN VIEW OF A TYPICAL WASTE DISPOSAL PANEL (4).

TABLE 2

SUMMARY OF EXCAVATION AND HAULAGE DISTANCE REQUIREMENTS FOR THE VARIOUS CONCEPTUAL REPOSITORY FACILITY LAYOUTS (4)

EXCAVATION AND HAULAGE	DISPOSAL LIMIT	ROOM WIDTH (M)	REPOSITORY LAYOUT: LINEAR	[illegible] TIE	MALTESE CROSS	SNOWFLAKE	[illegible]
TOTAL EXCAVATION (MILLION METRIC TONS)	UPPER	6.7 9.1	4.23 3.88	4.11 3.96	4.55 4.20	4.56 4.19	4.550 4.21
	LOWER	6.7 9.1	1.52 1.40	1.59 1.48	1.82 1.73	1.76 1.63	1.85 1.72
DEVELOPMENT EXCAVATION (I.E. NON-PRODUCTION EXCAVATION) AS A % OF TOTAL EXCAVATION	UPPER	6.7 9.1	16.9 16.2	18.1 17.7	22.5 22.3	22.3 22.1	22.7 22.6
	LOWER	6.7 9.1	19.5 19.1	23.2 23.0	33.1 33.0	28.7 28.0	33.6 32.3
AVERAGE ONE-WAY HAULAGE DISTANCE FROM DISPOSAL ROOMS TO MAIN HOISTING FACILITIES (METERS)	UPPER	6.7 9.1	1910 2285	1160 1230	940 995	575 620	745 775
	LOWER	6.7 9.1	815 900	490 535	635 655	320 335	595 605
AVERAGE ONE-WAY HAULAGE DISTANCE TO DISPOSAL ROOMS FROM ALPHA WASTE HOISTING FACILITIES (METERS)	UPPER	6.7 9.1	1910 2265	1100 1220	940 995	785 640	745 773
	LOWER	6.7 9.1	815 900	490 535	635 655	545 560	595 605

