ORNL/SUB-4269/8

DESIGN ASPECTS OF THE ALPHA REPOSITORY:

I. PRELIMINARY RESULTS OF FACILITY LAYOUT, ROOM STABILITY, AND EQUIPMENT SELECTION EFFORTS

Summary Progress Report RSI-0024

Paul F. Gnirk
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April 14, 1975

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I. PRELIMINARY RESULTS OF FACILITY LAYOUT, ROOM STABILITY, AND EQUIPMENT SELECTION EFFORTS

Submitted To

Oak Ridge National Laboratory
Oak Ridge, Tennessee

operated by

Union Carbide Corporation
for the
U. S. Atomic Energy Commission

by

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RE/SPEC Inc.
Rapid City, South Dakota

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(RSI-0024)

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CHAPTER 1

SUMMARIZED DISCUSSION OF DESIGN OBJECTIVES AND ACHIEVEMENTS

by

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

1.1. Statement of Objectives

The overall objective of the total project as regards the underground facilities for the alpha waste repository have been divided into three main study tasks, which are:

(1) A preliminary Analysis of the Stability of a Mine Layout in Each of the Three Candidate Salt Horizons;

(2) An Analysis and Evaluation of the Method and Equipment for Drilling Canister Emplacement Holes;

(3) An Analysis and Evaluation of Various Methods for Excavating Storage Rooms, etc., and Transportation of Excavated Salt to the Hoist Facilities.

These study tasks were delineated by a letter and attachments from Dr. William C. McClain to Dr. Paul F. Gnirk, dated January 17, 1975. Work on the tasks was initiated on March 3, 1975.

The objective of this report is to summarize progress to date on the three study tasks. Detailed conclusions and recommendations will be presented in the final report to be prepared at the end of FY 1975.

1.2. Summary of Preliminary Achievements

1.2.1. Repository Layout

The size of the Alpha repository was found to be controlled by the canister emplacement. Five candidate repository layouts were designed and their sizes determined for four limiting cases of ten inch canisters, one or two canisters per emplacement hole, and 12 inch canisters, one or two canisters per emplacement hole. Camparisons of development, haulage, ventways, and total tonnage were then made for the five designs for the four limiting cases.

1.2.2. <u>Stability Analysis of Room and Pillar Geometry</u>

Two typical room-and-pillar excavation models were examined with the use of:

(1) a plane strain elastic Finite-Element analysis in which the mine opening was completely "mined out" in the sense that load redistribution did not occur due to plasticity or creep;

(2) an analytical solution which explained the bending stresses in the roof.

The models were considered to be isotropic and homogeneous, except at the 2,100 foot horizon at which a ten foot thick anhydrite layer was modeled in the roof.

The results of the analysis showed that the maximum stress concentration factors occured at the roof-rib intersection, except at the 2,700 foot horizon, where the maximum occurred at the midpoint of the rib. The finite element analysis indicated further that the tensile stresses occurred in the center of the roof in the models at the 2,100 and 2,700 foot horizons without bed separation. It was found that in each model examined small regions existed where the factors of safety were less than one. The 1,900 foot and 2,100 foot horizons had, for the most part, allowable stress states, whereas at the 2,700 foot horizon the factors of safety were much lower.

The analytical solution for roof stability showed that the tensile bending stresses in a two foot thick roof exceeded the tensile strength at the upper surface of the roof "beam" near the rib, at the 1,900 and 2,700 foot horizon the factors of safety were much lower.

1.2.3. <u>Drilling Equipment Analysis</u>

Large hole drilling in underground mines was found to be fairly uncommon.

A variety of surface equipment has been developed for large hole drilling, and it was found that some of this equipment could be modified to drill the canister emplacement holes. Fifteen major drill manufacturers have been contacted, with only four of these manufacturers having presented machinery which, in their opinion, would perform the drilling task. Two other manufacturers are still studying the task and have yet to establish if they have a machine which will be applicable.

1.2.4. Excavation / Haulage Systems Analysis

Equipment for the excavation/haulage systems will come from "off-the-shelf" items which are now in general use in mines throughout the United States. Both conventional and continuous mining systems are being studied for possible application in the repository. Manufacturers of continuous and conventional mining equipment have been contacted, with most manufacturers supplying information on equipment specifications. Possible combinations of equipment are being studied for optimization of mining methods.

1.2.5. Safety Aspects

The nature of the use of the repository, as opposed to a normal mining operation, presents an unusual safety problem. Ventilation and escape ways are the primary safety considerations analyzed in this report. The different repository designs have unique safety features, which are discussed more on a qualitative than a quantitative level. Generally speaking, the more intricate layouts with panels interconnected by sub-main haulage ways would be considered the safest, because of the multiple escape routes and shorter distance to the surface access shafts.

CHAPTER 2

GEOLOGICAL AND ROCK PROPERTIES ASPECTS OF THE REPOSITORY SITE

by

Paul F. Gnirk and Francis D. Hanson

2.1. Geological Aspects of the Repository Site

The candidate mining horizons for alpha repositories have been tentatively selected by personnel of ORNL at depths of 1,900, 2,100, and 2,700 feet in the massive salt formations underlying Eddy and Lea counties in New Mexico. Columnar sections from AEC Holes No. 7 and 8 at these depths are illustrated in Figure 2.1. In general, the salt at these depths is massive, with interbeds and stringers of shaly salt, shale, anhydrite, and polyhalite.

At a depth of approximately 1,900 feet, there exists at least ± 100 feet of massive salt, with interbeds and stringers of shaly salt, shale and polyhalite. Beds of massive anhydrite, with a thickness up to about 10 feet, are situated at depths of approximately 2,050 and 2,100 feet. Massive salt exists above, in between, and below these anhydrite beds, with occasional stringers and interbeds of polyhalite, shale, and anhydrite. At a depth of 2,700 feet, including ± 100 feet above and below, the massive salt contains occassional stringers and interbeds of anhydrite. Below 2,900 feet, the structure contains alternating beds of salt and anhydrite with increasing thicknesses of the anhydrite beds with increasing depth.

2.2. Rock Properties of the Three Candidate Horizons

Mechanical properties data for the site rock as obtained to date by means of unconfined compression and indirect tensile tests or drill core, is presented in Table 2.1 for a depth internal of 1,900 to 3,900 feet. The density data was obtained from compensated density logs for AEC Hole No. 7 and 8. The rock property data is minimal at present, and scattered throughout the columnar sections. However, certain strength and elastic moduli trends are indicated; viz.:

(1) The compressive and tensile strengths of rock salt increases with decreasing contained impurities; e.g.:

(a) Rock Salt, w/Clay: C_o = 1,375 psi, T_o = 175 to 185 psi (at a depth of 1,971 to 1,972 ft.)

(b) Rock Salt, w/Minor Polyhalite: C_o = 2,300 psi, T_o = 175 to 185 psi (at a depth of 1,915 to 1,916 ft.)

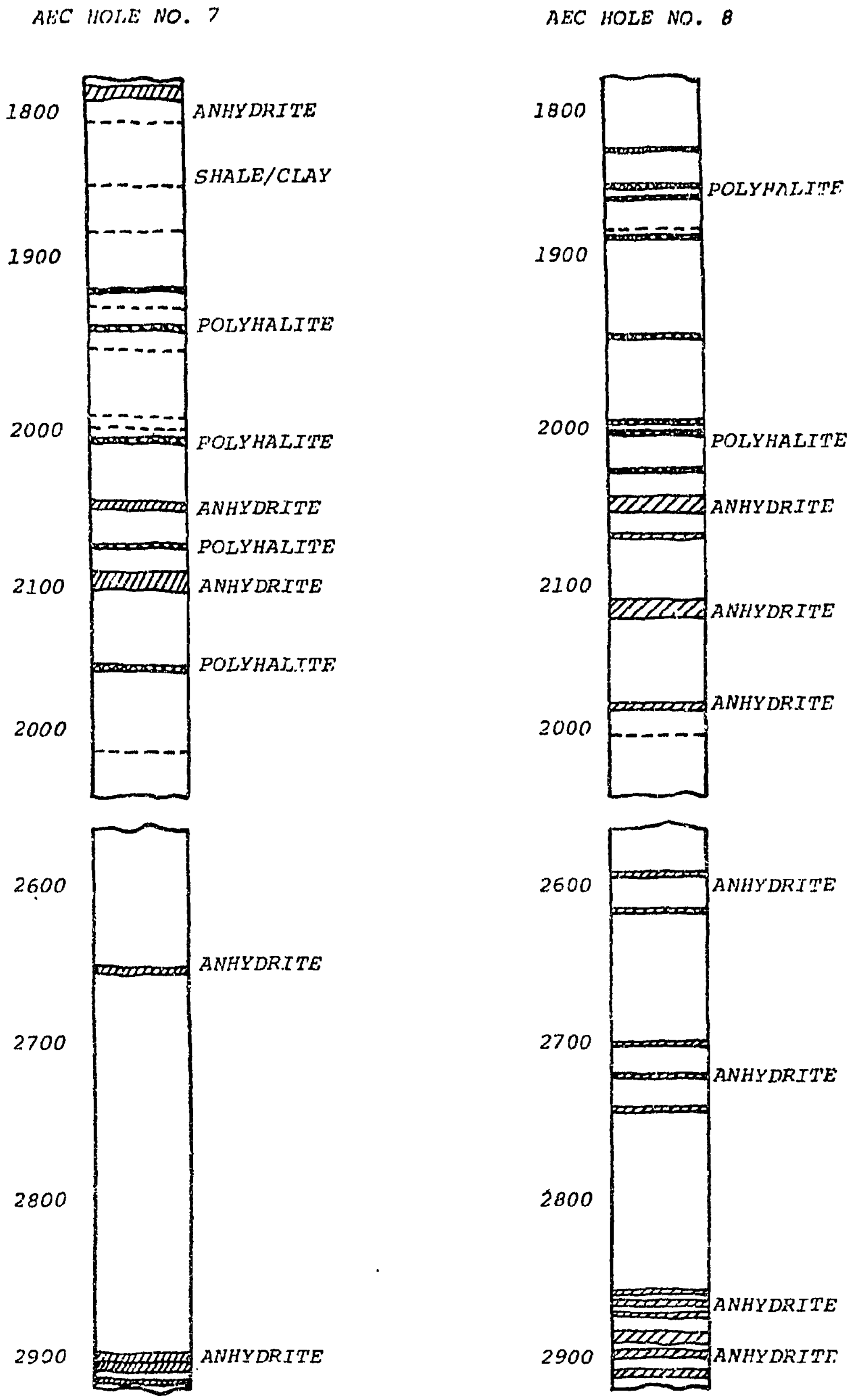
(c) Rock Salt: C_o = 3,050 psi, T_o = 250 psi (over depths of 2,706 to 2,796 ft.)

(2) The compressive strength of Polyhalite is of the order of 5,000 psi, and the tensile strength of the order of 500 psi (at a depth of 2,362 to 2,363 ft.)

(3) The compressive and tensile strengths of Anhydrite Rock and Anhydrite Rock, w/Halite range from 7,500 to 6,500 psi, and 550 to 750 psi, respectively (at depths of 2,552 and 2,049 ft.)

(4) The compressive and tensile strengths of Anhydrite Rock below 2,957 ft. are of the order of 13,500 psi and 835 psi, respectively.

In general, the modulus of elasticity for Rock Salt, with and without impurities, is of the order of 2,000,000 psi. However, Poissons' ratio appears to range from 0.28 to 0.48. The average modulus of elasticity for Anhydrite Rock is 10,000,000 psi, with an average Poisson's ratio of 0.36. Anhydrite Rock, w/Halite has a modulus of elasticity of the order of say 7,000,000 psi, and a Poisson's ratio of 0.33.



NOTE: Columner Sections are Salt unless otherwise indicated.

Figure 2.1. Columnar Sections Through Candidate Horizons for Repository.

TABLE 2.1

Mechanical and Physical Properties of Rock Strata at Repository Site

DEPTH (ft.)	CORE HOLE	MATERIAL	C_o (psi)	T_o (psi)	E (10^6psi)	ν	ρ
1,915	8	Rock Salt, w/Minor Polyhalite	2,475				2.09
1,916	8	Rock Salt, w/Minor Polyhalite		175			2.09
1,916	8	Rock Salt, w/Minor Polyhalite		185			2.09
1,935	8	Rock Salt, w/Minor Polyhalite	2,200		1.72	0.48	2.15
1,971	7	Rock Salt, w/clay	1,375				2.09
1,972	7	Rock Salt, w/clay		180			2.09
1,972	7	Rock Salt, w/clay		175			2.09
2,049	8	Anhydrite Rock, w/Halite	6,450		6.87	0.33	2.65
2,049	8	Anhydrite Rock, w/Halite		755			2.65
2,362	8	Polyhalite Rock	4,925				2.14
2,363	8	Polyhalite Rock		400			2.14
2,363	8	Polyhalite Rock		600			2.14
2,552	8	Anhydrite Rock		560			2.72
2,553	8	Anhydrite Rock	7,500		10.9	0.34	2.72
2,706	7	Rock Salt	3,650				2.09
2,706	7	Rock Salt		245	2.12	0.28	2.09
2,720	7	Rock Salt		280			2.12
2,720	8	Rock Salt		260			2.12
2,741	8	Rock Salt	3,200				
2,742	8	Rock Salt		220			2.13
2,742	8	Rock Salt		235			2.13
2,796	8	Rock Salt	2,300				2.13

TABLE 2.1

Continued

DEPTH (ft.)	CORE HOLE	MATERIAL	C_o (psi)	T_o (psi)	E (10^6psi)	ν	ρ
2,957	7	Anhydrite Rock		945			2.77
2,959	7	Anhydrite Rock		950			2.60
2,960	7	Anhydrite		951			2.48
3,007	8	Anhydrite Rock	13,925		9.36	0.39	2.99
3,019	8	Anhydrite Rock		780			2.60
3,019	8	Anhydrite	13,925		9.89	0.35	2.60
3,339	7	Anhydrite Rock	10,725		8.17	0.35	2.94
3,340	7	Anhydrite Rock		565			2.93
3,388	7	Anhydrite Rock		850			2.93
3,623	7	Anhydrite Rock		695			2.93
3,623	7	Anhydrite Rock		1,025			2.93
3,624	7	Anhydrite Rock	15,350		12.7	0.39	2.94
3,858	7	Anhydrite Rock		760			2.94

CHAPTER 3

PRELIMINARY MINE LAYOUTS

by

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

3.1. Introductory Remarks

Five repository layouts are presently being considered. In particular, these layouts are designated as:

(1) Linear
(2) Bow Tie
(3) Maltese Cross
(4) Snowflake
(5) Sash Window

These name designations were selected on the basis of the geometrical resemblence of a given layout to a physical item of familiarity; e.g., the linear repository design is established along a straight line, while the overall shape of the snowflake design resembles a hexagonal snowflake.

All repository layouts were developed on a building block principle, with the basic building block being the individaul room, as shown in Figure 3.1. The typical room for the purpose of initial calculations has a length of 300 ft., a width of 30 ft., and a height of 16 ft. By employing a square pattern for the canister emplacement holes, with a distance of 3 ft. between the rib and the center line of the outer hole and 4 ft. between adjacent holes, a total of 74 rows of holes with seven holes per row is obtained. This gives a total of 518 holes per room. In addition to the emplacement area, a 20 ft. wide x 16 ft. high x 20 ft. long entry to the main haulage way and a 15 ft. wide x 16 ft. high x 15 ft. long connector to the ventilation drift are included as an integral part of a typical room.

By use of the basic room dimensions, a typical panel layout is established. This panel then becomes the basic building block for all five repository layouts. This panel design is exemplified by Figure 3.2, and features a

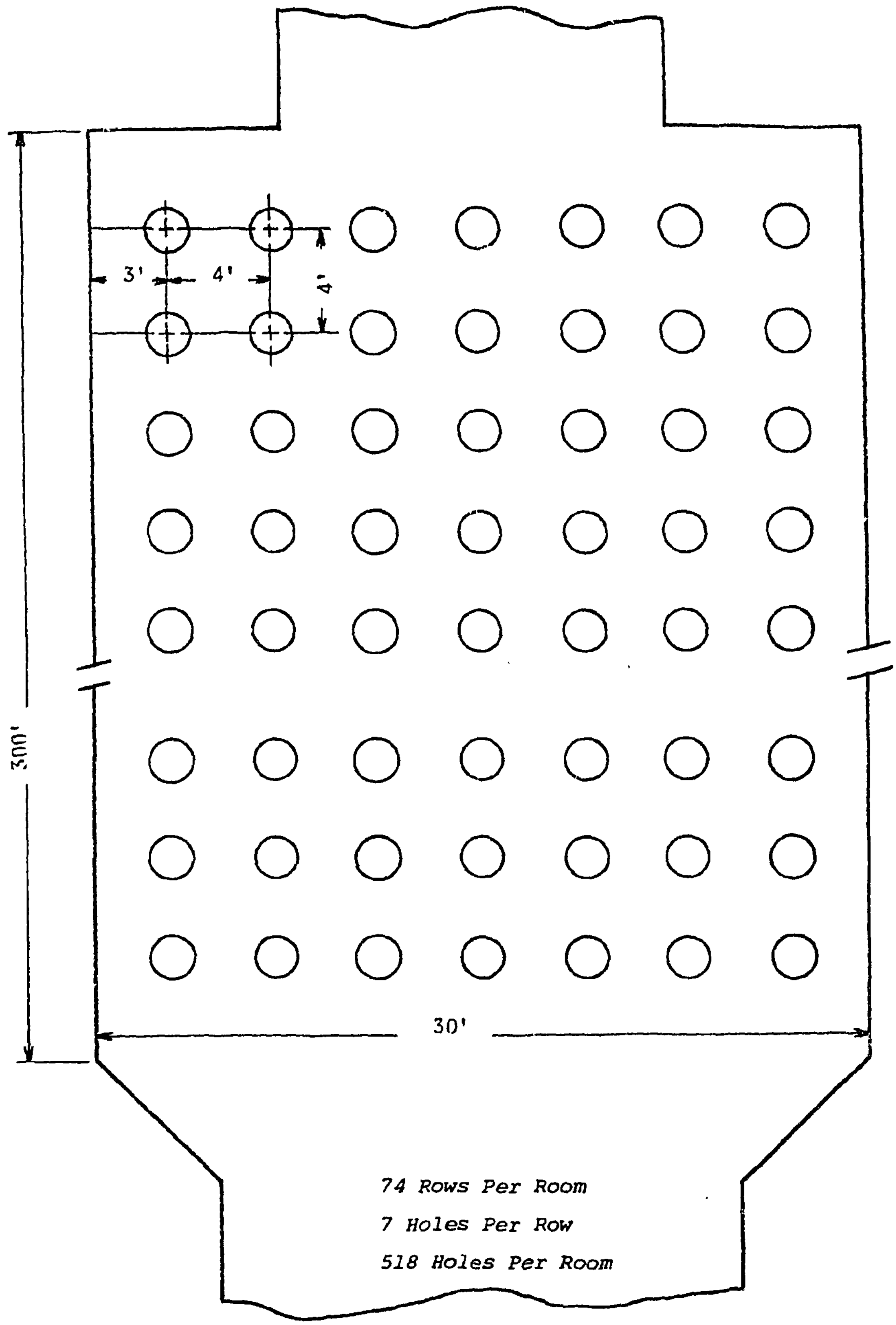


Figure 3.1. Typical Room

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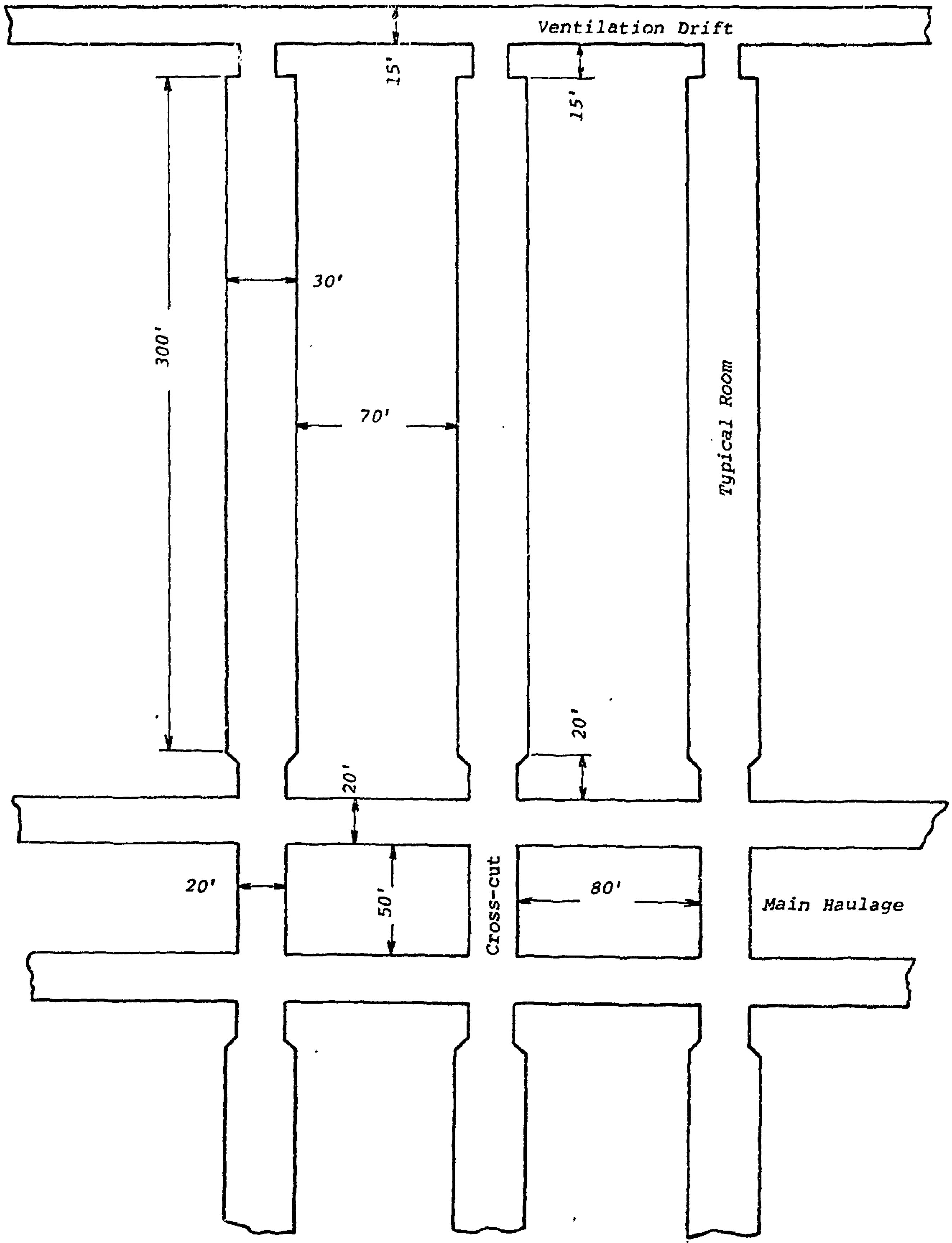

Figure 3.2. Typical Panel Layout

pillar width of 70 ft. between adjacent rooms.

The main haulage way for the panel is a double heading of 20 ft. wide x 16 ft. high drifts, with 20 ft. wide by 16 ft. high cross cuts every 100 ft. The headings are separated by a 50 ft. wide pillar. The rooms are arranged perpendicular to the main haulage and in line with the cross cuts.

The extent of the panel is determined by the individual repository layout. Other controlling factors are the number of canisters to be stored and the number of canisters which can be deposited in each hole. The layouts shown in this interim report are not drawn strictly to scale. In addition, the various shaft locations are illustrated, but the shaft bottom design are not detailed.

3.2 Presentation and Discussion of Proposed Mine Layouts

3.2.1. "Linear" Repository

The least complicated repository design is the Linear layout. This layout is shown by Figure 3.3. The Linear design has a single panel which is connected directly to the shaft facility has a single panel which is connected directly to the shaft facility by one long main haulage way. Ventilation is provided by a single ventilation shaft, located at the end of this panel.

The Linear repository can easily be increased in size by two procedures after production has been initiated. The first and simplest would be to increase the length of the rooms. The second would be to develop a second panel as a mirror image of the first; this would then be similar to the layout for the Bow Tie repository.

3.2.2. "Bow Tie" Repository

The Bow Tie, as shown by Figure 3.4., has two panels diametrically opposed about a centrally located shaft facility. Ventilation is provided by two ventilation shafts located at the ends of the panels which are furthermost from the central shaft facilities. In essence, the Bow Tie is the next extension of the Linear repository design with the second panel a mirror image of the first.

In order to increase the size of the Bow Tie Repository, after production has been initiated, the room length could be increased. The length of the second panel could be increased, if the panel were still under development. Also, two additional panels could be added at 90° to the original two.

3.2.3. "Maltese Cross" Repository

The Maltese Cross, as shown by Figure 3.5, has four panels connected by sub-main haulage drifts into a main haulage way. These panels are situated

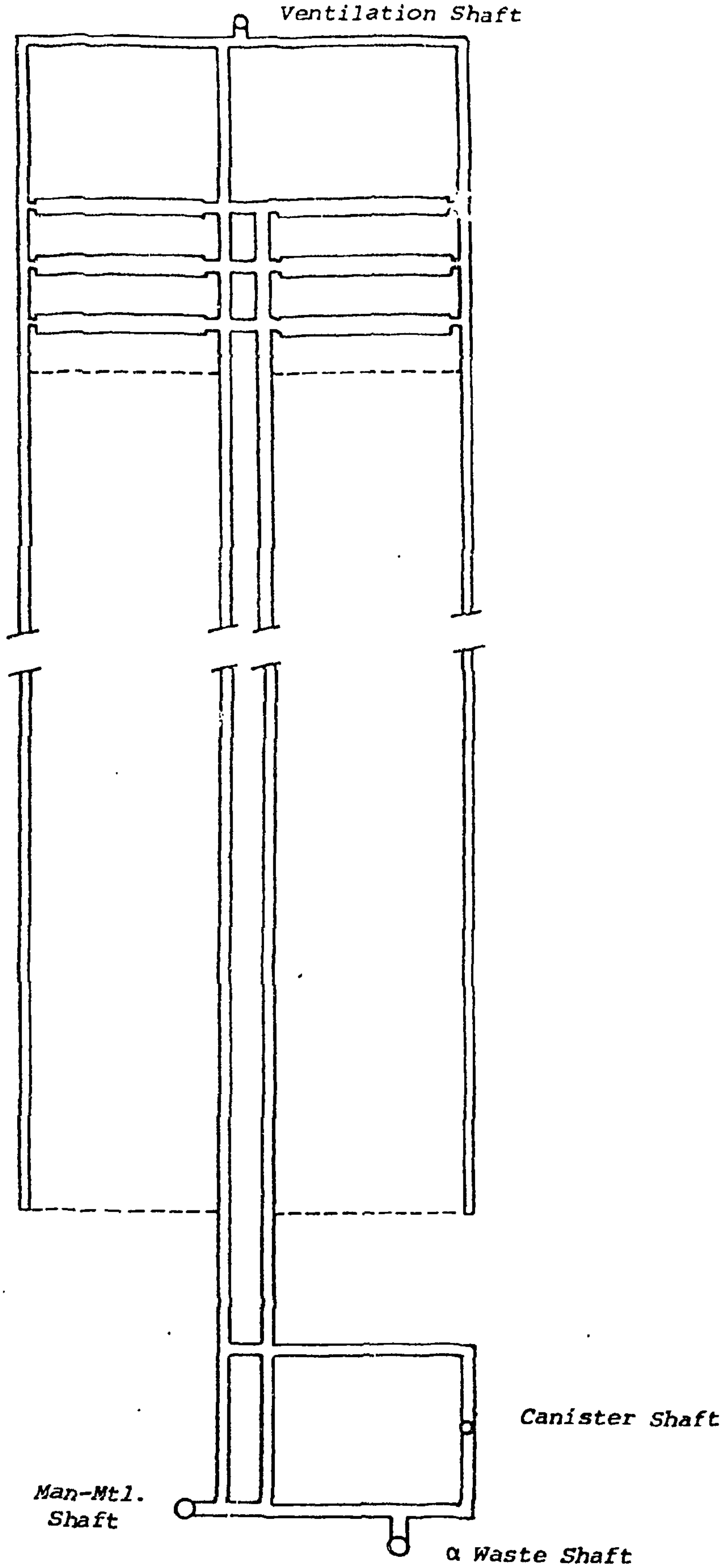

Figure 3.3. Linear Repository Layout

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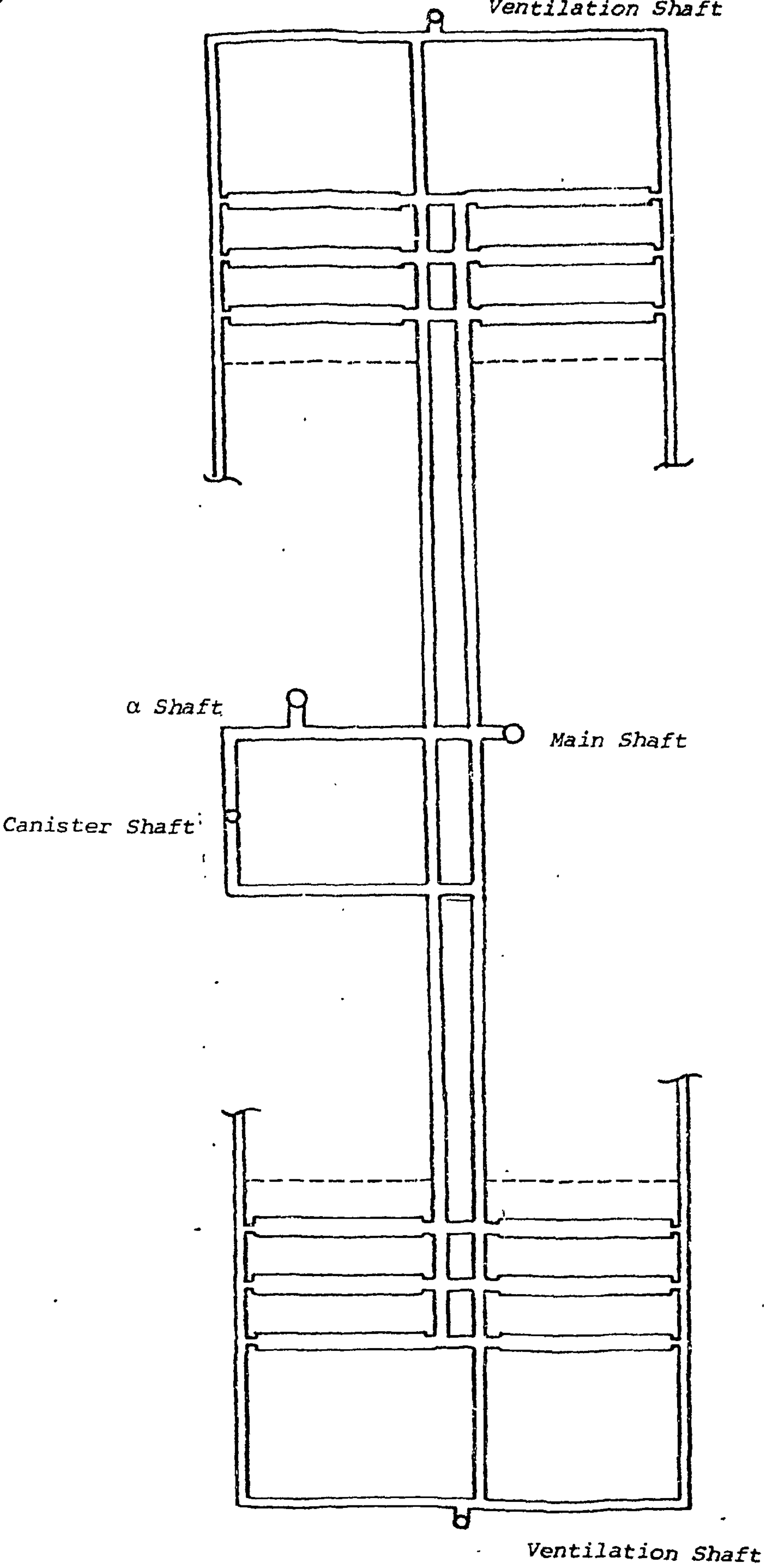

Figure 3.4. "Bow Tie" Repository Layout

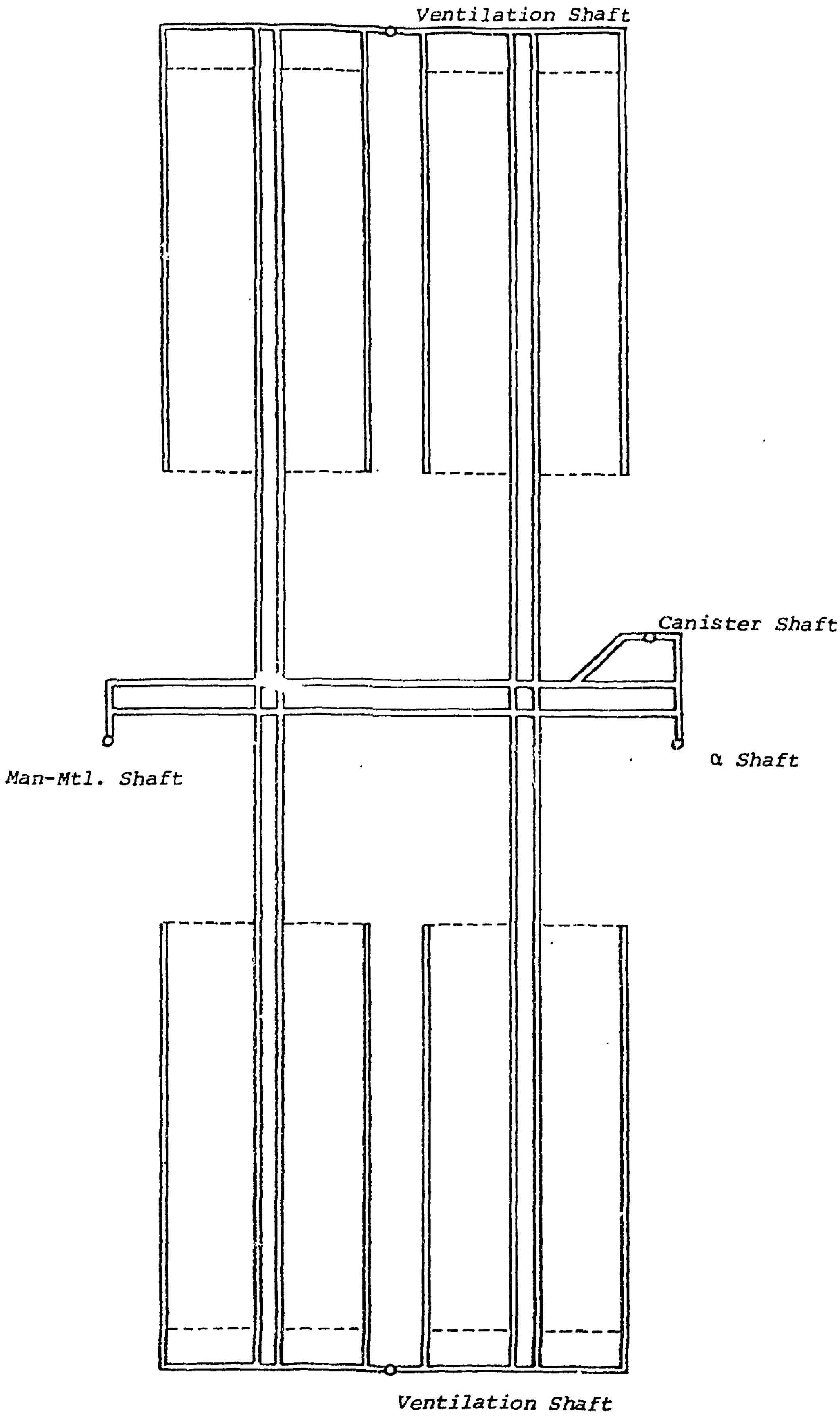

Figure 3.5. "Maltese Cross" Repository Layout

such that there are two opposing pairs of panels with the sub-main haulage drifts being in line. The main man-material-skip shaft is situated at one end of the main haulage, and the alpha waste and canister hoisting shaft situated at the other end. Ventilation is provided by two ventilation shafts, with each shaft providing ventilation for the panels situated on either side of the main haulage.

To increase the size of the Maltese Cross repository after production has been initiated, again, the room length could be increased. Also undeveloped panels could be increased in length. Additional panels can be added by extending the main haulage way in the direction away from the alpha waste and canister hoisting shafts, adding as many panels as are economically feasible.

3.2.4. "Snowflake" Repository

The Snowflake, as shown by Figure 3.6, is based on a hexagonal pattern, where five panels radiate outward from the man-material-skip shaft and the sixth portion is used to locate the alpha waste and canister hoist shafts. In addition to the main dual entry haulage ways, there is a hexagonal single heading which circumvents a central shaft in the shaft pillar. This heading would be used to provide a pathway for the waste emplacement, which is isolated from the salt haulage. A ventilation drift connecting the five panels at their apexes, with a single ventilation shaft midway between the first and second panel, provides the ventilation for the repository.

To increase the extent of the Snowflake repository after production has been initiated, the room length can be increased. Additional panels can be developed in the four triangular areas between the five original panels. Additional panels could be developed in the area adjacent to the alpha

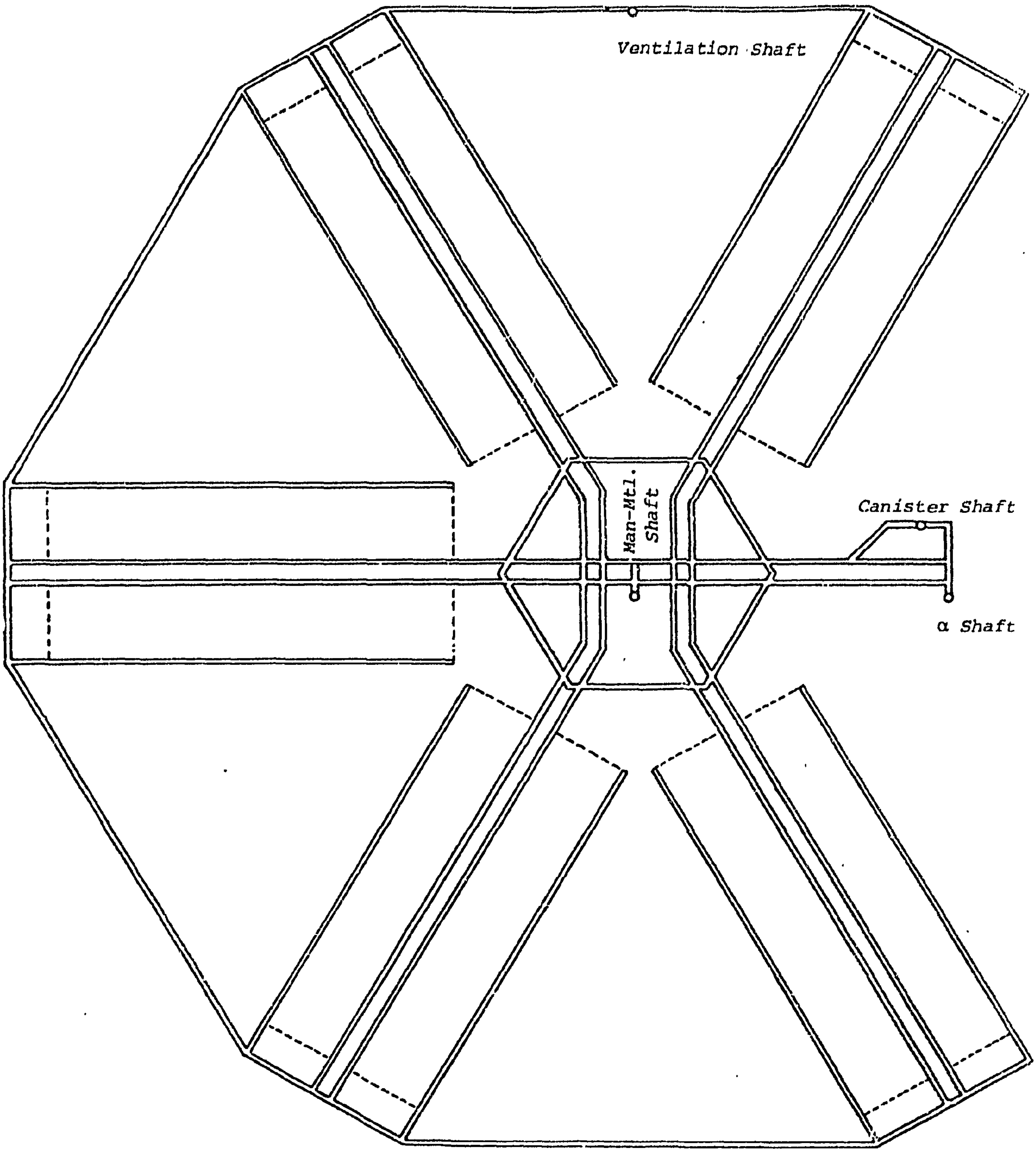

Figure 3.6. "Snowflake" Repository Layout

waste and canister hoisting facilities. Any undeveloped panel could be increased in size by simply extending its overall length.

3.2.5. "Sash Window" Repository

The Sash Window layout is shown in Figure 3.7 and features four panels connected by sub-main haulage drifts to a main haulage drift. The main haulage way is continuous past the centralized shaft facilities. There are four panels on either side of the shaft, arranged such that the sub-main haulage drifts of the opposing panels are in line and perpendicular to the main haulage. There are two ventilation drifts parallel to the main haulage with a centralized ventilation shaft on each ventilation drift. Thus, each ventilation shaft provides the ventilation for the four panels on its side of the main haulage.

To increase the extent of the Sash Window repository after production has started, the length of the rooms can be increased. The length of any undeveloped panel can also be increased. Additional panels can be added by extending the main haulage way and adding as many panels as are economically feasible.

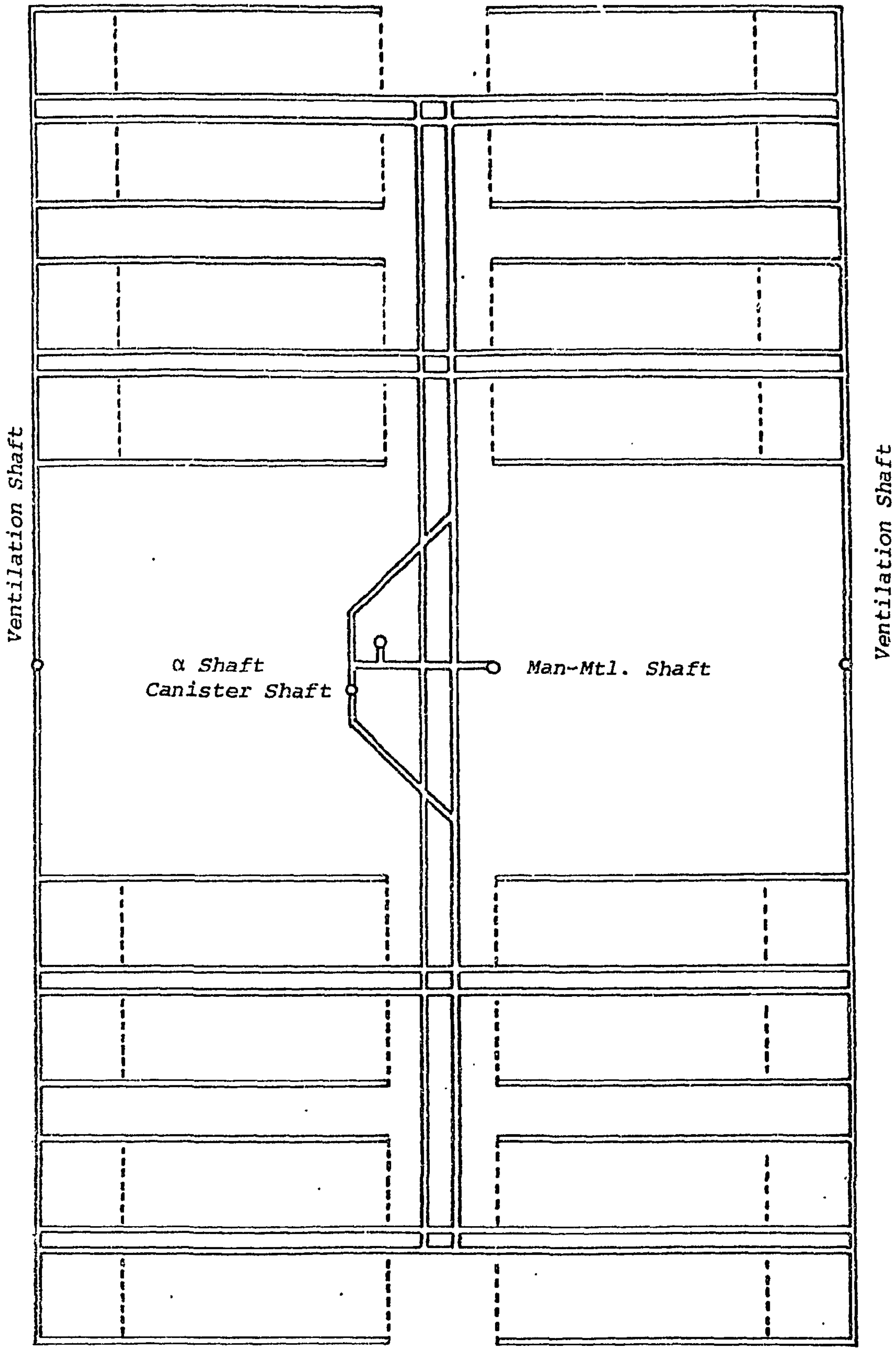

Figure 3.7. "Sash Window" Repository Layout

3.3. Summary of Development, Total Excavation, and Haulage Limits for Proposed Mine Layouts

3.3.1. Development Limits

The development required for any of the various repository designs is defined as that excavation, excluding shaft sinking, which is necessary to provide the first room for alpha waste and canister emplacement i.e., the minimum excavation required prior to the initiation of production in the sense of waste emplacement. There are two criteria which affect the amount of development for any particular design. The first criterion is the number of canisters which must be emplaced over the life of the facility. The difference in the total number of canisters is due to a variation in the diameters of the canisters, although the total amount of spent fuel cladding remains a constant. The second criterion is the number of canisters which can be emplaced in a given hole. With close packing, the alpha waste packages will fit into the smallest repository; hence, they do not become the limiting criterion for the size of the repository.

The following discussion of the development will cover these cases:

(1) Ten inch canisters: one canister per hole.
(2) Twelve inch canisters: one canister per hole.
(3) Ten inch canisters: two canisters per hole.
(4) Twelve inch canisters: two canisters per hole.

The first case, ten inch canisters with one canister per hole, gives the upper limit of the repository, and the last case, twelve inch canisters with two canisters per hole, gives the lower limit.

The development excavation was determined by calculating the linear feet of haulage heading, ventway, and a single room. These workings were then converted to the tonnages mined, using 135 pounds per cubic foot as the density of the material. Once these computations were completed, a percent of the total excavation for development was determined.

The development portions of the various repository designs, as opposed to the production excavations, are shown as the shaded regions in Figures 3.8., 3.9., 3.10., 3.11., and 3.12. These figures show the total extent of each repository layout, and relationship of the layout to the required development. Normal development would involve first sinking the production shaft, and then driving the development headings. During the development, one of the shafts, probably the alpha hoisting shaft, would be used as an upcast ventilation shaft. The double entry haulage drifts and breakthroughs at appropriate distances would provide adequate ventilation during development. Once a connection to the main ventilation shaft is made, temporary ventilation facilities at the development shaft can be removed and the primary ventilation used. No further ventilation facilities need be used in the linear repository, but additional, underground ventilation will be needed to open up the other panels in the remaining four repoisitory designs.

To enable a comparison of the development of the various repository designs, the following parameters were calculated:

(1) Linear feet of development haulage.
(2) Linear feet of ventway.
(3) Total development tonnage.
(4) Percent of total excavation for development.

These parameters were calculated for the four limiting cases of canister size and number of canisters emplaced per large hole. Tables 3.1, 3.2, 3.3, and 3.4 show the results of these calculations.