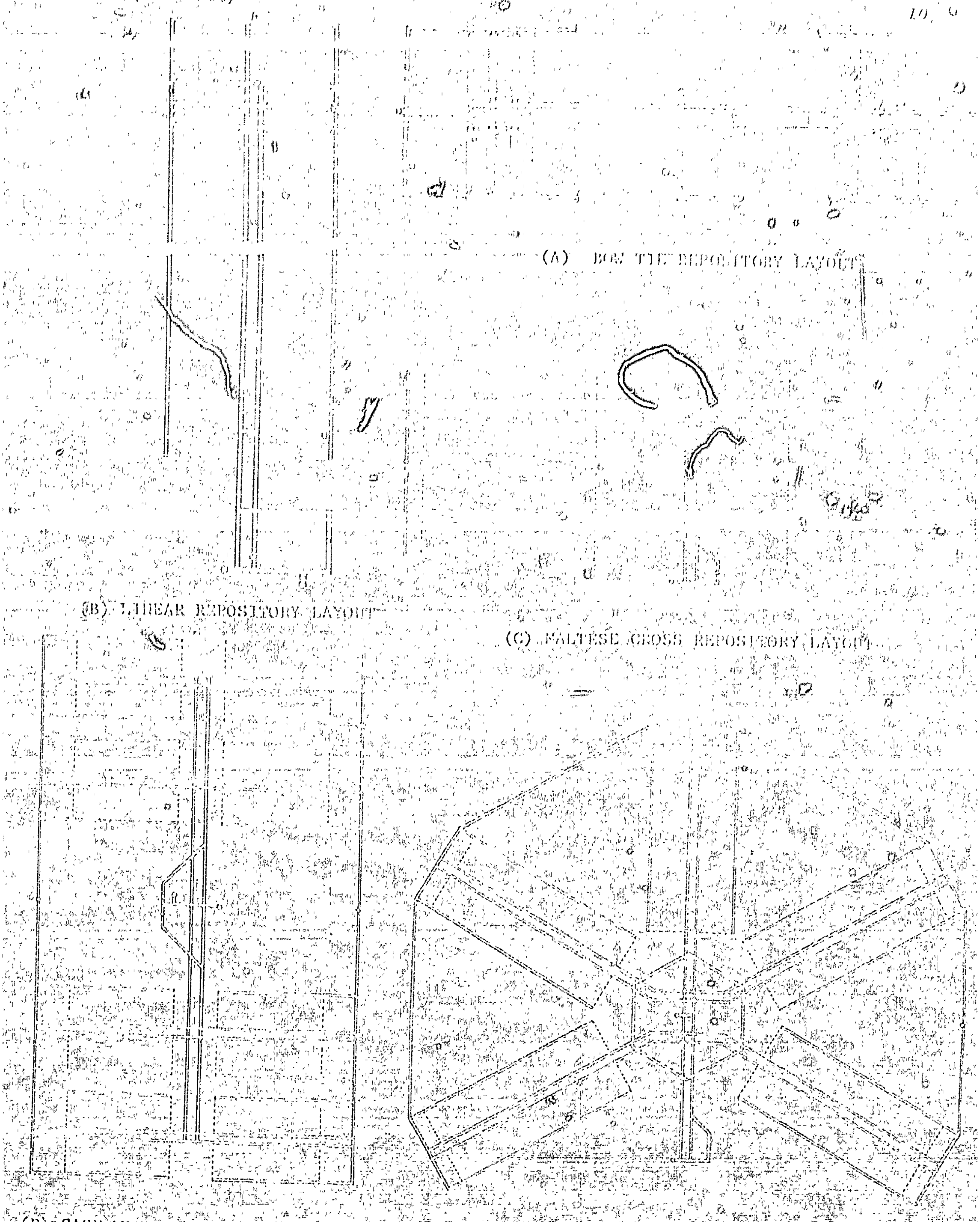


FIG. 5 — VARIOUS CONCEPTUAL LAYOUTS OF UNDERGROUND REPOSITORY FACILITIES (4).

canister per emplacement hole, the excavation requirements are of the order of 4 to 4.5 million metric tons. By emplacing two 0.3 m diameter canisters in each emplacement hole, the total excavation tonnage can be reduced by approximately 60%, or of the order of 3 million metric tons. The use of a room with a width of 9.1 m reduces the excavation tonnage by about 5 percent as compared to the use of a room with a width of 6.7 m. From the aspects of development excavation and haulage distances, the Snowflake layout is the most favorable concept.

From the viewpoint of ventilation, the Maltese Cross layout is the most favorable due to the relatively short ventilation flow paths, ease of separation of the ventilation air, and the use of two ventilation shafts. As regards safety, considering multiple escape paths and relative proximity of escape paths to egress shafts, the Snowflake layout is the most favorable. Finally, the Snowflake layout is the only design where the radioactive waste haulageway can be conveniently separated from the mining operations.

In general, when evaluating both the quantitative and qualitative features of a conceptual repository layout, the optimum repository design would appear to be a multiple panel layout with centrally located main hoisting facilities and remote radioactive waste hoisting facilities. A conceptual facility with these features is schematically illustrated in Fig. 6. The separation of the mining and waste disposal operations would also be considered a prime design criterion. In addition, the layout should have a ventilation system such that excavation for both haulageways and disposal rooms would be either remote or upstream from any waste emplacement operations.