Figure 3.13 relates the development haulage ways for the four limiting cases for all repository designs. In all cases, the haulage way is longest for the limiting case of ten inch canisters, one canister per hole. The emplacement of twelve inch canisters, two canisters per hole, provided the shortest haulage development in all repository designs. The upper limit in

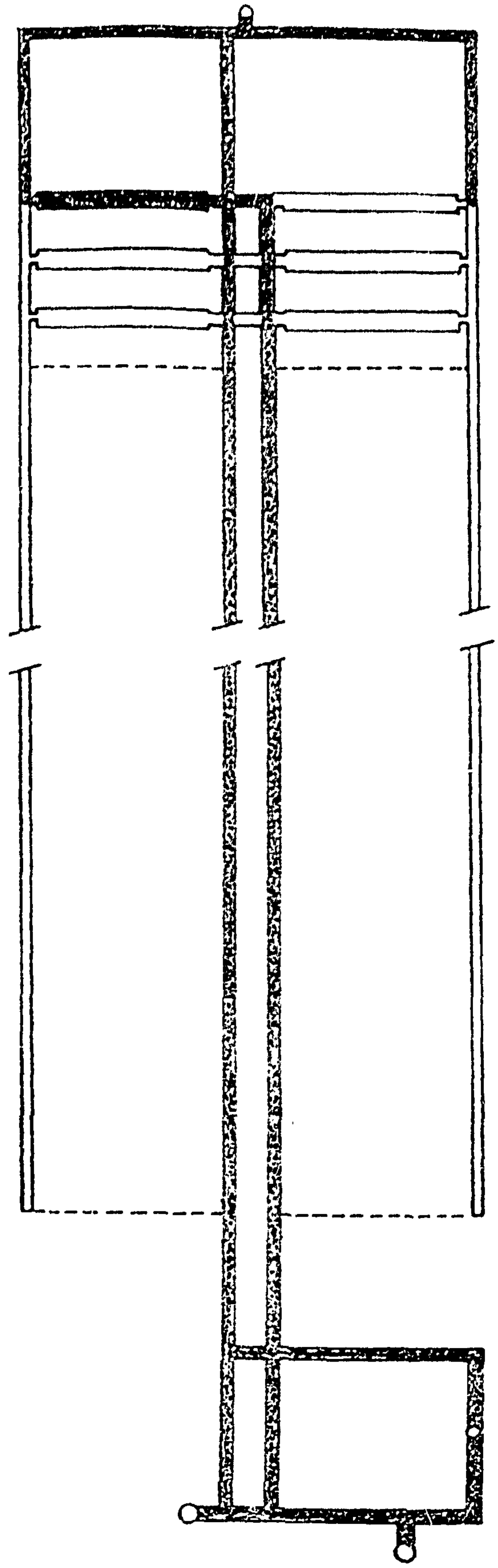

Figure 3.8. "Linear" Development (Shaded)

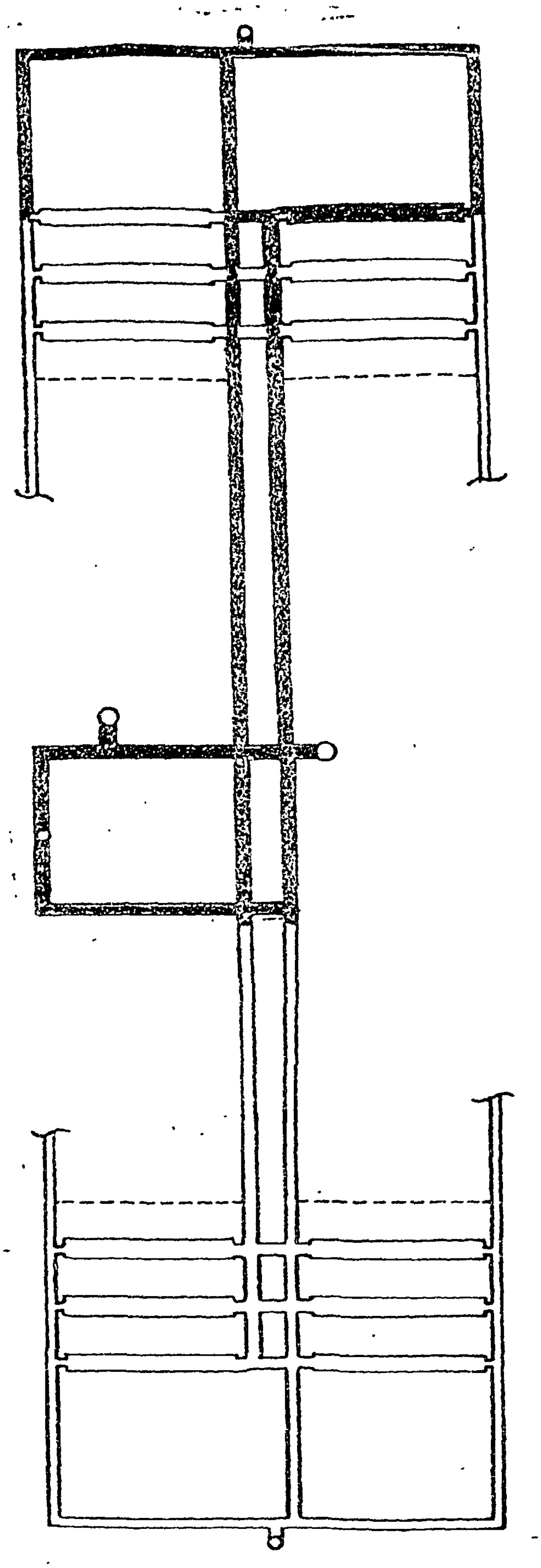

Figure 3.9. "Bow Tie" Development (Shaded)

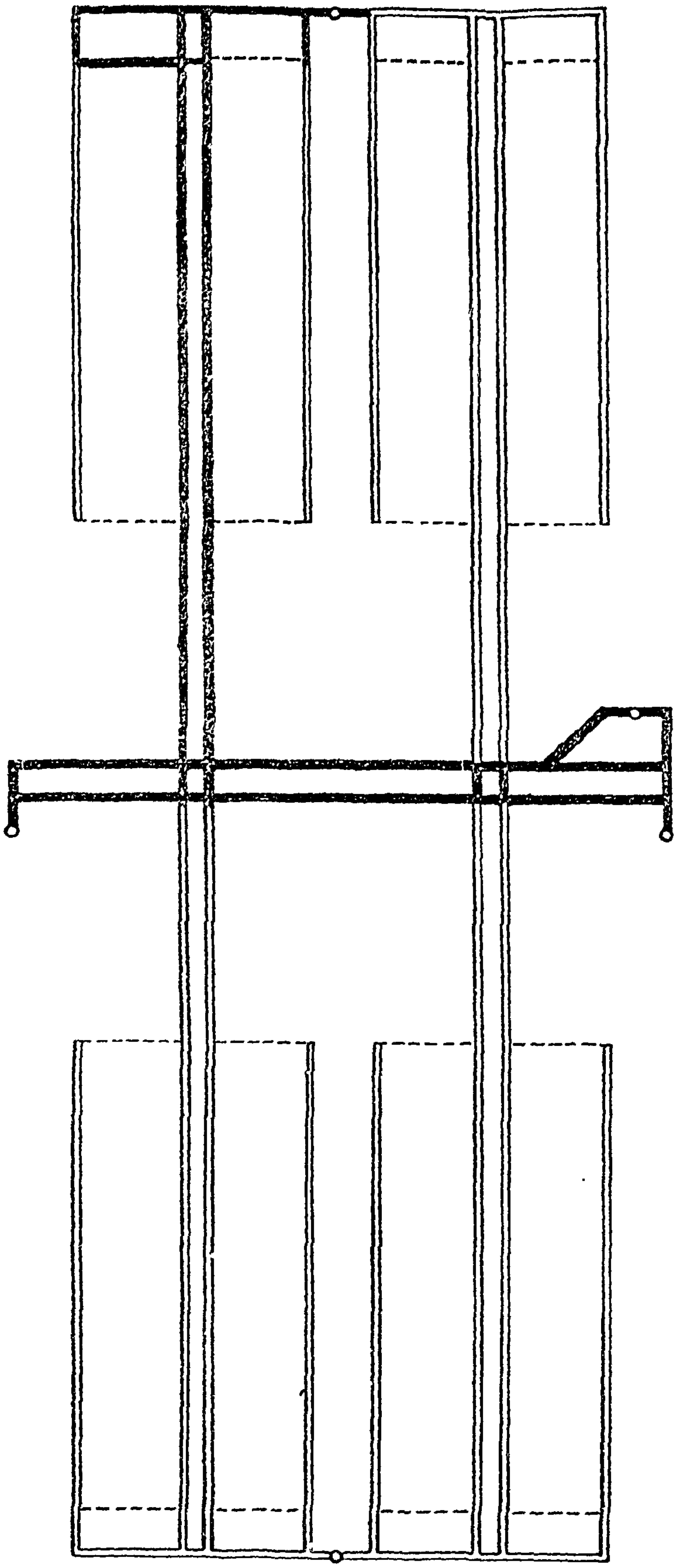

Figure 3.10. "Maltese Cross" Development (Shaded)

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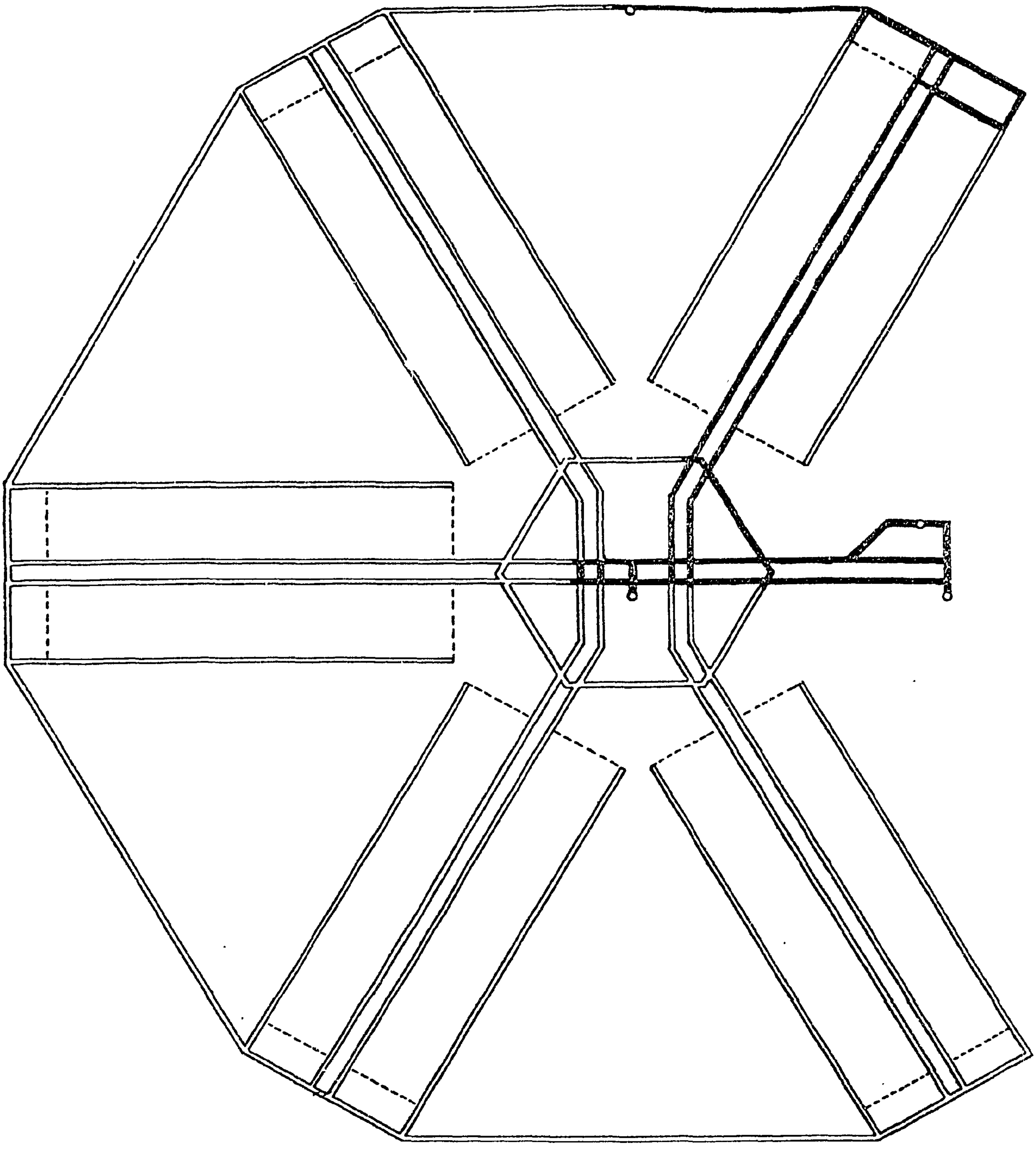

Figure 3.11. "Snowflake" Development (Shaded)

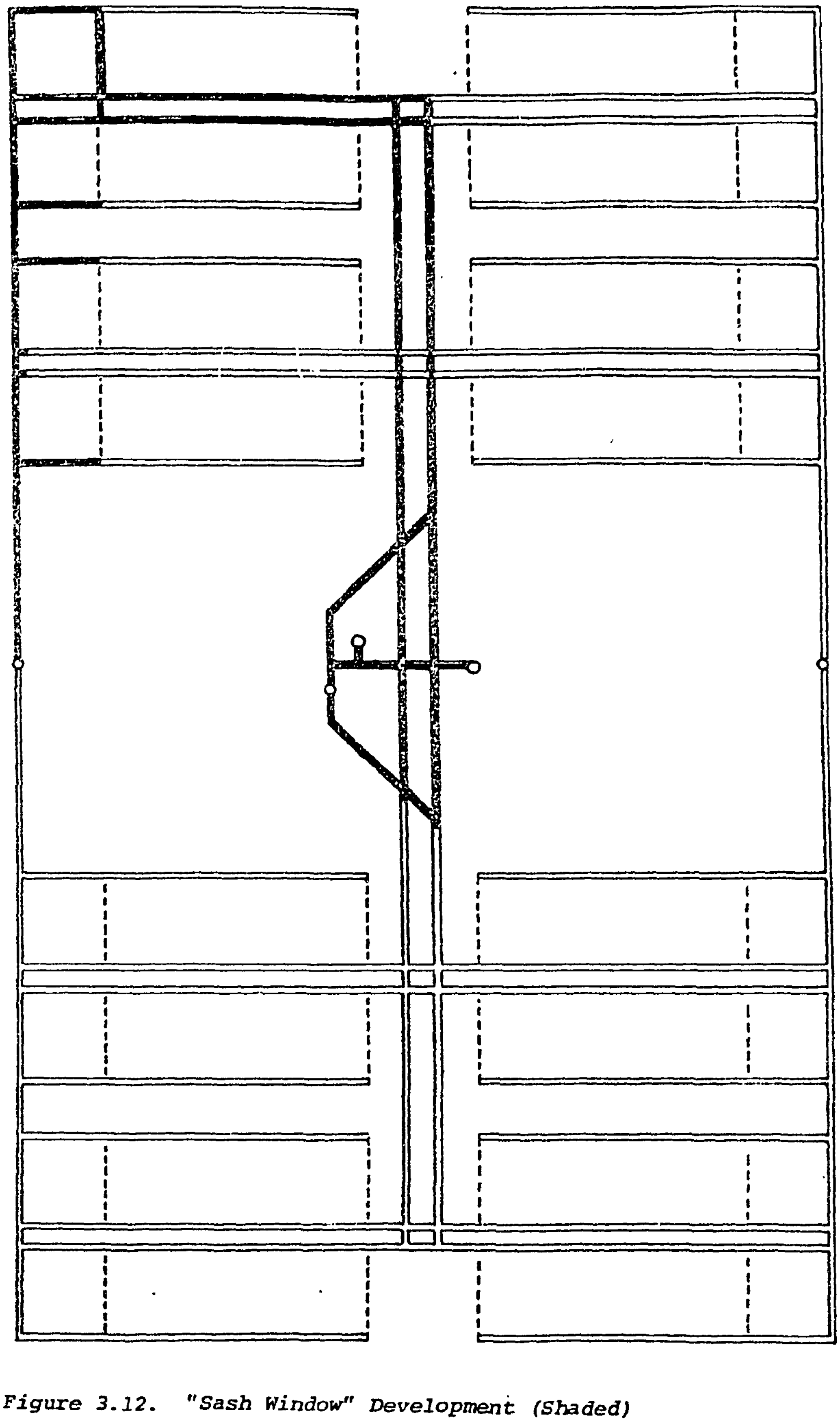

Figure 3.12. "Sash Window" Development (Shaded)

Table 3.1. Development Excavation Parameters for the Various Repository Designs for 10 inch Canisters with One Canister Per Emplacement Hole.

LAYOUT	HAULAGEWAY	VENTWAY	TOTAL TONS	% OF TOTAL EXCAVATION
Linear	30,500 ft.	1,100 ft.	687,182	16
Bow Tie	17,475 ft.	1,150 ft.	406,652	9
Maltese Cross	14,900 ft.	1,200 ft.	351,842	9
Snowflake	12,400 ft.	2,650 ft.	321,332	7
Sash Window	11,950 ft.	2,900 ft.	315,662	7

Table 3.2. Development Excavation Parameters for the Various Repository Designs for 12 inch Canisters with One Canister Per Emplacement Hole.

LAYOUT	HAULAGEWAY	VENTWAY	TOTAL TONS	% OF TOTAL EXCAVATION
Linear	22,500 ft.	1,100 ft.	514,382	17
Bow Tie	13,475 ft.	1,150 ft.	320,252	10
Maltese Cross	12,900 ft.	1,200 ft.	308,642	10
Snowflake	10,800 ft.	2,275 ft.	280,697	8
Sash Window	10,950 ft.	2,900 ft.	294,062	8

Table 3.3. Development Excavation Parameters for the Various Repository Designs for 10 inch Canisters with Two Canisters Per Emplacement Hole.

LAYOUT	HAULAGEWAY	VENTWAY	TOTAL TONS	% OF TOTAL EXCAVATION
Linear	16,500 ft.	1,100 ft.	384,782	18
Bow Tie	10,475 ft.	1,150 ft.	255,452	11
Maltese Cross	11,500 ft.	1,200 ft.	278,402	12
Snowflake	9,600 ft.	1,950 ft.	249,512	10
Sash Window	9,950 ft.	1,900 ft.	256,262	10

Table 3.4. Development Excavation Parameters for the Various Repository Designs for 12 inch Canisters With Two Canisters Per Emplacement Hole.

LAYOUT	HAULAGEWAY	VENTWAY	TOTAL TONS	% OF TOTAL EXCAVATION
Linear	12,500 ft.	1,100 ft.	298,382	19
Bow Tie	8,475 ft.	1,150 ft.	212,252	13
Maltese Cross	10,500 ft.	1,200 ft.	256,802	15
Snowflake	8,800 ft.	1,725 ft.	228,587	12
Sash Window	8,950 ft.	1,900 ft.	234,662	13

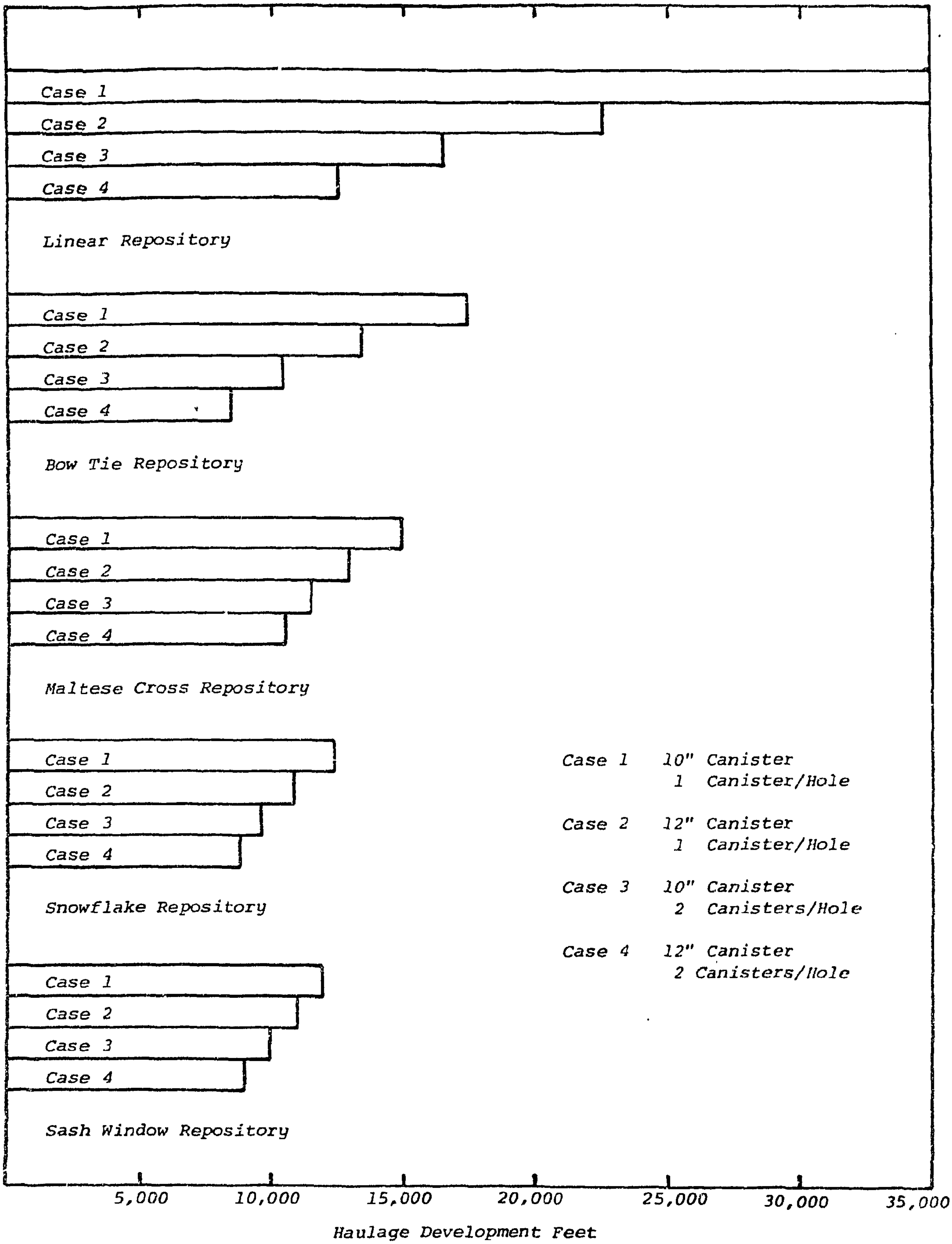

Figure 3.13. Development Haulageway Distances

development haulage was found to be the Linear repository, while the Bow Tie repository had the shortest possible development.

The lineal feet of ventway for development is shown in Figure 3.14. It is interesting to note that the amount of development ventway for the Linear, Bow Tie, and Maltese Cross designs are all approximately the same, and do not vary for the four limiting cases of canister size and number of canisters per emplacement holes. The Sash Window repository has the longest possible ventilation development, while the Snowflake repository is a very close second.

The total tonnage is probably the single most important parameter for development. This is graphically illustrated by Figure 3.15. The total tonnage is consistently largest in all repository designs for ten inch canisters, one canister per hole, with the lower limit being the twelve inch canisters, two canisters per hole. The upper limit for development is the Linear repository, while the smallest total development tonnage is the Bow Tie. Figure 3.15 shows that the development tonnage for the Linear repository is comparatively the largest, while the other four designs are approximately equal.

The percentage of development tonnage as compared to the total repository excavation is shown in Figure 3.16. When comparing these percentages to the total development tonnage, in general, one sees that the cases which have the largest development tonnage have the smallest total repository excavation tonnage. The Linear repository has the largest percentage of excavation for development, while the Sash Window repository has the smallest, with the Sash Window and Snowflake repositories being almost identical.

3.3.2. Excavation Limits

To compare the various repository designs, the following parameters

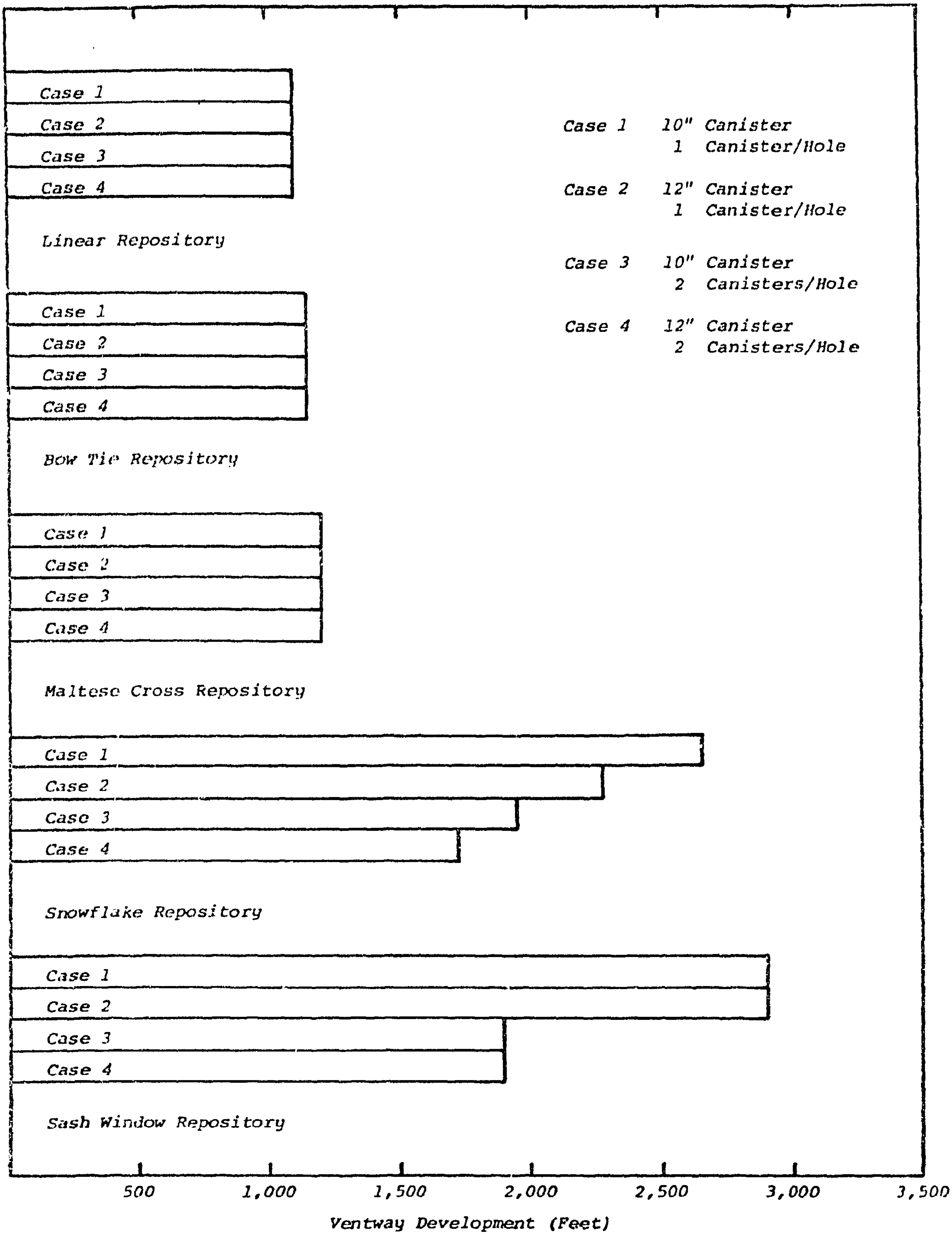

Figure 3.14. Development Ventway Distances

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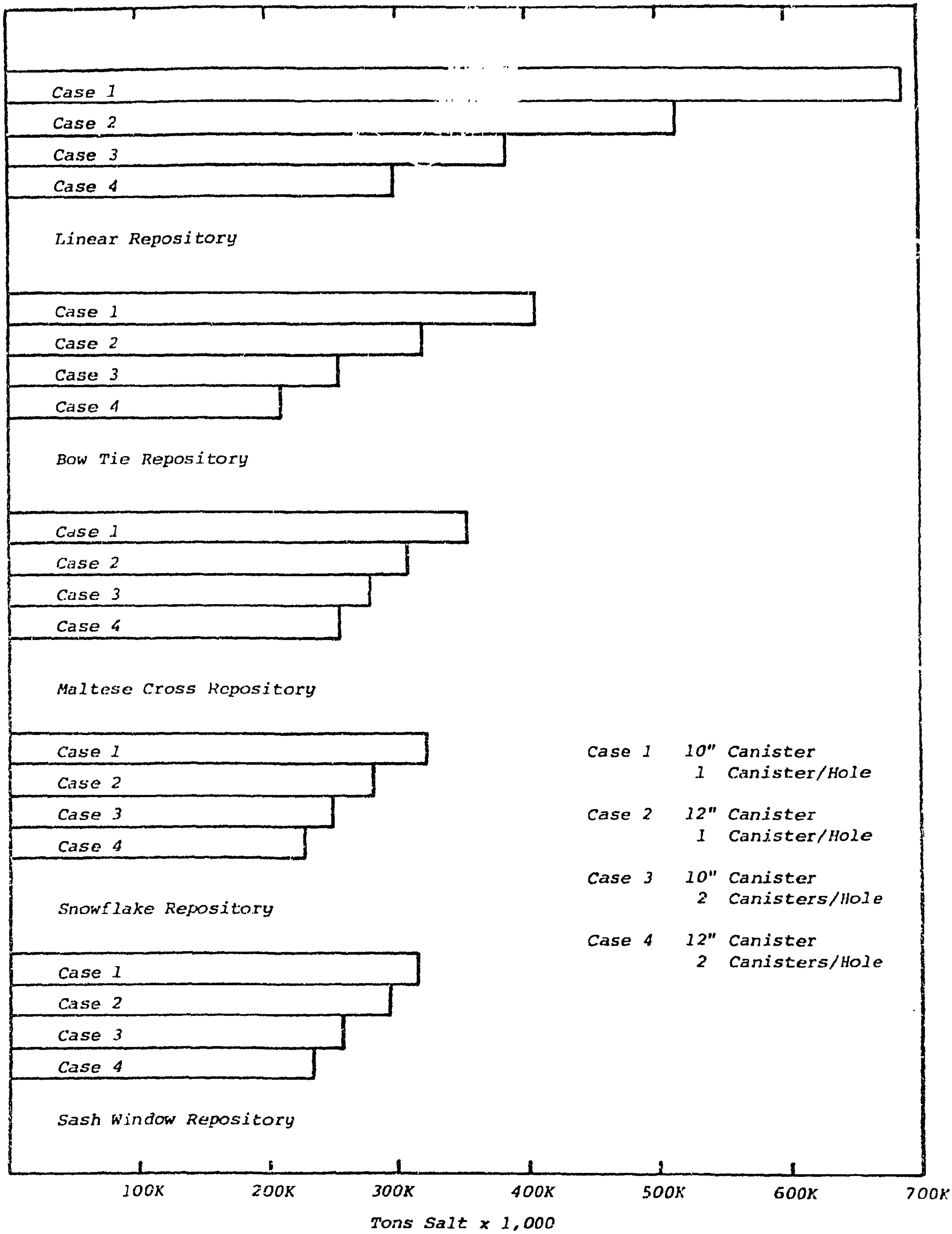

Figure 3.15. Development Tonnage

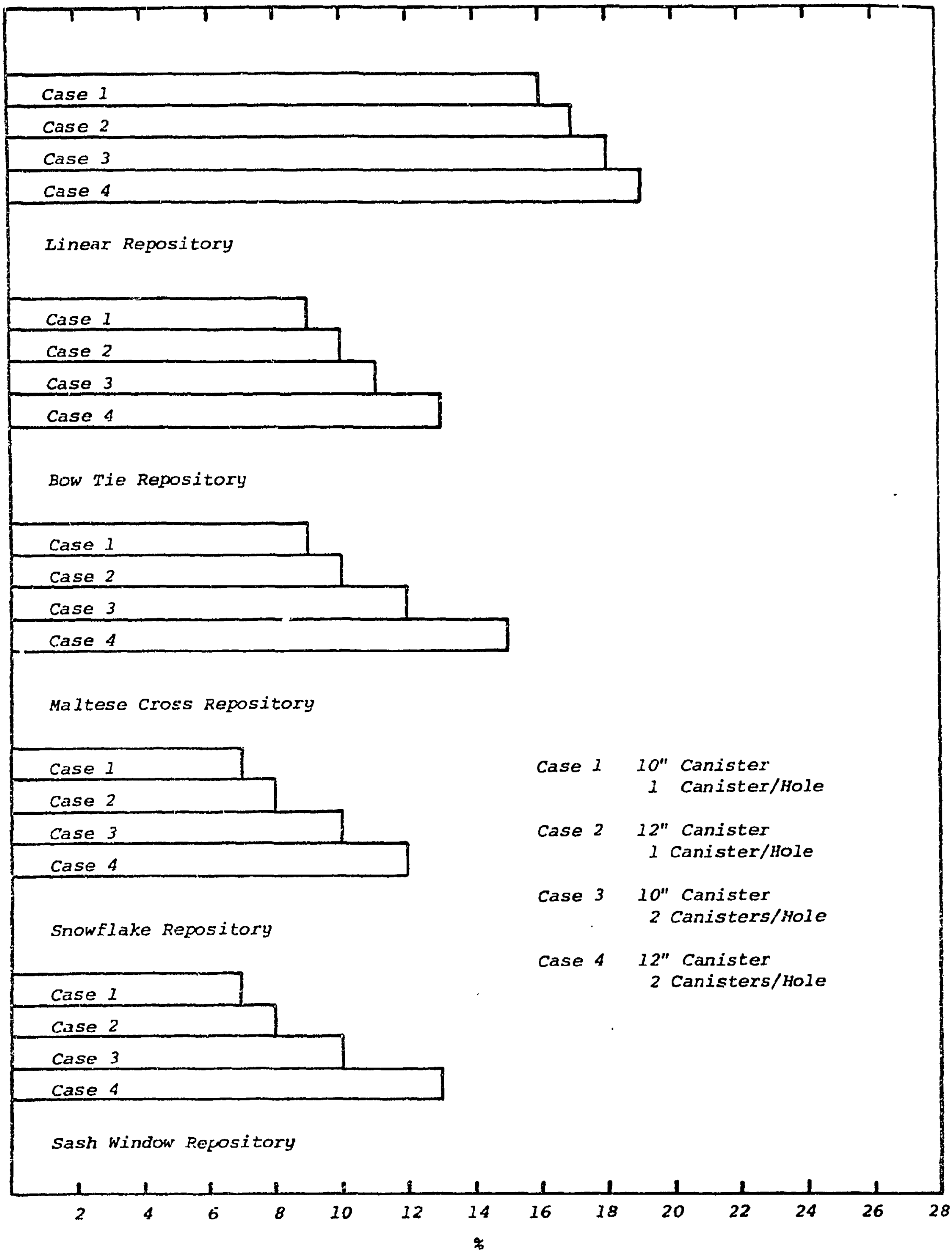

Figure 3.16. Development as a Percent of Total Extraction

were considered:

(1) Average room haulage
(2) Average foot-tons
(3) Ventway
(4) Haulageway
(5) Total tons
(6) Average tons/day

The average room haulage was computed by finding the center of each panel and computing the distance from this center to the main shaft. This distance plus half the length of a typical room averaged for all the panels gives a close approximation of the average room haulage. The average foot tons was computed for the rooms only, by calculating the total tonnage for the rooms and multiplying this by the average room haulage. The ventway is simply the total linear feet of ventilation drifts in the repository. Likewise, the haulageway is the total linear feet of main and sub-main haulageways in the repository. The total tonnage is the tons of material for excavation of rooms, haulage drifts and ventilation drifts. Given a twenty year mine life and 250 working days per year, the average tons per day is calculated directly from the total tons.

Tables 3.5, 3.6, 3.7, and 3.8 enumerate these parameters for the following four cases:

(1) 10 in. canisters, 1 canister per hole
(2) 12 in. canisters, 1 canister per hole
(3) 10 in. canisters, 2 canisters per hole
(4) 12 in. canisters, 2 canisters per hole

The calculations show the same trends for the above four cases as was found in the development sequence.

The average room haulage will give a reasonable comparison of overall haulage costs for the various repository layouts. Figure 3.17 shows the various average room haulage distances for any particular repository layout for the four canister size-canisters per hole study

Table 3.5. Total Repository Excavation Parameters for the Various Repository Designs for 10 inch Canisters with One Canister Per Emplacement Hole.

LAYOUT	AVG ROOM HAULAGE	AVG. FT-TONS	VENTWAY	HAULAGEWAY	TOTAL TONS	AVG TONS/ DAY
Linear	7,715 ft.	2.28×10^{10}	29,400 ft.	37,600 ft.	4.25×10^{6}	849.2
Bow Tie	4,400 ft.	1.31×10^{10}	30,800 ft.	39,760 ft.	4.32×10^{6}	863.0
Maltese Cross	3,965 ft.	1.17×10^{10}	16,600 ft.	41,750 ft.	4.13×10^{6}	825.6
Snowflake	2,465 ft.	7.29×10^{9}	45,400 ft.	43,475 ft.	4.63×10^{6}	926.4
Sash Window	2,965 ft.	9.02×10^{9}	41,600 ft.	52,700 ft.	4.85×10^{6}	970.8

Table 3.6. Total Repository Excavation Parameters for the Various Repository Designs for 12 inch Canisters with One Canister Per Emplacement Hole.

LAYOUT	AVG ROOM HAULAGE	AVG. FT-TONS	VENTWAY	HAULAGEWAY	TOTAL TONS	AVG TONS/ DAY
Linear	5,715 ft.	1.21×10^{10}	21,400 ft.	27,600 ft.	3.06×10^{6}	611.1
Bow Tie	3,440 ft.	7.26×10^{9}	22,800 ft.	29,760 ft.	3.12×10^{6}	624.9
Maltese Cross	3,465 ft.	7.32×10^{9}	12,600 ft.	33,750 ft.	3.05×10^{6}	609.1
Snowflake	2,065 ft.	4.36×10^{9}	34,400 ft.	35,475 ft.	3.44×10^{6}	687.2
Sash Window	2,715 ft.	5.96×10^{9}	33,600 ft.	42,700 ft.	3.66×10^{6}	732.7

Table 3.7. Total Repository Excavation Parameters for the Various Repository Designs for 10 inch Canisters with Two Canisters Per Emplacement Hole.

LAYOUT	AVG ROOM HAULAGE	AVG. FT-TONS	VENTWAY	HAULAGEWAY	TOTAL TONS	AVG TONS/ DAY
Linear	4,215 ft.	$6.23x10^9$	15,400 ft.	20,100 ft.	$2.16x10^6$	432.5
Bow Tie	2,690 ft.	$3.98x10^7$	16,800 ft.	22,260 ft.	$2.23x10^6$	446.3
Maltese Cross	3,115 ft.	$4.74x10^9$	9,800 ft.	28,150 ft.	$2.29x10^6$	457.6
Snowflake	1,765 ft.	$2.61x10^9$	25,800 ft.	29,475 ft.	$2.53x10^6$	496.9
Sash Window	2,315 ft.	$3.42x10^9$	22,000 ft.	27,900 ft.	$2.48x10^6$	496.9

Table 3.8. Total Repository Excavation Parameters for the Various Repository Designs for 12 inch Canisters with Two Canisters Per Emplacement Hole.

LAYOUT	AVG ROOM HAULAGE	AVG. FT-TONS	VENTWAY	HAULAGEWAY	TOTAL TONS	AVG TONS/ DAY
Linear	3,215 ft.	$3.40x10^9$	11,400 ft.	15,100 ft.	$1.53x10^6$	306.6
Bow Tie	2,190 ft.	$2.31x10^9$	12,800 ft.	17,260 ft.	$1.64x10^6$	327.3
Maltese Cross	2,615 ft.	$3.15x10^9$	7,800 ft.	24,750 ft.	$1.76x10^6$	351.9
Snowflake	1,565 ft.	$1.65.10^9$	20,000 ft.	25,475 ft.	$1.93x10^6$	386.1
Sash Window	2,065 ft.	$2.18x10^9$	18,000 ft.	22,900 ft.	$1.84x10^6$	368.5

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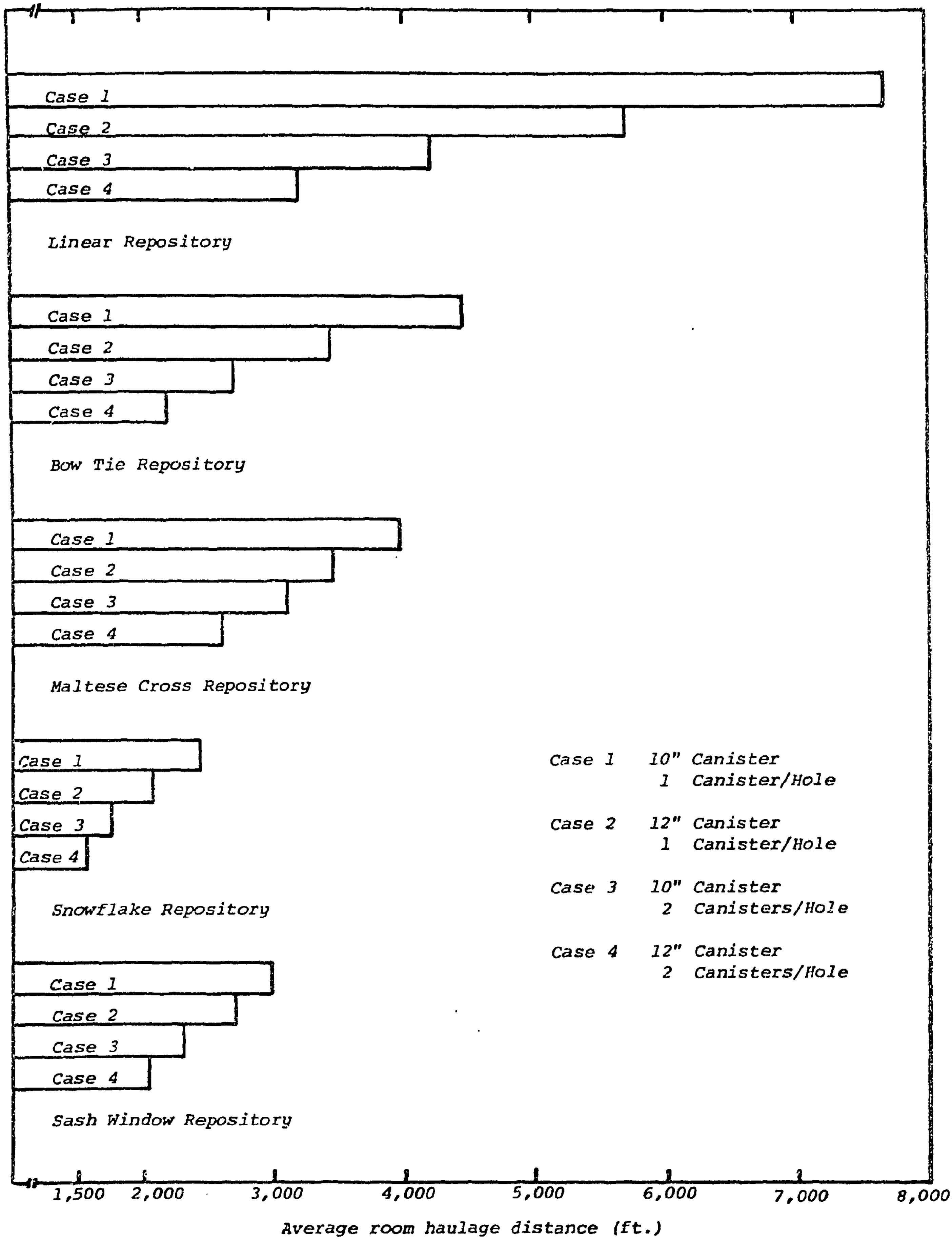

Figure 3.17. Average Room Haulage

cases. The Linear repository has the longest haulage distance for all cases and the Snowflake repository has the smallest. The Sash Window repository appears only slightly worse than the Snowflake repository as regards overall room haulage.

The result of the foot-tonnage calculation for the haulage of the salt removed from the rooms is very similar to the average room haulage distances. The largest value for the foot-tons figure was again the Linear repository, and the smallest was the Snowflake repository. The reason that the Snowflake repository is the best as regards haulage is that all five panels are equal distance from the shaft facilities.

Ventilation drifts and haulageways, along with the emplacement rooms, comprise the total excavation used in these calculations. The Snowflake repository has the largest amount of ventways, with the smallest amount of ventways being in the Maltese Cross repository. The Linear repository has the next smallest amount of ventways, and is very similar to the Maltese Cross repository. The Sash Window repository has the largest amount of haulageways, while the smallest amount of haulageways occurs in the Linear repository, even though it has the largest foot-ton figure.

The total tonnage, not including the amount of salt removed by the large hole drilling, for the various repository designs is shown in Figure 3.18. The total tonnage for all repositories is very similar, with the variation between the largest and smallest for any canister size-canister per hole case being about 17 percent. The range of tonnage per day is from a high of 970 tons per day for the Sash Window repository with 10 inch canisters, one canister per hole to a low of 307 tons per day for the Linear repository with 12 inch canisters, 2 canisters per hole.

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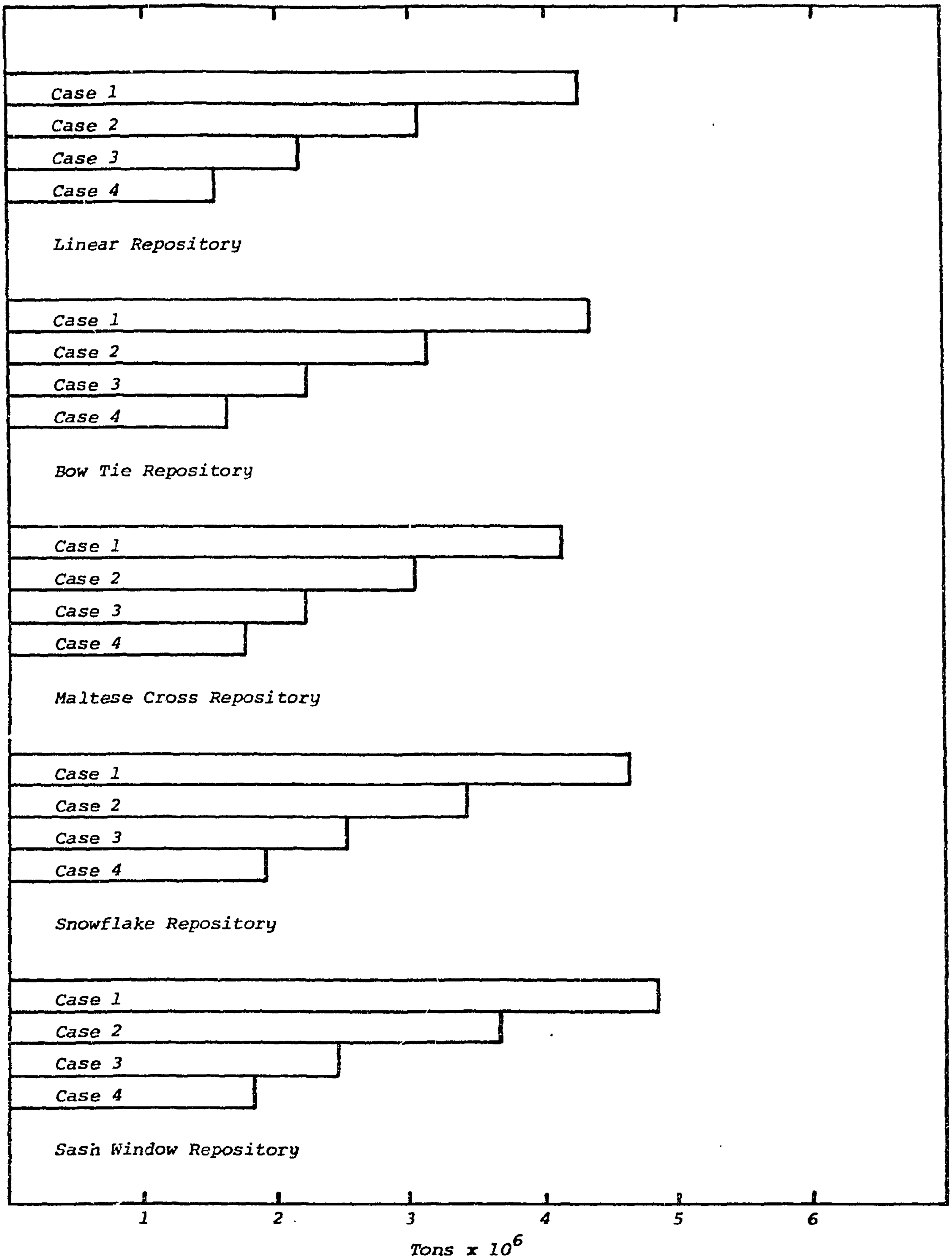

Figure 3.18. Total Tonnage

3.4. Generalized Ventilation and Safety Requirements

3.4.1. Discussion of Safety Requirements

The safety requirements discussed here are those pertaining to availability of access to safety shafts and escapeways if an area of the mine is contaminated by radioactive material. The only radioactive material which could be considered dangerous would be the canisters of spent fule cladding. The boxes of alpha waste are of low enough energy to be relatively harmless should a box be broken or accidently spilled. In all repository designs, the alpha waste shaft and canister hoisting shaft have upcase ventilation, whereby any contamination in the shafts or at the shaft station would be carried away from the bulk of the repository to the surface. Ventilation of the repositories has flow patterns going down the main shaft, out the main haulage, through the rooms, and into a ventilation drift whereby it goes up the main ventilation shaft to the surface. Since repository production mining, as opposed to development mining, would proceed from the furtherest extent fo a panel toward the main shaft, the alpha waste material and canisters would be emplaced at the same far ends of the panel first and progress toward the main shaft.

When the waste emplacement is completed in a room, the room would be sealed with permanent stoppings. This would create a dead aire condition in the room, thus containing any airborne radioactive material in this room. If a mishap occurred in a room while waste material was being emplaced, the ventilation path would take any airborne contaminates away from the main haulage into the ventilation drift. Thus any unsafe room would be essentially remote from any active mining and down stream of the major work force.