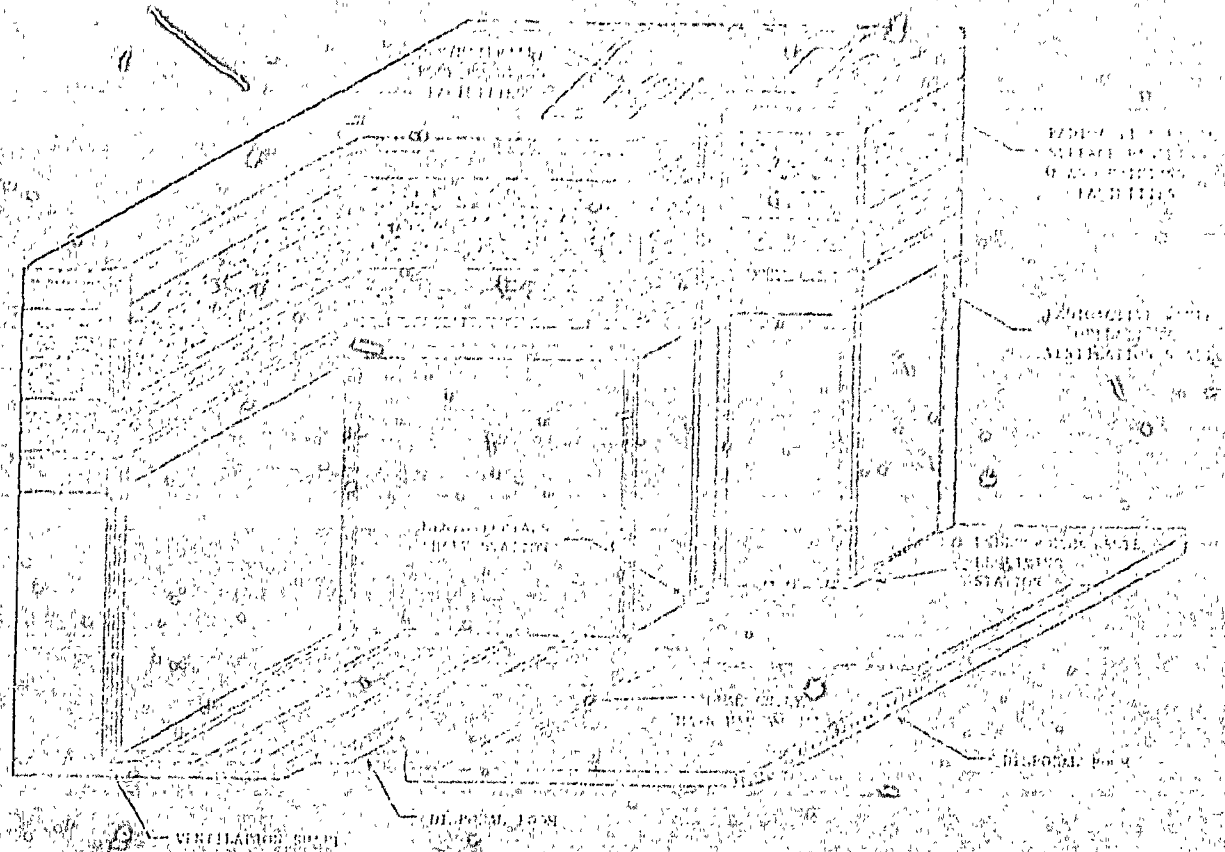


FIG. 6 — CONCEPTUAL SINGLE-LEVEL UNDERGROUND ALPHA REPOSITORY IN BEDDED SALT.

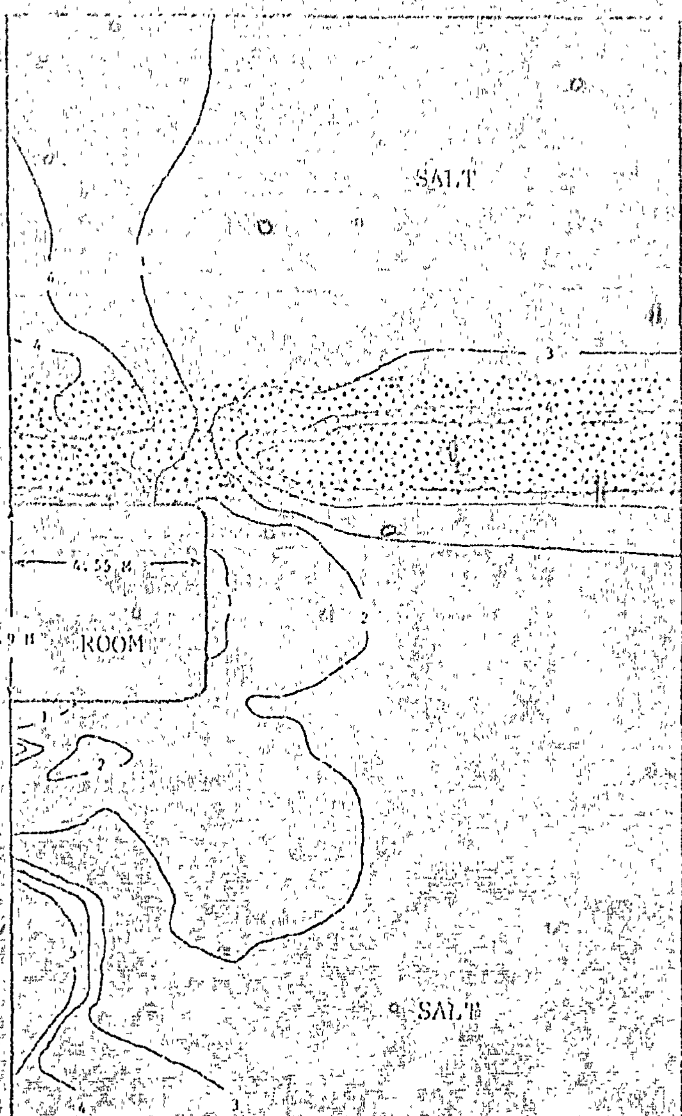
5. STRUCTURAL STABILITY ANALYSIS OF DISPOSAL ROOMS