One other safety consideration is the escapeways and distances to the emergency shafts. These shafts are the main shaft, alpha waste shaft, and the main ventilation shaft. It may be necessary to provide auxiliary hoisting facilities for safety considerations.

3.4.2. Linear Repository Ventilation

Figure 3.19 shows the ventilation path for the Linear repository. This repository design is the simplest, with a single ventilation shafts, one for each panel. Safety wise, this repository would be safer than the Linear repository because the distances to the safety shafts would be approximately halved and there would be one more safety shaft.

3.4.3. Bow Tie Repository Ventilation

Figure 3.20 shows the ventilation path for the Bow Tie repository. The ventilation for this repository is controlled by two ventilation shafts, one for each panel. Safety wise, this repository would be safer than the Linear repository because the distances to the safety shafts would be approximately halved and there would be one more safety shaft.

3.4.4. Maltese Cross Repository Ventilation

Ventilation directions for the Maltese Cross repository are shown by Figure 3.21. The ventilation flow pattern is again down the main shaft, along the main haulage, through the rooms, into the ventilation drift, and up the ventilation shaft. The repository is divided into two ventilation sections each with its own ventilation shaft. Thus any malfunction of a main ventilation vent would not necessarily require the repository be shut down. The distances to the safety shafts are relatively short with possibilities of multiple escape paths to the emergency shafts. Additional safety is provided by the remote location of the alpha waste and canister hoisting shafts.

3.4.5. Snowflake Repository Ventilation

Ventilation for the Snowflake repository is shown by Figure 3.22.

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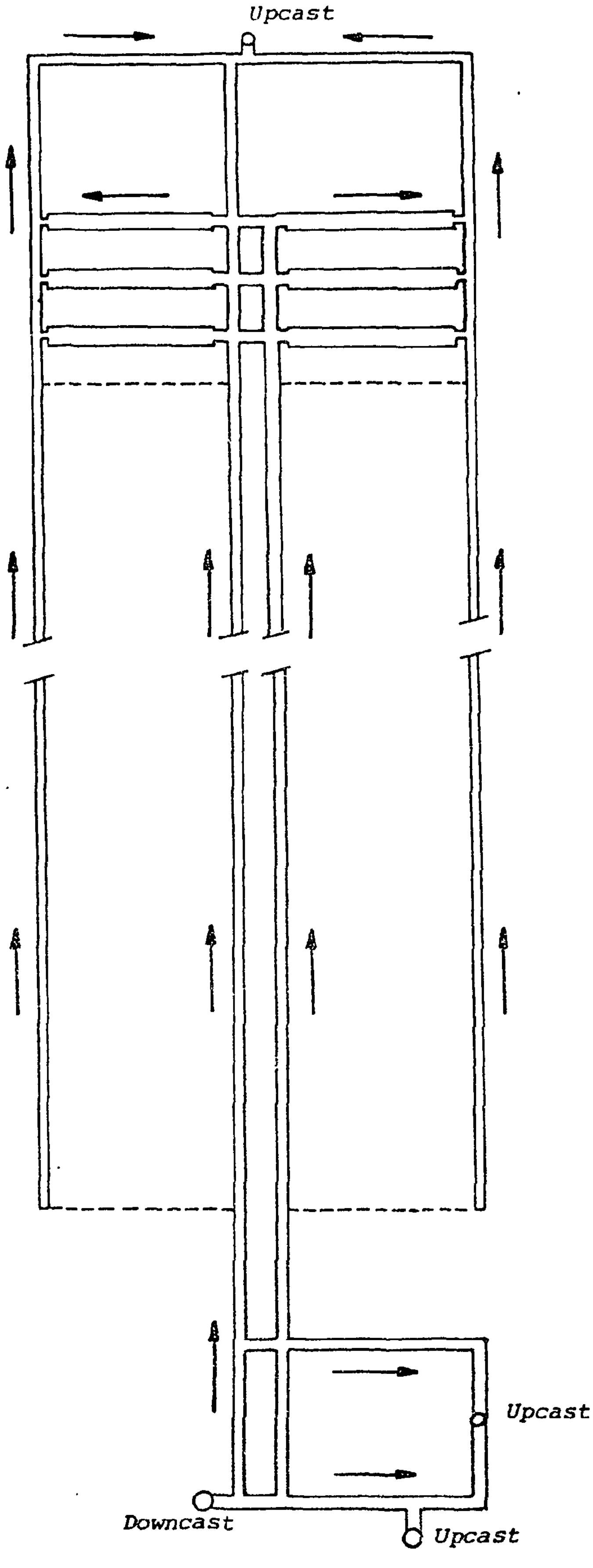

Figure 3.19. "Linear" Ventilation Directions

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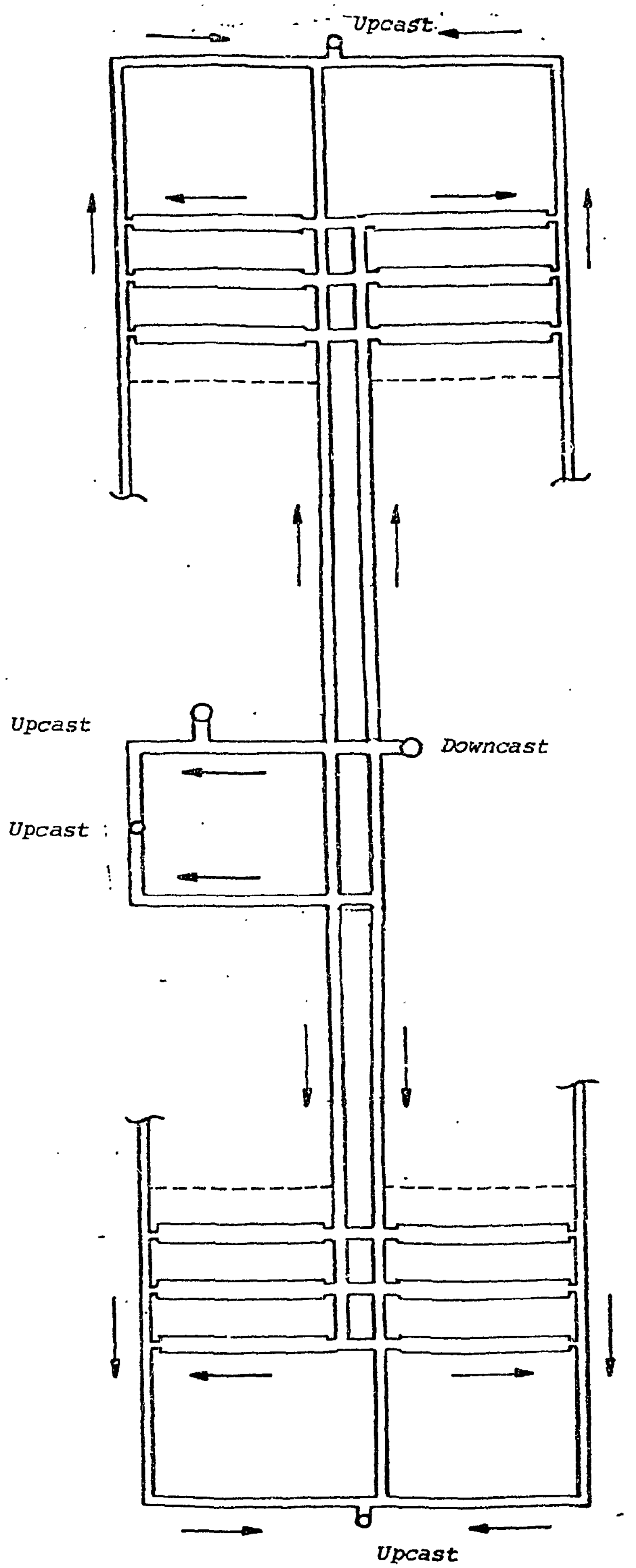

Figure 3.20. "Bow Tie" Ventilation Directions

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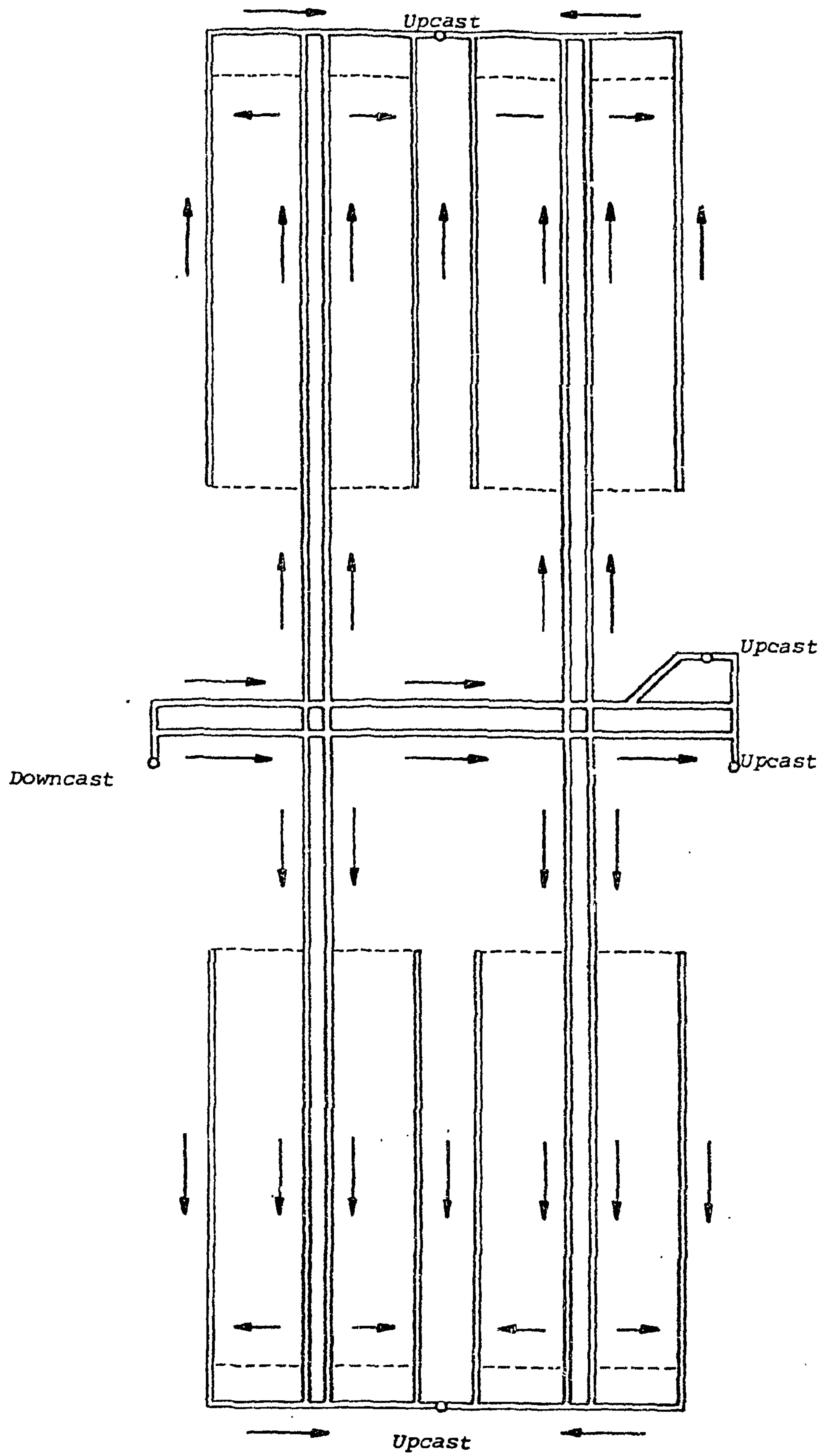

Figure 3.21. "Maltese Cross" Ventilation Directions

The ventilation is cOntrolled by a single ventilation shaft, but more ventilation shafts cna be sunk if the need arises. Ventilation drifts are the longest of any of the repository designs. This design is probably the safest due to the close proximity of all panels to the main shaft, and the relative isolation of the alpha waste hoisting shafts. The hexagonal access drift around the shaft pillar provides an additional safety benefit by allowing the waste haulage to bypass the main shaft facilities. Multiple escape paths are also present, although they may be extremely long is escape is accomplished through the ventilation drifts.

3.4.6. Sash Window Repository Ventilation

Ventilation for the Sash Window repository is shown by Figure 3.23. Two ventilation shafts divide the ventilation equally. Ventilation of the Sash Window repository is similar to that of the Maltese Cross repository. Safety considerations for this repository are almost as good as the Snowflake repository. The Snowflake repository is better only because of the isolation of waste haulage and the isolation of waste hoisting facilities.

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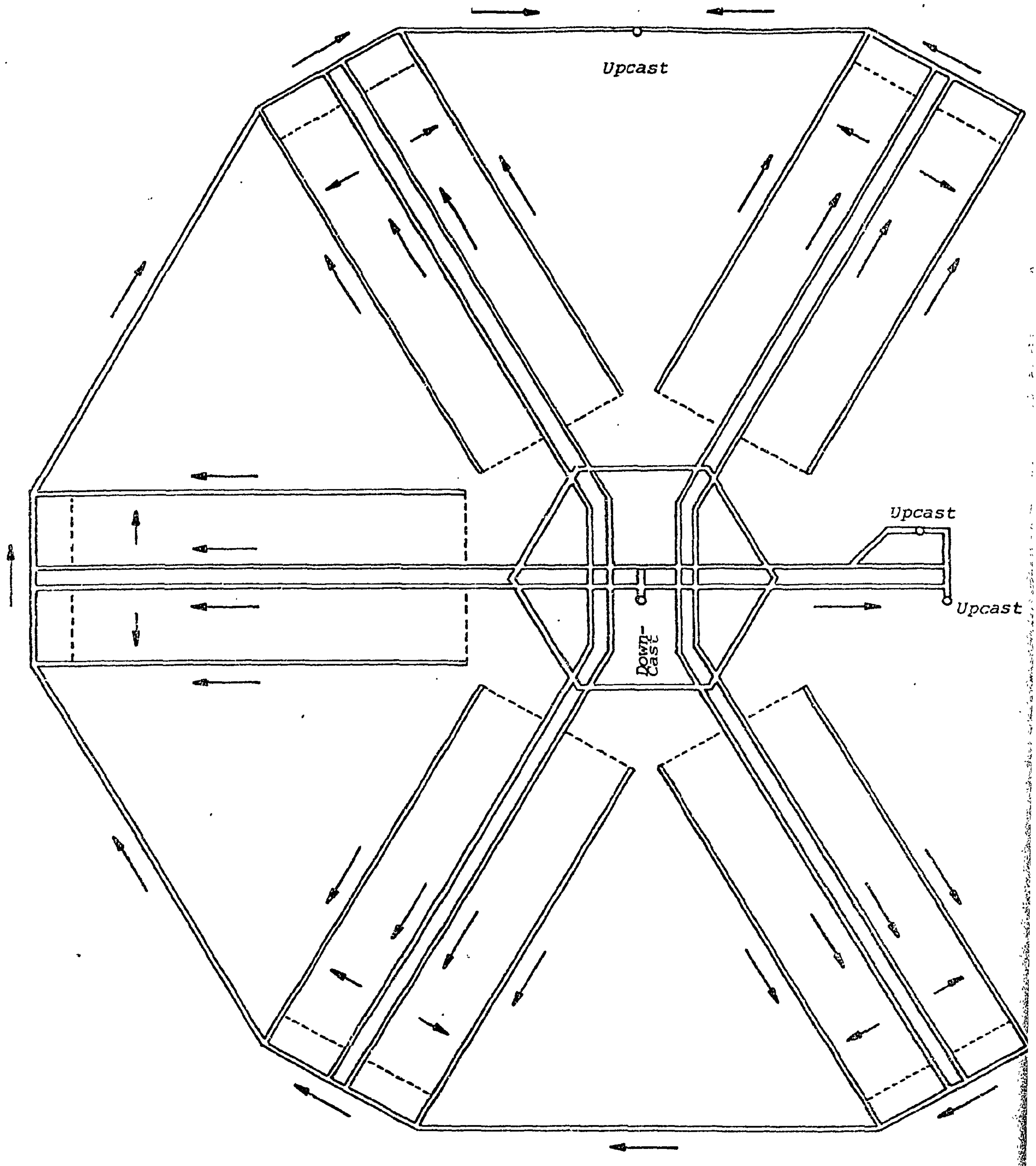

Figure 3.22. "Snowflake" Ventilation Directions

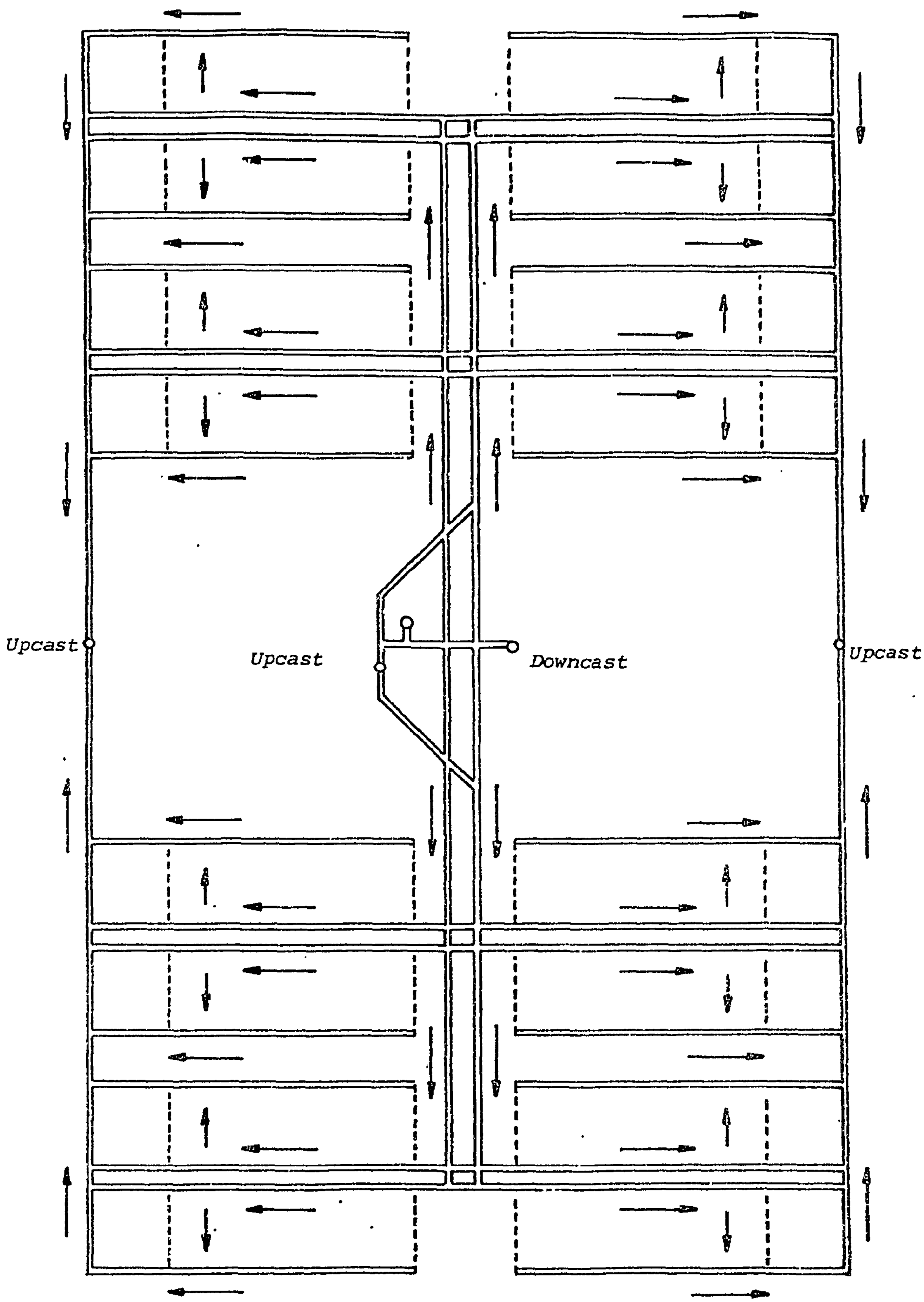

Figure 3.23. "Sash Window" Ventilation Directions

CHAPTER 4

BASIC REQUIREMENTS FOR THE USAGE OF THE REPOSITORY

by

William H. Grams and Thomas J. Zeller

4.1. Relationship Between Alpha Waste Delivery, Emplacement, and Salt Extraction Rates

An evaluation of the relationships between the alpha waste delivery, emplacement, and salt extraction was made for the five mine layouts for the purpose of determining upper and lower limits. The lower limit was found to be the Linear repository layout (twelve inch canisters, one canister per emplacement hole), and the upper limit was the Sash Window repository layout (ten inch canisters, one canisters per emplacement hole). To enable a comparison between mining and waste emplacement, the total tonnage for the repository is divided by the total number of canisters. This figure, the average tonnage per canister, when accumulated over the life of the repository gives the amount of material excavation needed at any given time to permanently store the canisters.

Figure 4.1 graphically illustrates the relationship of canister emplacement rate to the mining rate for the Sash Window repository layout for ten inch canisters, one canister per emplacement hole. Repository life is assumed to start at year 1983 and end at year 2003. Therefore, year zero would correspond to 1983. The Sash Window repository requires a total excavation of 4.85 x 10^6 tons, which gives a linear mining rate of 970 tons per day, it takes slightly over one year to develop the mine to a state where the first canisters can be emplaced. The canisters available still out number the rooms available until about year 2.5. After this, the mining rate is substantially ahead of the canister arrival until year 20 at which time the mining is equal to the canister arrival.

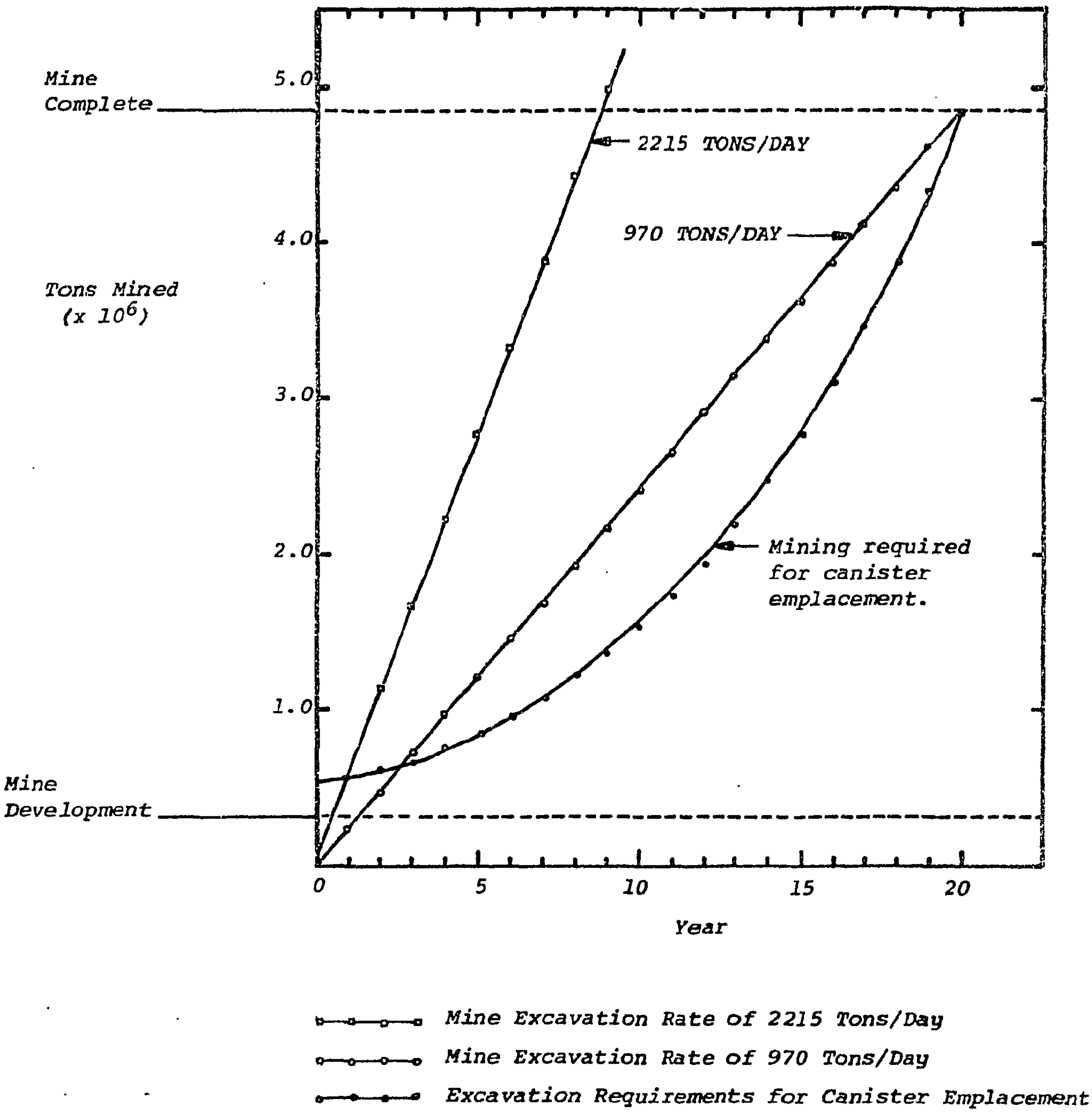

Figure 4.1 Mining Rate as Regards Canister Emplacement Rate - Upper Limit - Sash Window Repository-10 in. Canisters, 1 Canister Per Hole.

The canister arrival rate may be accelerated. Therefore, a possibility of expanding the repository exists and a large excavation rate could be considered. The steeper straight line on the graph is the accumulated tonnage mined at a rate of 2,155 tons per day, which is the excavation rate needed to stay abreast of the canister arrival at the year 20. At the accelerated extraction rate, the development is completed in six months, and space is created for the existing canisters by end of year one. The total mining necessary for the emplacement of all the alpha waste to year 20 is completed by year 9.

Figure 4.2 graphically illustrates the relationship of canister emplacement to mining rates for the Linear repository layout for 12 inch canisters, two canisters per emplacement hole. This graph is set up in the same format as Figure 4.1. The Linear repository requires 1.53×10^6 tons of salt to be excavated in order to provide the amount of room necessary to emplace the anticipated amount of alpha waste. Over the twenty year life, this would give a straight line extraction rate of 306 tons per day. The development would be completed in slightly more than four years, and the mining catches up to the canister arrival between the 6th and 7th year. After that point, the mining is substantially ahead of canister arrival until year 20, at which time they become equal. The steeper line represents the straight-line mining rate equal to the canister arrival emplacement rate at year 20. If this accelerated rate is used, the development would be completed in slightly over two years and the mining could surpass the canister arrival before the third year. Enough rooms would be provided by year nine to store all the alpha waste arriving through year 20.

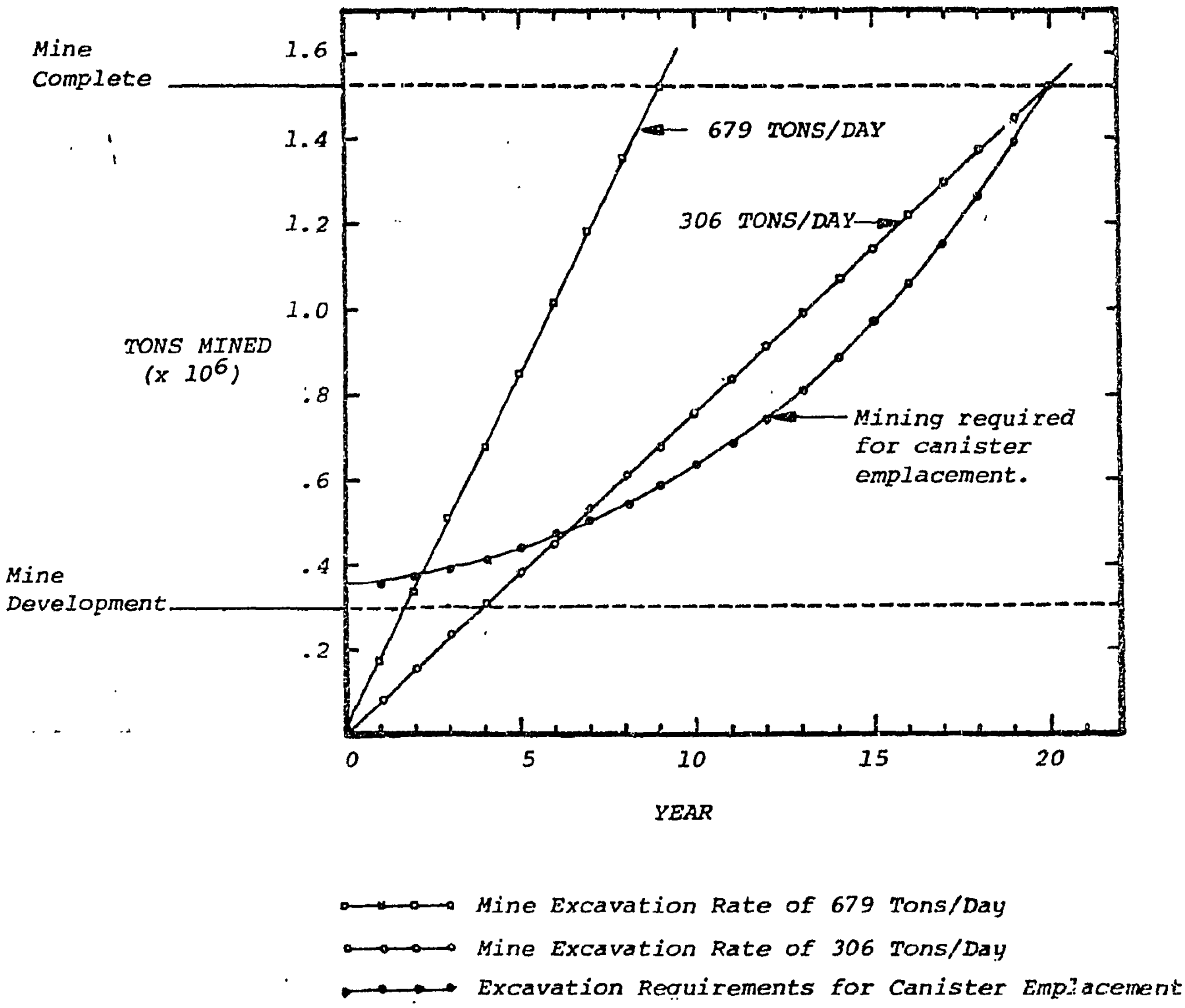

Figure 4.2 Mining Rate as Regards Canister Emplacement Rate - Lower Limit, Linear Repository - 12 in. Canisters, 2 Canisters Per Hole.

4.2. Sequence and Rate of Panel Development

The five repositories are constructed on the building block principle with the room being the basic building block. The rooms are arranged to form a panel which is typical to all the repository designs. The difference between the panels for the various repositories is in the length or the number of rooms in each panel. In all cases a panel is developed from the far end toward the main shaft. Figure 4.3 illustrates the sequence of mining operation in a general sense, as the type of equipment used determines the actual sequence. For instance, continuous mining would probably be done as shown, but any cyclic method, i.e. drill-blast-muck and finally bolt, would require several rooms being developed simultaneously. In other words, a drill jumbo would be preparing the face in one room for blasting, the roof bolting jumbo would be securing the roof in another room, explosives would be loaded in another room, and finally mucking would be in progress for still another room. Thus the number of rooms being prepared for the large hole drills in any given time would vary as to the type and amount of equipment being used.

The sequence of panel development is scheduled such that the stresses and deformation in the shaft pillar are balanced. There is no induced caving as is found in normal room and pillar mining where the pillars are robbed. Therefore, the effect of mining on the shaft should be slight.

To further illustrate the panel development, Figures 4.4, 4.5, 4.6, 4.7, and 4.8 define the order of panel development for the five repository designs.

The length of time to develop the panels is a function of the number of panels and the number of rooms per panel for each repository design. The longest panel development time would be for the linear repository. As there is only one panel, the development for this would be slightly less *than 20 years. The Sash Window repository has eight panels; therefore, panel development would progress at the rate of 2.5 years per panel.*

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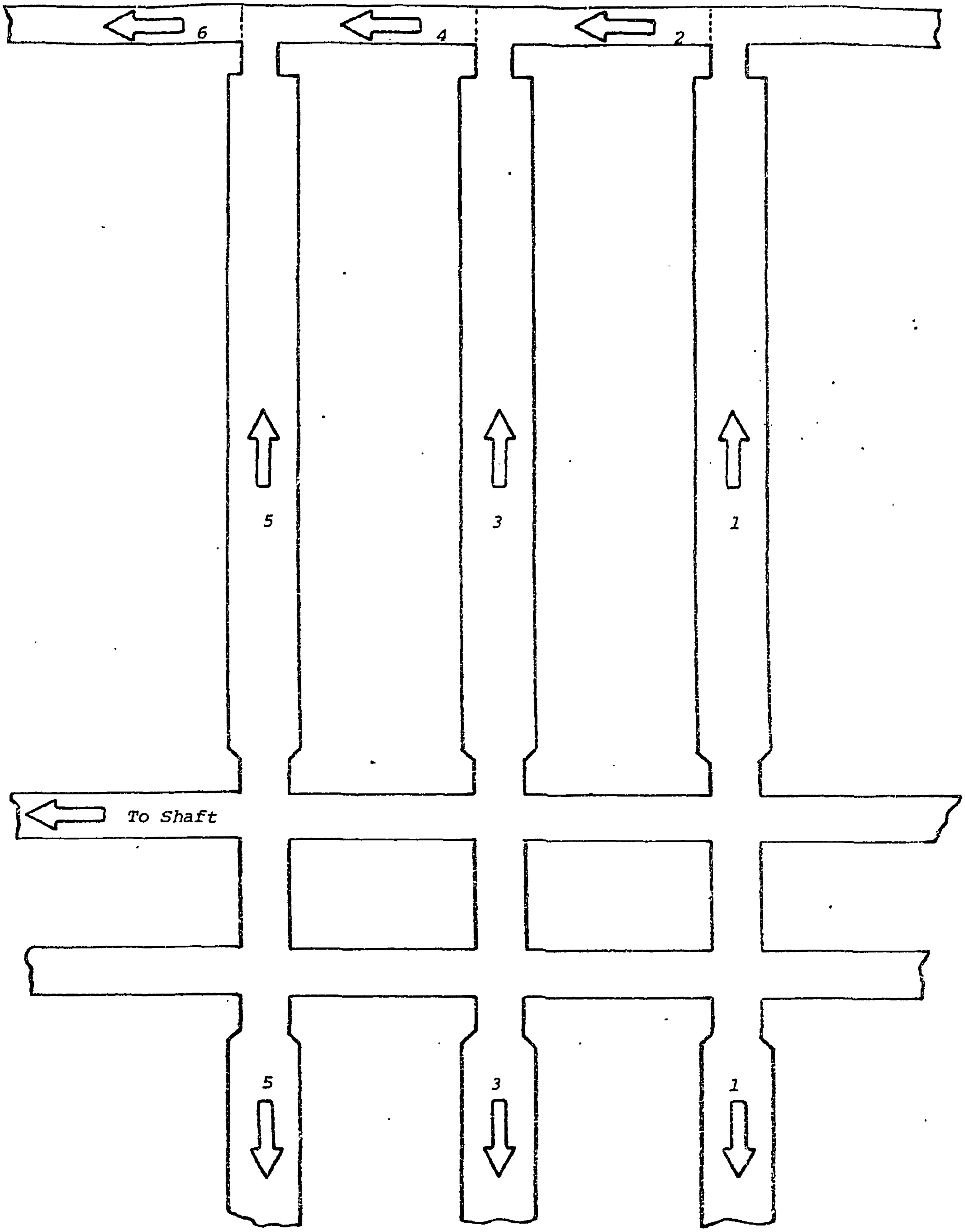

Figure 4.3 *Generalized Panel Mining Sequence*

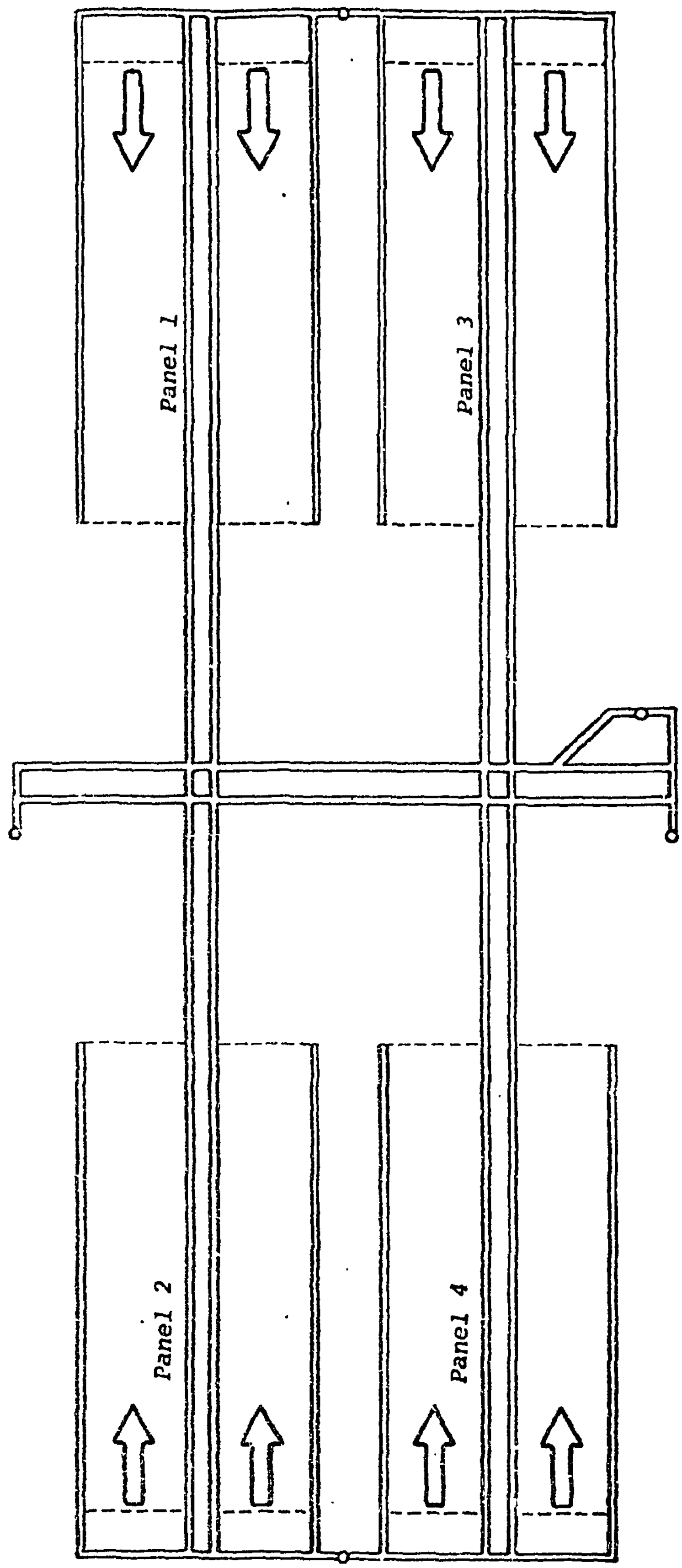

Figure 4.4 Maltese Cross Repository Panel Development Sequence

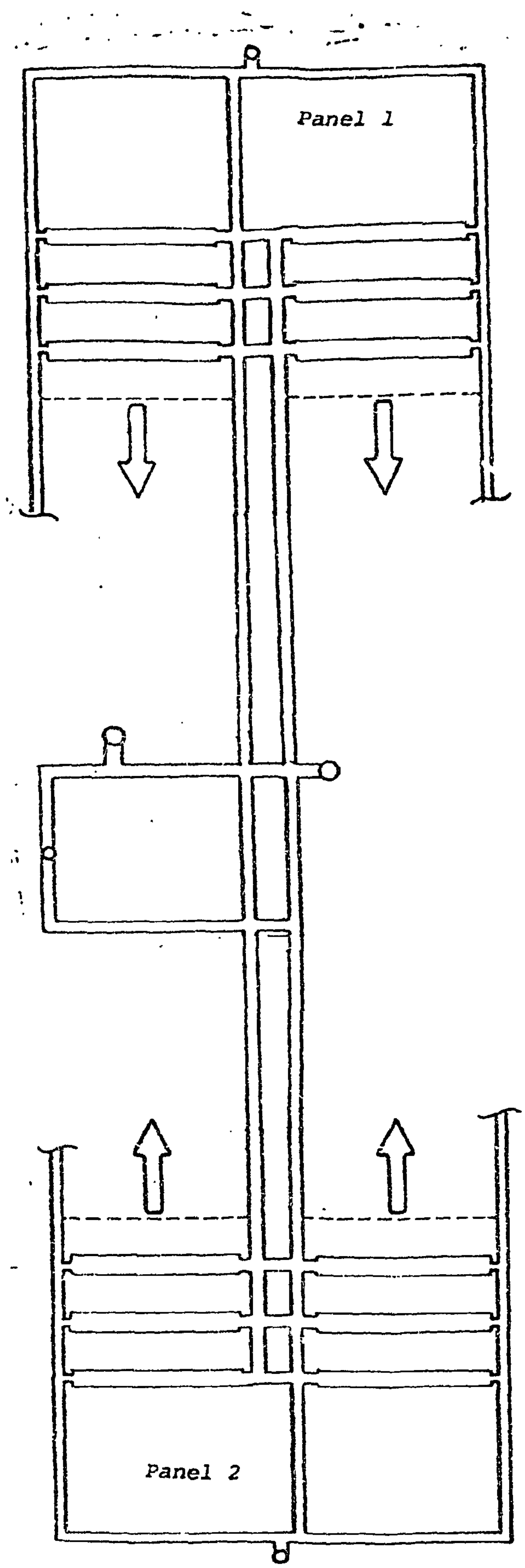

Figure 4.5 Bow Tie Repository Panel Development Sequence

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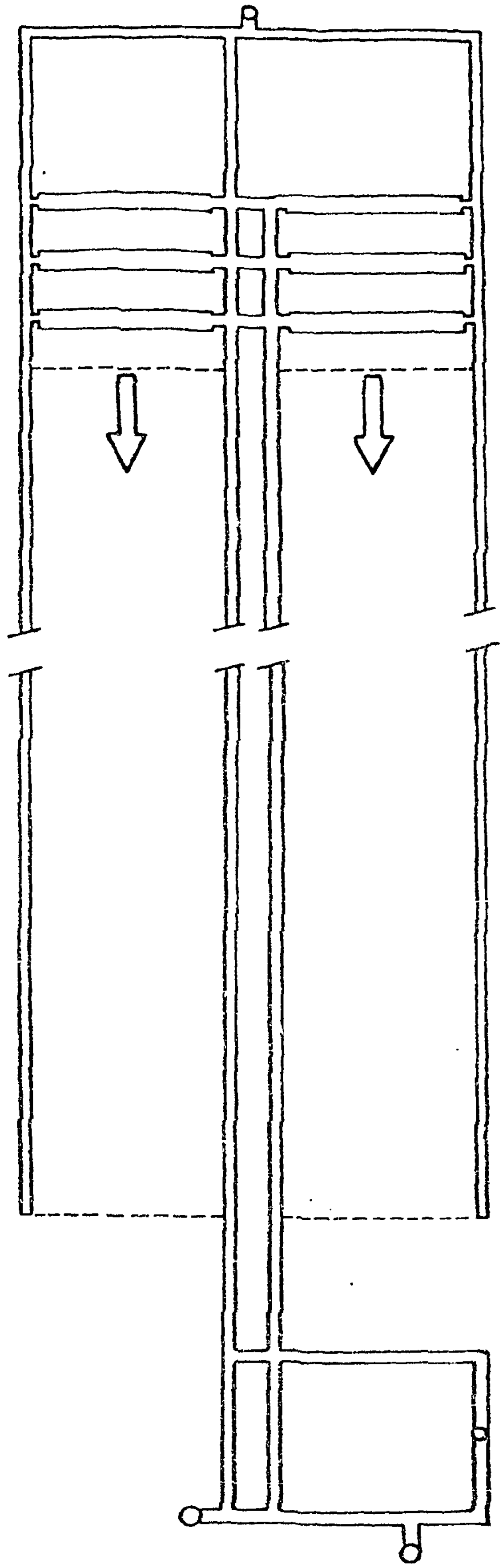

Figure 4.6 Linear Repository Panel Development Sequence

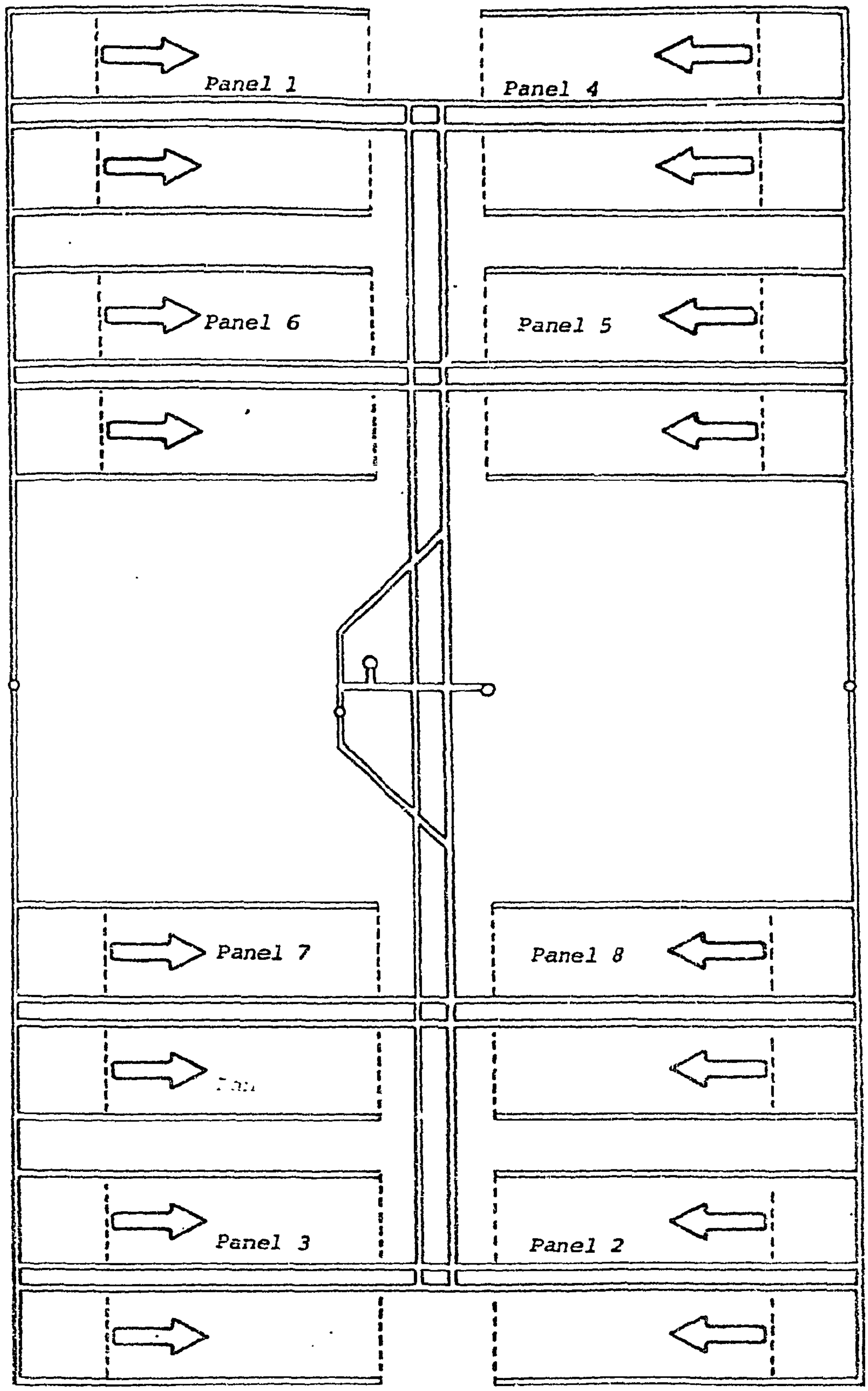

Figure 4.7 Sash Window Repository Panel Development Sequence

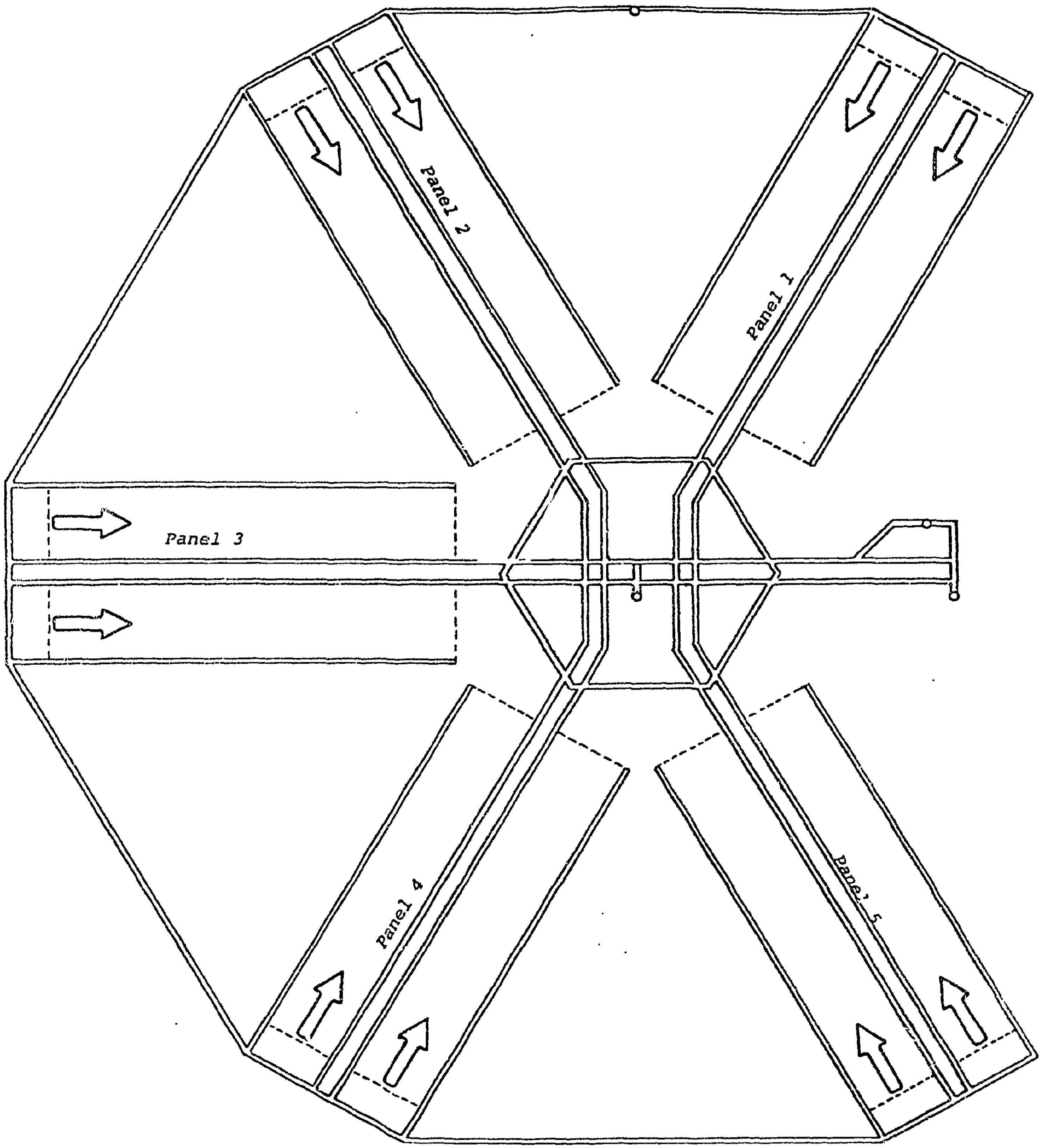

Figure 4.8 Snowflake Repository Panel Development Sequence

CHAPTER 5

PRELIMINARY STABILITY ANALYSIS OF EXCAVATION GEOMETRIES

by

Arlo F. Fossum, Joe L. Ratigan, and William G. Pariseau

5.1 Introduction

Stability analysis of the underground alpha waste repository opening excavation geometries to date has been two-fold, viz:

(1) Elastic Finite-Element analysis of two typical room-and-pillar configurations at each of the three candidate mining horizons, employing the rock properties data discussed in Chapter 2;

(2) Analytical formulation and subsequent evaluation of applicable mechanics equations for roof stability in room-and-pillar excavations.