The primary goal of this aspect of the study was to provide preliminary evaluations of the structural stability of typical room-and-pillar geometries in the three candidate horizons, including the effect of the canister emplacement drillholes in the room floor (5). As a supplementary task, the local structural behavior of the drillholes was analyzed. The structural evaluations were obtained by use of elastic finite element modeling of the room-and-pillar geometries employed in the development of the repository facility layouts. Such models inherently contain the macroscopic "stiffness" of the proposed drillhole patterns in an effort to determine the global pillar behavior. Finite element models of the drillhole patterns were also developed and analyzed for each of the candidate horizons.

Fig. 7 is an illustration of the factor of safety contours around a disposal room with an extraction ratio of 30 percent at a depth of 640 m. In this particular model, a layer of anhydrite with a thickness of 3 m was included in the roof of the disposal room. The pre-mining state of stress is assumed to be lithostatic. Since the stiffness of the floor is reduced by the introduction of the drillhole, the modulus of elasticity of the salt in the floor is reduced by about 14 percent, which is equal to the reduction in the floor material volume as a consequence of the drillhole excavation. By the use of the finite element method, the post-mining state of stress around the room can be calculated. By utilizing these stresses, the linear Mohr-Coulomb failure condition, and the strength properties from Table 1, the factors of safety given in Fig. 7 were computed. A factor of safety of one or less indicates a potential for failure. For the two extraction ratios and the three candidate mining horizons, the center of the pillar and the roof-rib intersection exhibited factors of safety greater than one. However, in all instances the mid-point of the rib of the room exhibited a factor of safety of less than one, indicating potential for pillar spalling. Only the rooms at a depth of 640 m exhibited factors of safety greater than one at the midpoint of the roof span, indicating a lack of potential for bed separation. The presence of the anhydrite layer at this depth undoubtedly contributed to the stability of the roof. The candidate mining horizon at a depth of 640 m appears to be the most favorable from the viewpoint of structural stability. It should be noted, however, that neither of the two room-and-pillar geometries appear to give rise to pillar instability in any of the three horizons.

Factor of safety contours were also computed for the salt around the canister drillholes in the floor of a 9.1 m wide room at a depth of 640 m. The 51 cm diameter drillholes are situated on 1.2 m centers in a square grid pattern in the floor of a disposal room. A factor of safety of one or less was not observed for either room-and-pillar geometry at any of the three candidate horizon depths, for a situation of in-plane loading. Based on previous viscoelastic (creep) closure calculations of canister emplacement drillholes in salt, a creep closure of approximately 13 cm after 20 years is expected in the whole canister emplacement drillholes. A similar analysis of the offset pattern of drillholes indicated only a small increase in effective stress over the square drillhole pattern.

FIG. 7 — FACTOR OF SAFETY CONTOURS AROUND A DISPOSAL ROOM IN SALT AT A DEPTH OF 640 m FOR AN EXTRACTION RATIO OF 30% (5)



6. EVALUATION OF EXCAVATION/HAULAGE SYSTEMS

With regard to excavation, two systems were analyzed on the basis of a disposal room width of 9.1 m, excavations of 1.7 and 4.1 million metric tons of rock salt, a 24 year mine life, and haulage distances varying between 490 and 1675 m (6). The most common excavation system is conventional drilling and blasting. This system has the advantage of being flexible for simultaneously mining multiple headings, while requiring a relatively low initial investment. However, it is labor intensive, and it is sometimes difficult to control the overbreak in blasting.

The second excavation system considered the use of a continuous miner. The advantages of a drum-type miner or a boring-type miner are that the mining operation creates smooth and relatively undisturbed faces and manpower productivity is increased. The disadvantages are that a relatively high initial capital investment is required, little experience exists for mining of salt, and "double-benching" mining methods would be required. From the viewpoint of haulage systems for the excavated rock salt, load-haul-dump (LHD) units, trucks, and conveyors were all found to be applicable within the given parameters. Continuous haulage systems, composed of an extensible and fixed conveyor, can be joined to a continuous miner to form a completely mechanized system. For LHD unit and conveyor haulage, a feeder-breaker would be required for reducing the rock salt to a size small enough to be transferred on a conveyor belt.

For purposes of the computer simulation, consideration was given to four suites of equipment: (1) conventional mining with LHD and truck haulage; (2) conventional mining with LHD, feeder breaker and conveyor haulage; (3) continuous drum-type miner with continuous haulage (extensible and fixed conveyor); and, (4) continuous boring-type miner with continuous haulage (extensible and fixed conveyors). Power consumption, utilizing both diesel fuel and electricity, was analyzed for all suites of equipment. A continuous drum-type miner with continuous haulage and conventional mining with LHD haulage were the least expensive power consumers. Conversely, the most expensive power consumption was achieved by the continuous boring-type miner with continuous haulage.

The manpower requirements vary from a minimum of eight people per shift at the lower limit of the excavation requirement, to a maximum of 22 people per shift at the upper limit. Production per man-shift varies from approximately 36 metric tons per man shift for a conventional mining system, with LHD and truck haulage, up to a potential of approximately 70 tons per man shift for a continuous boring-type miner with conveyor haulage.

By assuming a 6% rate of inflation and a mining operation beginning in 1979, a total cost for the excavation/haulage system can be determined over the life of the mine. Various excavation rates and numbers of shifts per day of operations make the mine life different for each set of equipment. According to Table 3, for an upper limit repository excavation of 4.1 million metric tons, the continuous drum-type miner with continuous haulage would require the least total cash outlay. It should be noted that such factors as extensive roof bolting, an increased rate of inflation, and restrictive federal, state and local regulations could alter these cost estimates over the next 25 years.

TABLE 3

REPOSITORY EXCAVATION AND HAULAGE COSTS FOR THE
THE UPPER LIMIT EXCAVATION OF 4.1 MILLION METRIC TONS (6)

MINING METHOD	COST BASIS	TOTAL COSTS	TOTAL COST PER METRIC TON	OPERATING COST PER METRIC TON
1. CONVENTIONAL/ LHD - TRUCK HAULAGE	1975 U.S.A. DOLLARS 14 YEAR MINE LIFE* TO BEGIN IN 1979	$16,020,000 30,450,000	$3.91 7.40	$2.97 5.63
2. CONVENTIONAL/ LHD - FEEDER BREAKER - CONVEYOR HAULAGE	1975 U.S.A. DOLLARS 19 YEAR MINE LIFE* TO BEGIN IN 1979	11,090,000 29,125,000	3.21 7.13	2.41 5.19
3. CONTINUOUS DRUM-TYPE MINER/CONTINUOUS HAULAGE	1975 U.S.A. DOLLARS 15 YEAR MINE LIFE* TO BEGIN IN 1979	13,230,000 25,925,000	3.24 6.35	2.26 4.62
4. CONTINUOUS BORING-TYPE MINER/CONTINUOUS HAULAGE	1975 U.S.A. DOLLARS 14 YEAR MINE LIFE* TO BEGIN IN 1979	17,550,000 33,180,000	4.30 8.18	3.13 5.94

NOTE: *1979 U.S.A. DOLLARS WITH 6% RATE OF INFLATION
MINING METHODS 1 AND 3 ARE TWO SHIFTS PER DAY OPERATIONS
MINING METHODS 2 AND 4 ARE [illegible] SHIFT PER DAY OPERATIONS

7. ANALYSIS OF TECHNIQUES AND EQUIPMENT FOR DRILLING CANISTER EMPLACEMENT HOLES

The objective of this aspect of the study was to review the availability of techniques and equipment for drilling canister emplacement holes in the floors of the disposal room (7). Only two representative drilling machines were determined to be worthy of extensive evaluation in light of the drilling task conditions. In particular, drilling holes with diameters upwards to 75 cm and depths to 9 m in a room with a height of approximately 5 m is an unusual task.