The Finite-Element models mentioned in (1) above were developed through the use of the computer program RSI/PILMESH which has the capability of rapidly developing Finite-Element meshes for room-and-pillar excavations for single or multiple mining horizons. Models generated by the program will reflect any stratigraphic sequence desired. However, for purposes of this preliminary report, all models generated were isotropic and homogeneous, with the exception of the models located in the 2100 foot horizon. At this particular horizon, the ten foot thick anhydrite layer was modeled in the roof of the room. The results of the Finite-Element Analysis are presented in greater detail in Section 5.2.

In an effort to better understand the stress states present in the roofs of room-and-pillar excavations, an analytical formulation of bending(flexural) and shear stresses for a beam on discrete elastic foundations (pillars) has been developed. The formulation has the capability of analyzing situations of variable pillar size (width and height), room width, and modulus of elasticity (roof and pillar moduli may vary independently). The solution is a state-of-the-art level analysis in the field of "Beams on Elastic

Foundations" and is presented in more detail in Section 5.4.

5.2. Elastic Finite-Element Analysis of Typical Room-and-Pillar Configurations

As was previously stated in the introduction, two typical room-and-pillar excavation models were examined in each of the three candidate mining horizons. It should be noted that the present analysis has been limited to plane strain elastic Finite-Element solutions of mine openings fully "mined out." Thus, the results do not reflect reorientation of stress states ocurring during mining operations, load redistribution due to plasticity, or creep. The models examined were homogeneous and isotropic with the exception of those in the 2100 foot mining horizon. The models in this horizon inherently contained a ten foot anhydrite roof.

In order to reduce the localized effects of modeling overburden loads on the stress states around the opening, each of the Finite-Element models were extended a distance of approximately five times the room height below the room floor before "fixing" the model, and above the roof of the opening before emplacing nodal point loads. The models analyzed contained 496 elements and 288 nodes.

At each mining horizon, two particular excavation geometries were examined, viz:

(1) A room-and-pillar configuration with pillar width, room width, and room height equal to 60 feet, 22 feet and 16 feet, respectively.

(2) A room-and-pillar configuration with pillar width, room width, and room height equal to 70 feet, 30 feet and 16 feet, respectively.

The configurations result in extraction ratios of 26.8% and 30%, respectively, neglecting crosscuts. The particular room widths employed enable emplacement of five or seven waste canister holes, respectively. For the purposes of preliminary analysis the pillar width was increased from 60 feet to 70 feet when the room width was extended from 22 feet to 30 feet, in order to vary extraction ratio only slightly.

5.2.1. Stress Concentrations

Stress concentration factors at four discrete locations in each of the six models examined are presented in Tables 5.1 through 5.3. The four aforementioned locations are the geometric center of the pillar, the midpoint of the rib, the roof centerline, and the roof-rib intersection. The location identified as the midpoint of the rib is located five inches back from the plane of the rib. The roof-rib intersection location is horizontally positioned on the plane of the rib and vertically five inches above the plane of the roof. The centerline of the roof is also located five inches above the plane of the roof.

For the purposes of this report, a stress concentration factor is defined as the ratio of the post-mining stress to the pre-mining stress. The pre-mining stress is calculated from overburden loading and the post-mining stress is extracted from the Finite-Element results. A negative stress concentration factor is indicative of the presence of tensile stress. From observation of the tabulated stress concentration factors, one can observe that tensile stress is present in the center of the roof of the models at the 2100 and 2700 foot horizons. Maximum stress concentration factors occur at the roof-rib intersection with the exception of the models at the 2700 foot horizon, where the maximum occurs at the midpoint of the rib.

TABLE 5.1

Summary of Stress Concentration Factors for an Underground Room-and-Pillar Configuration Located in the 1900 Foot Horizon

Geometrical Location	W_R = 22Ft.;	W_P = 60Ft.	W_R = 30Ft.;	W_P = 70Ft.
	Vertical (Sy)	Horizontal (Sx)	Vertical (Sy)	Horizontal (Sx)
Geometric Center of the Pillar	1.002	0.774	0.986	0.829
Midpoint of the Rib	1.209	0.077	1.385	0.123
Roof-Rib Corner	1.441	1.290	1.505	1.329
Midpoint of Roof Span	0.076	0.625	0.091	0.538

TABLE 5.2

Summary of Stress Concentration Factors for an Underground Room-and-Pillar Configuration Located in the 2100 Foot Horizon

Geometrical Location	W_R = 22Ft.;	W_P = 60Ft.	W_R = 30Ft.;	W_P = 70Ft.
	Vertical (Sy)	Horizontal (Sx)	Vertical (Sy)	Horizontal (Sx)
Geometric Center of the Pillar	1.001	0.882	0.971	0.944
Midpoint of the Rib	1.094	0.059	1.278	0.103
Roof-Rib Corner	1.400	2.514	1.529	2.888
Midpoint of Roof Span	0.062	-0.256	0.065	-1.009

Note: (1) Negative Stress Concentration Factors indicate tensile stress states.
(2) Stress Concentrations are defined as the ratio of post-mining stress to pre-mining stress.

TABLE 5.3

Summary of Stress Concentration Factors for an Underground Room-and-Pillar Configuration Located in the 2700 Foot Horizon

Geometrical Location	W_R = 22Ft.;	W_p = 60Ft.	W_R = 30Ft.;	W_p = 70Ft.
	Vertical (Sy)	Horizontal (Sx)	Vertical (Sy)	Horizontal (Sx)
Geometric Center of the Pillar	0.986	1.000	0.997	1.093
Midpoint of the Rib	1.431	0.127	1.614	0.164
Roof-Rib Corner	1.280	1.140	1.370	1.254
Midpoint of Roof Span	0.032	-0.095	0.036	-0.281

Note: (1) Negative Stress Concentration Factors indicate tensile stress states.

(2) Stress Concentrations are defined as the ratio of post-mining stress to pre-mining stress.

5.2.2. Factors of Safety

Contour plots or maps of the factors of safety occuring in the Finite-Element models are presented in Figures 5.1 through 5.6. The factors of safety are based on a linear Mohr-Coulomb criteria. In each model examined, finite regions possessing factors of safety less than or equal to one are present. Thus, the elastic solutions in these regions are not totally accurate if the linear Mohr-Coulomb criteria is assumed.

In the 1900 foot and 2100 foot horizons, the factors of safety indicate allowable stress states for the most part. However, in the 2700 foot horizon, the factors are considerably lower.

The presence of the anhydrite roof in the models located at the 2100 foot horizon is quite noticable in the contour plots. In fact, if the roof at this horizon were modeled with the same material properties possessed by the pillar, the contours would be quite similar to those in the 1900 foot horizon.

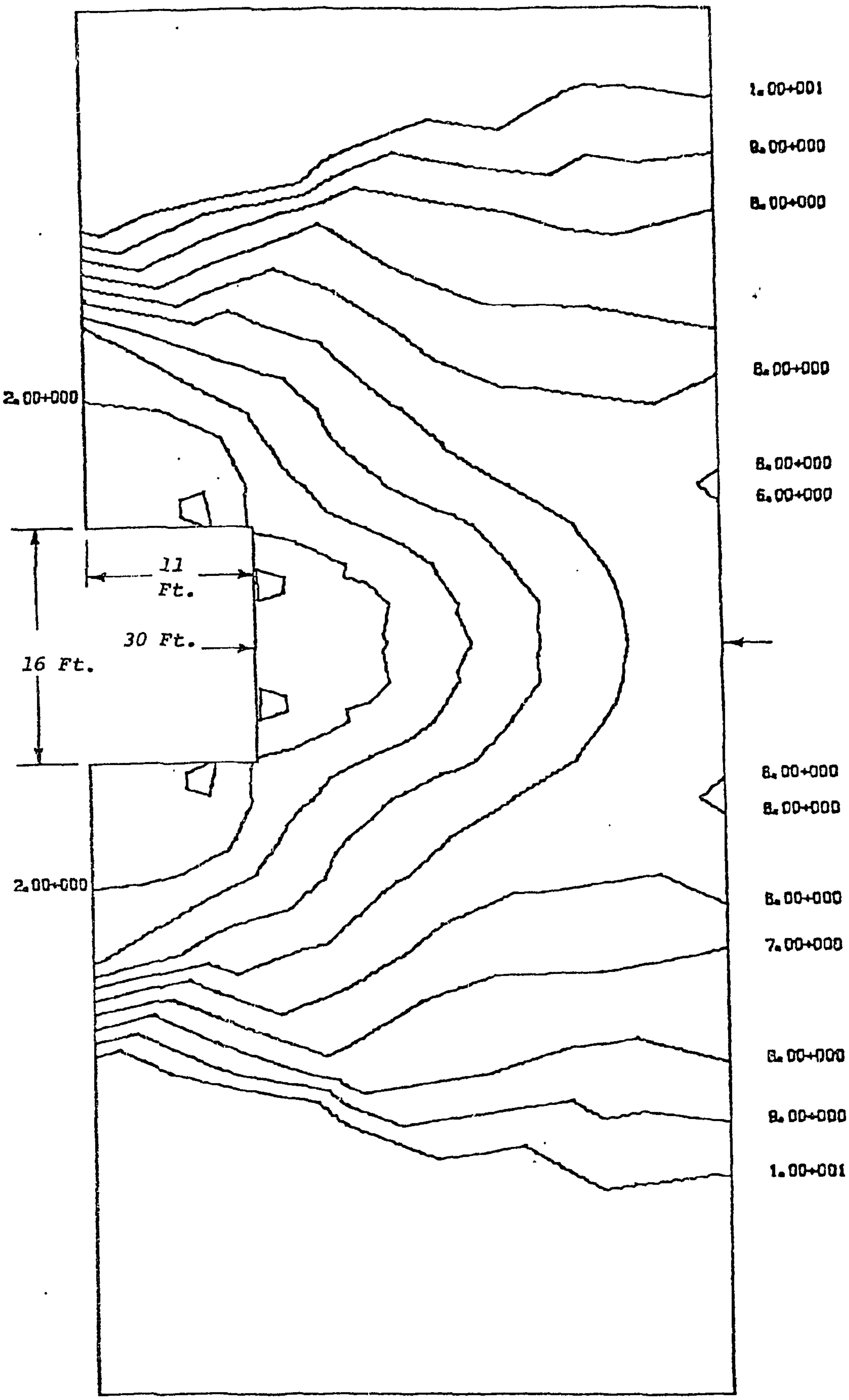

Figure 5.1 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 1900 feet.

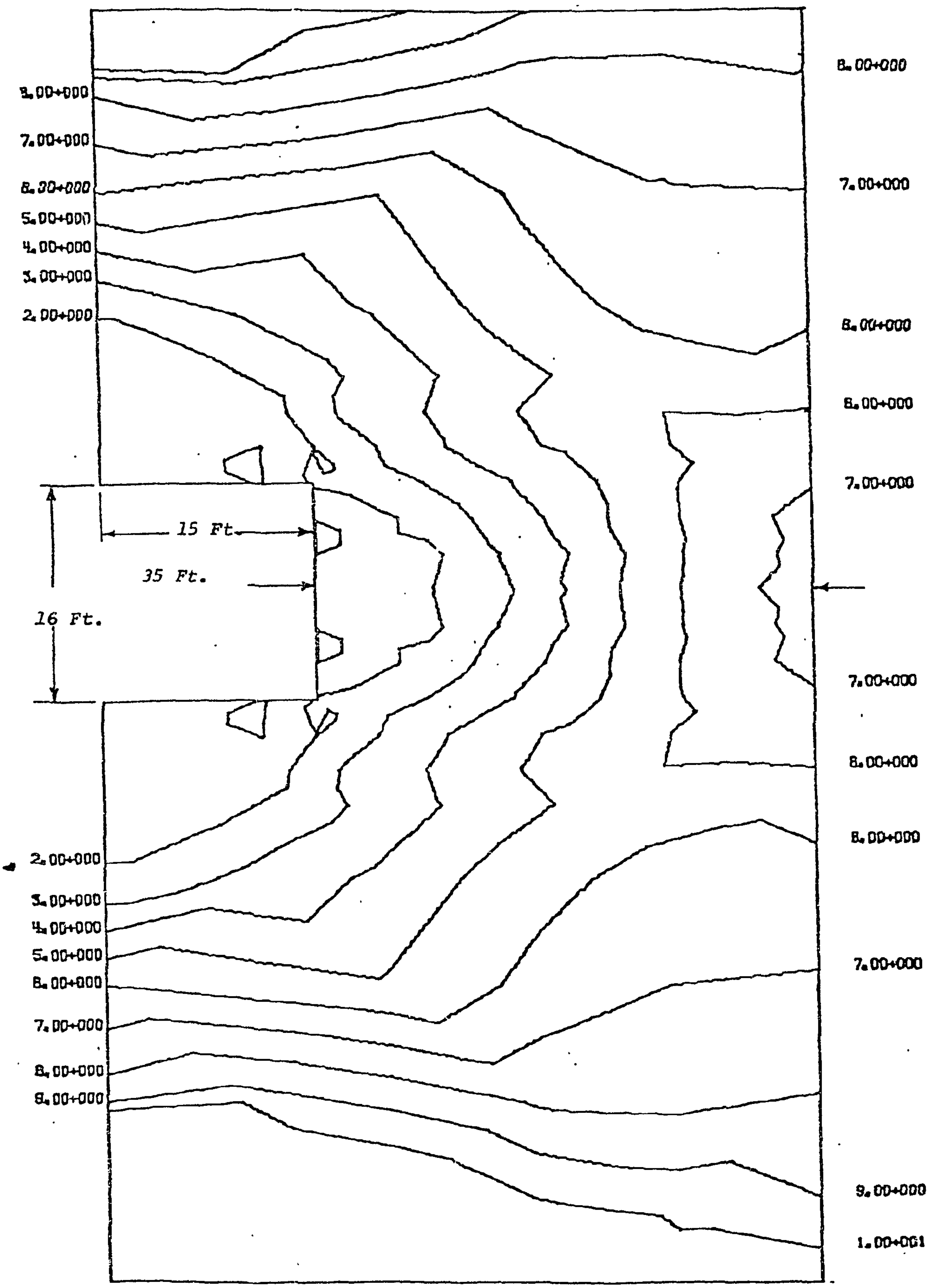

Figure 5.2 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 1900 feet.

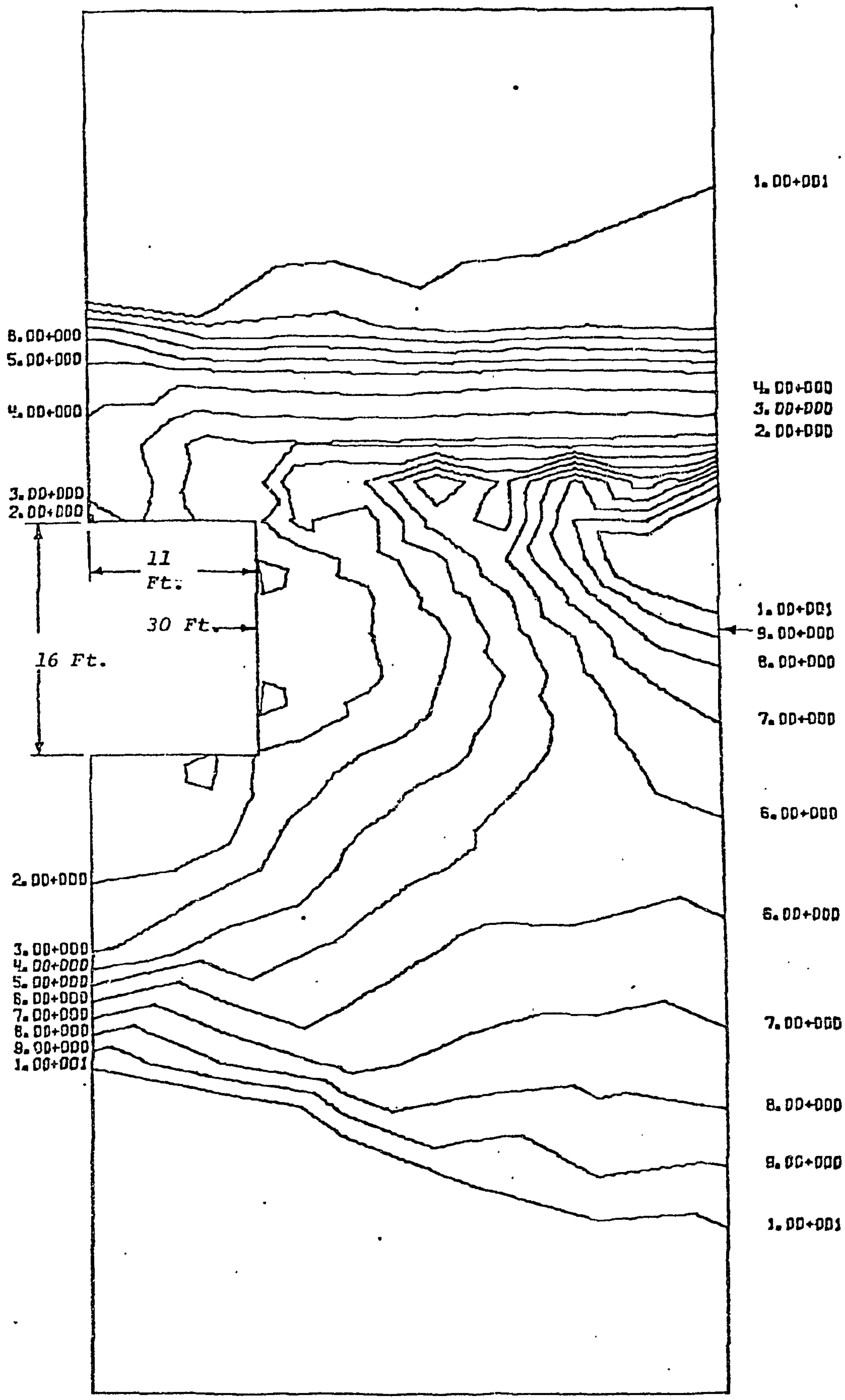

Figure 5.3 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 2100 feet. (Note: 10 feet of anhydrite is modeled in the roof).

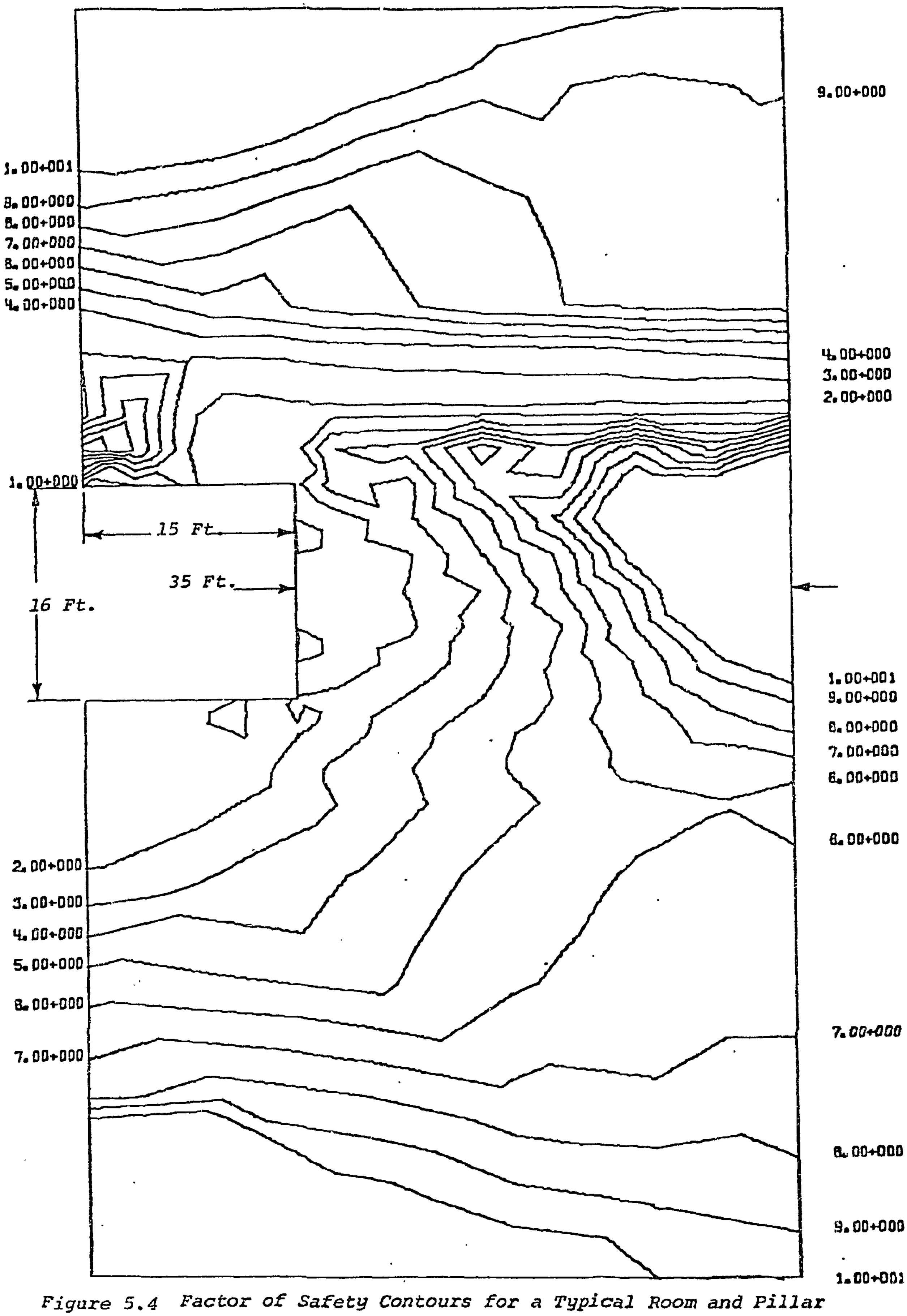

Figure 5.4 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 2100 feet. (Note: 10 feet of anhydrite is modeled in the roof.)