The machines selected for the computer simulation were the Calweld Model 150B rotary [illegible] (mounted on [illegible]) and the Model [illegible] core drill (skid mounted). Employing data supplied by the manufacturer and estimated by personnel [illegible] for such items as set-up time, steel addition/subtraction time, etc., a series of drilling cycle simulations was performed in conjunction with the repository facility layouts. The simulation results presented in Table 4 indicate drilling costs of the order of $22 to $50 per [illegible]. With reference to the upper and lower limits of repository size in terms of number of canister emplacement drill holes required, the total cost ranged between 3 million and 32 million dollars. It was finally concluded that none of the representative machines were ideally suited for the desired application and that it was doubtful whether a machine with the required capabilities would become available as standard equipment.

For the above reasons, the specifications for a conceptual machine were developed within the realm of state-of-art technology and subjected to a drilling cycle simulation (8). The conceptual drilling machine would conceivably be an electrical powered rotary drill, mounted on a crawler chassis and utilizing either a drag bit or a tricone pilot bit with a hole enlarger. The drill cuttings would be removed by air to a hopper or haulage machine and a mechanized drill steel addition/subtraction system would be included. The machine would be stabilized by roof jacks. In addition, such features as a sound reducing, air-conditioned cab, dust control system, roof fall protector, and roll-over protector would be added. A penetration rate of 0.3 m/min was thought to be feasible with the conceptual machine. In general, many of the components of the machine were off-shelf items. The computer simulation demonstrated that the total cost of drilling the canister emplacement holes could be reduced by approximately 4 million dollars for the lower limit of repository size, and by approximately 15 million dollars for the upper limit. It was further demonstrated that for a penetration rate of less than 0.2 m/min a substantial cost savings could still be realized in comparison with the other two drilling [illegible]

TABLE 4

[illegible]

DRILLING TECHNIQUE	[illegible]	[illegible]	[illegible]	[illegible]
CARBIDE [illegible] ROLLER BITS, [illegible]	LOWER LIMIT	[illegible]	821.58	$ 6,239,000
	UPPER LIMIT	300.04	32.61	22,8[illegible]
DIAMOND BITS, CORE DRILLING AND REAMING	LOWER LIMIT	229.10	31.36	12,0[illegible]
	UPPER LIMIT	224.[illegible]	49.35	33,317,[illegible]
CONTINUOUS [illegible] DRILL, CRAWLER MOUNTED	LOWER LIMIT	67.24	11.65	4,315,[illegible]
	UPPER LIMIT	54.[illegible]	11.[illegible]	7,630,000

NOTE: LOWER LIMIT: 50,740 DRILLHOLES; 0.[illegible] METER DIAM. CANISTERS/ONE CANISTER PER HOLE

UPPER LIMIT: 141,435 DRILLHOLES; 0.25 METER DIAM. CANISTERS/ONE CANISTER PER HOLE

8. CONCLUDING REMARKS

This paper has dealt primarily with an analysis of certain design engineering aspects of a repository in salt for the disposal of packaged low-level solid waste and sealed metal canisters of spent-fuel cladding waste. The design of a comparable facility for the emplacement of heat-generating radioactive waste would be comparatively a much more difficult task. Inherently, due to the heat generation of the waste and the heat dissipation characteristics of a particular rock type, the number of canisters per disposal room would be considerably reduced. Some benefit may be gained by forced ventilation of the disposal room, but the air volume required and associated velocities may be prohibitive. Further, [illegible] in hard rock will be more difficult and more costly than indicated by the results of the present study. One may also consider a specialized canister-handling equipment during the emplacement process and potentially retrievability requirements.

(RST-0033) [illegible] 020

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