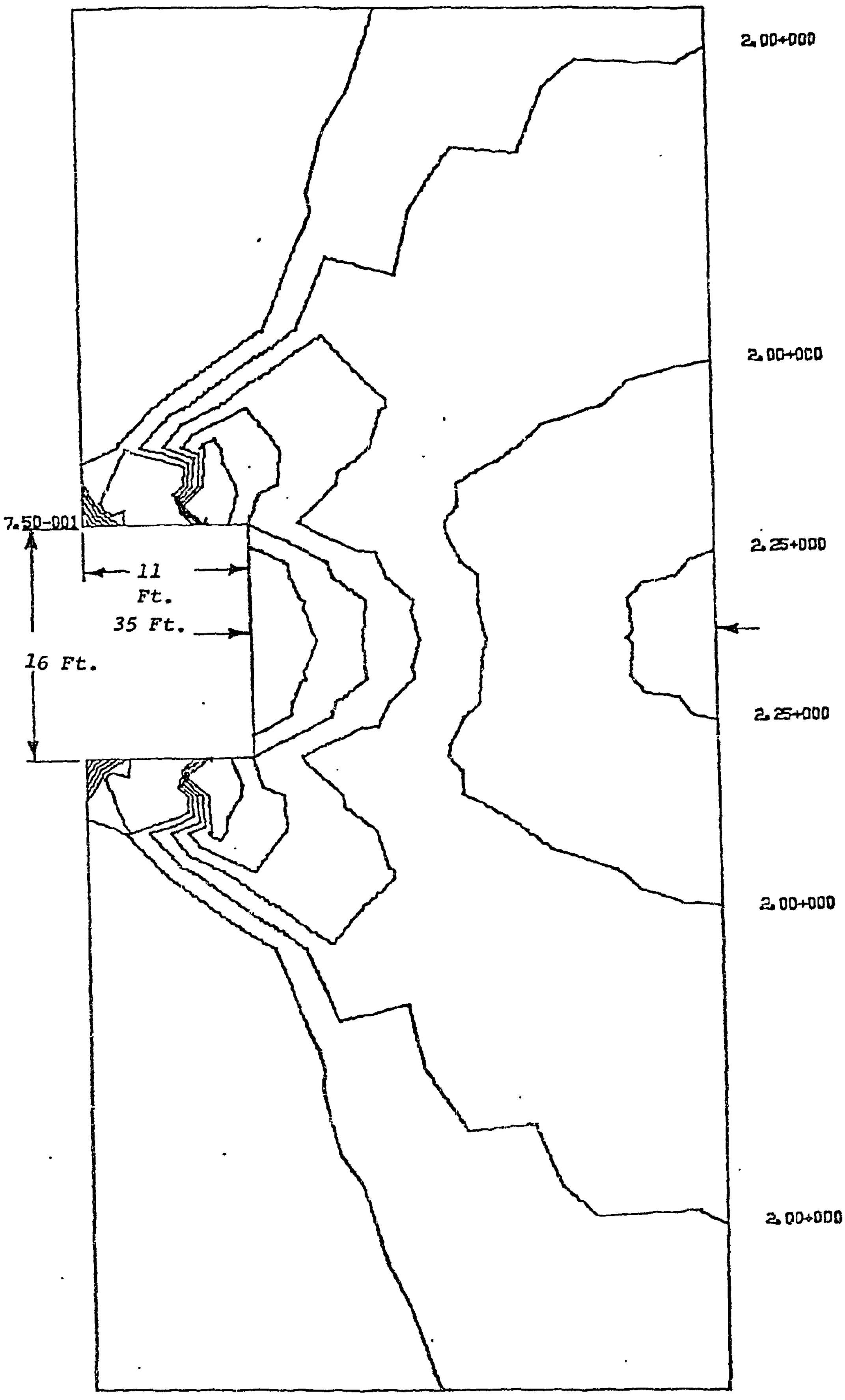

Figure 5.5 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 2700 feet.

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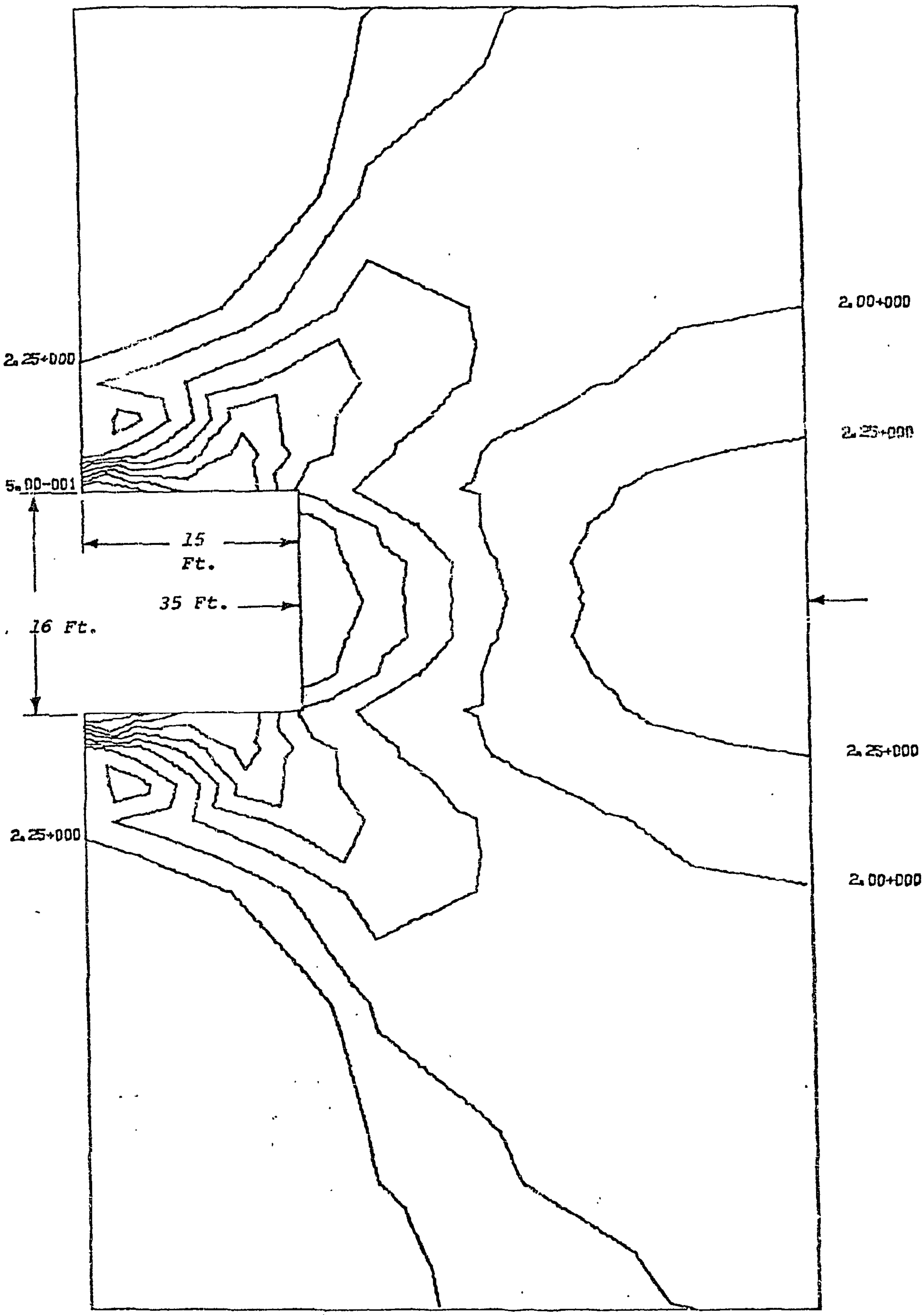

Figure 5.6 Factor of Safety Contours for a Typical Room and Pillar Configuration with Roof Level Located at 2700 feet.

5.3. Future Finite-Element Analysis

As stated previously, Finite-Element Analysis to date on the preliminary Alpha Repository excavation geometries has been an elastic analysis on fully "mined-out" geometries, neglecting the presence of canister emplacement holes. Future modeling will include analysis of the room-and-pillar configurations with the canister holes modeled "macroscopically" with, say, reduced moduli to determine the effect of the presence of the holes upon pillar stability. The canister holes will also be modeled "microscopically" in order to understand local material behavior.

The methods of analysis will include further elastic solutions, visco-elastic, and elastic-plastic. In addition to Finite-Element Analysis, analytical solutions will be employed whenever applicable.

5.4. Analysis of Roof Stability Using an Analytical Solution

The roof analysis presented herein is for the immediate roof, i.e., for a single lamina spanning the width of the room such that it may be considered as a beam acted upon by gravity. The ends of the beam are elastically clamped over the pillars by the overlying rock. It is assumed that the thickness of the beam is uniform and that the rock can be considered as linear elastic. For the present, it will be assumed that no end forces act axially on the beam. Deformations will be permitted in the pillars on which the beam is clamped, i.e. the beam is clamped on an elastic foundation. The usual practice in the design of roofs is based on a beam rigidly clamped to the pillar. The arguement frequently given to support this procedure is that the tensile and compressive stresses occuring at the edge of the pillars will be a maximum and hence the procedure will be a conservative one. It should be noted however, that when the beam is elastically clamped to the pillar, the possibility exists that the maximum values of tensile and/or compressive stress will occur at locations in the beam other than at the edges of the pillars. It is possible, if only theoretically, that certain geometries of room and pillar widths, beam thickness, material properties, etc. will give negligible bending stress at the edges of the pillars. For example, the maximum bending stresses may occur at a point in the beam corresponding to the center of the pillar.

5.4.1. Formulation of the Solution

The configuration for which an analytical solution is sought consists of a sequence of regularly spaced rooms and pillars for which the immediate roof is formed by a single lamina loaded by its own weight over the width of the rooms and by the overburden over the width of the pillars. In general the pillar width is assumed different than the room width. The additional assumption is made that the length-to-span ratio of the room is sufficiently large to consider the roof as a beam. Since interest is centered here on the flexural stresses, the uniform gravity load is considered to act only on the center span as this is the only load which will cause bending. If the uniform load is considered to act over the portion of the beam overlying the pillars, a determinable quantity is added to the deflection, but the shear, slope, and moment remain unchanged.

An end-conditioning principle is used to arrive at the general solution for the portion of the beam overlying the elastic foundation. The requirement of continuity of slope and displacement is then used to extend the solution to the portion of the beam overlying the rooms. The complete solution is used to analyze the stability of the immediate roof for room-and pillar geometries in the three candidate stratigraphic horizons.

5.4.2. Analysis of Roof Stability in Candidate Horizons for the Alpha Repository

Two different values for pillar width, room width, and pillar height were used at each horizon. In the first case the pillar width was 60 feet, the room width was 22 feet, and the pillar height was 16 feet. In the second case these values were respectively, 70 feet, 30 feet, and 16 feet. The roof thickness was varied in steps of two feet, from two feet to ten feet for each case. The horizons were at 1900, 2100, and 2700 feet respectively. At the 1900 ft. level, the roof and pillars had a modulus of 1.75×10^6 psi, specific weight of 144 lb/cu. ft., and tensile strength of 180 psi. At the 2100 ft. level, the roof was a layer of anhydrite with a modulus of 10^7 psi and tensile strength of 810 psi.

In all cases considered, the two foot beam resulted in the highest bending stresses, with the maximum tensile stress being located on the upper side of the roof near the edges of the pillars. The fact that the highest stresses occurred in the smallest beam is not surprising, since the weight of the beam increases with its volume which has dimensions of length cubed, but its moment of inertia increases as a length dimenison to the fourth power. A number of interesting observations can be made form the results. From the first geometry of rooms and pillars to the second geometry, the extraction ratio increased by 11%, yet the bending stresses near the edge of the pillar for the two foot thick beam increased by nearly 100%! For the first geometry, the tensile bending stresses never exceeded the tensile strength of the roof for all cases considered. For the second geometry the tensile strength was exceeded at the upper surface of the two foot beam near the edges of the pillars at the 1900 and 2700 foot horizons. At the 2100 foot horizon with a ten foot layer of anhydrite, the maximum tensile bending stress occurred on the lower face of the beam at the midpoint of the span overlying the room. On the pillar side, the maximum bending stress occurred at a point corresponding to a point six feet into the pillar. A plot of the flexual stress versus distance along the roof is shown for several different situations in Figures 5.7 through 5.10. The stresses are shown for the lower face of the beam.

On the opposite face of the beam, bending stresses of equal magnitude but opposite sign are present. Hence, in the figures the horizontal position of maximum compressive bending stresses is also the position of maximum tensile bending stresses.

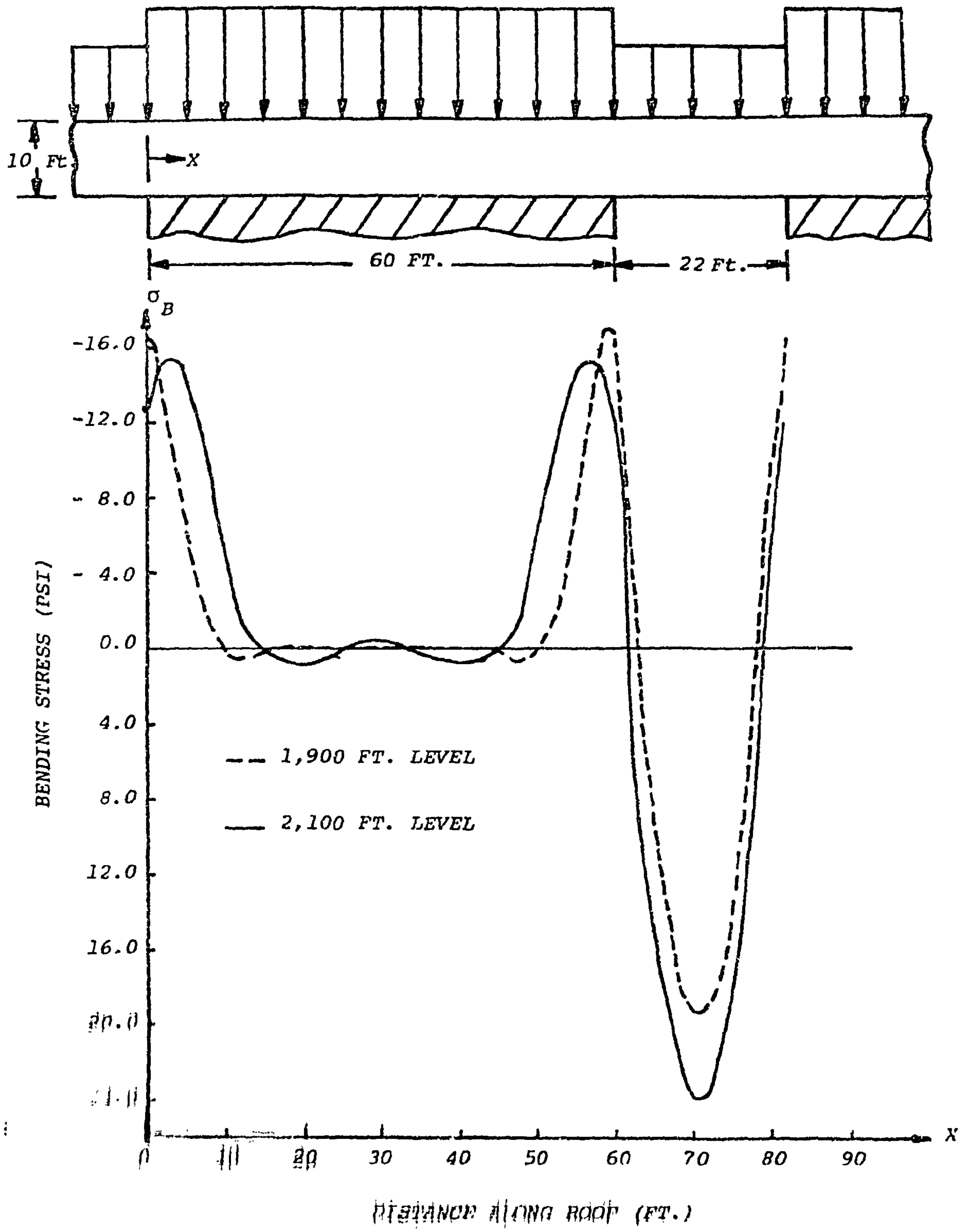

Figure 5.7 Bending Stress Versus Distance Along a 10 Ft. Thick Roof at 1,900 and 2,100 Ft. Levels for a 22 Ft. Room and 60 Ft. Pillar.

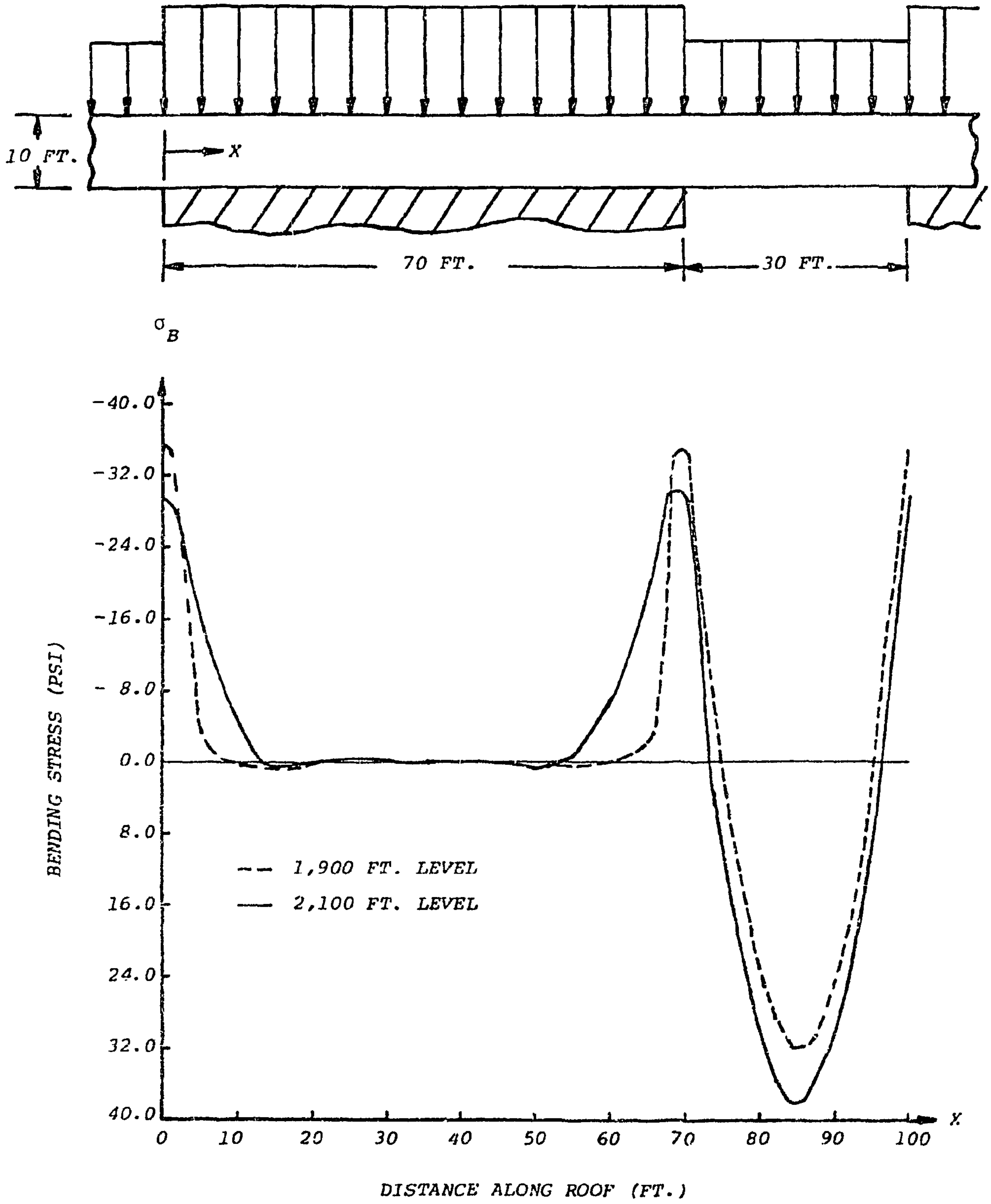

Figure 5.8 Bending Stress Versus Distance Along a 10 Ft. Thick Roof at 1,900 and 2,100 Ft. Levels for a 30 Ft. Room and 60 Ft. Pillar.

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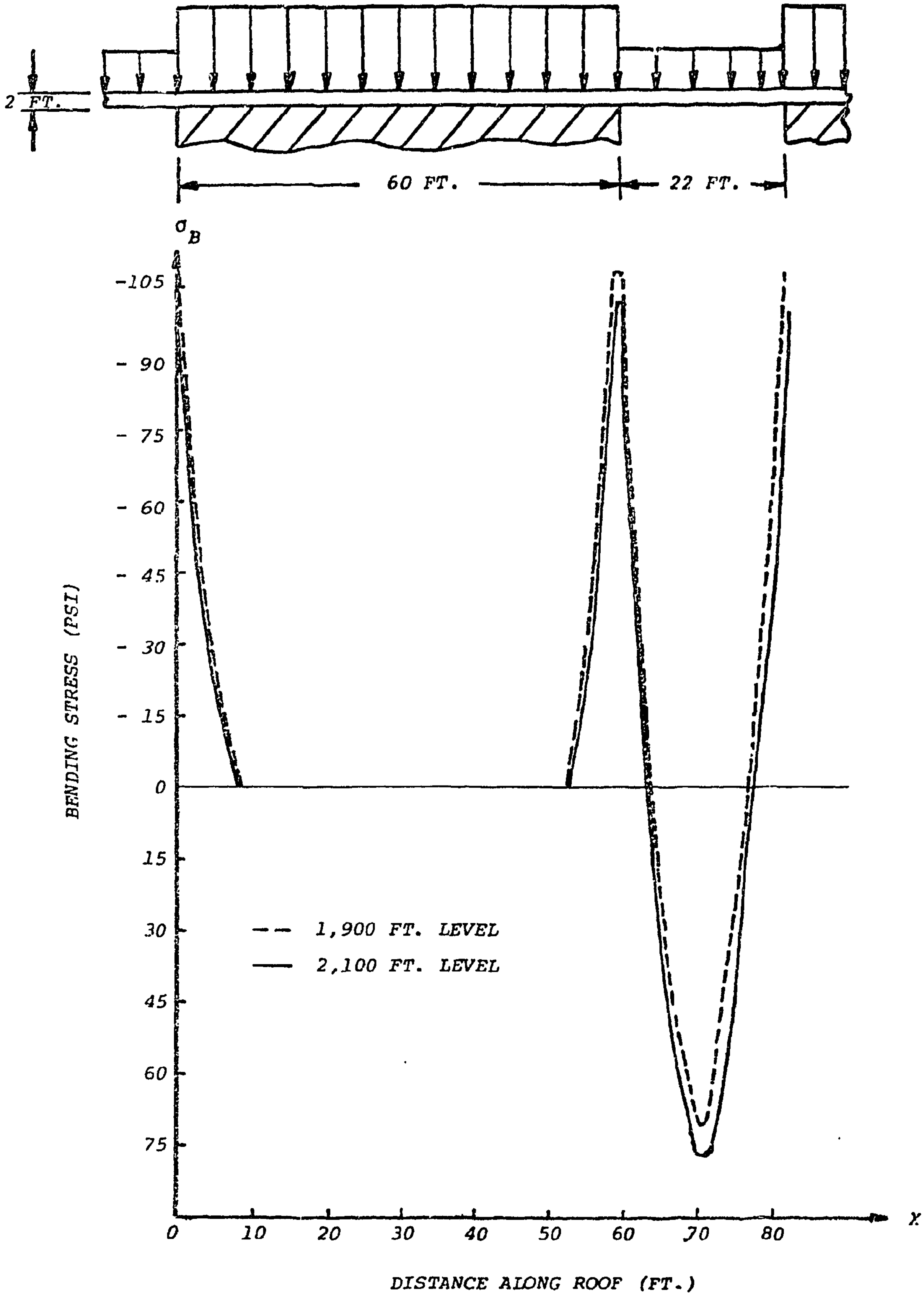

Figure 5.9 Bending Stress Versus Distance Along a 2 Ft. Thick Roof at 1,900 and 2,100 Ft. Levels for a 22 Ft. Room and 60 Ft. Pillar.

(RSI-0024)

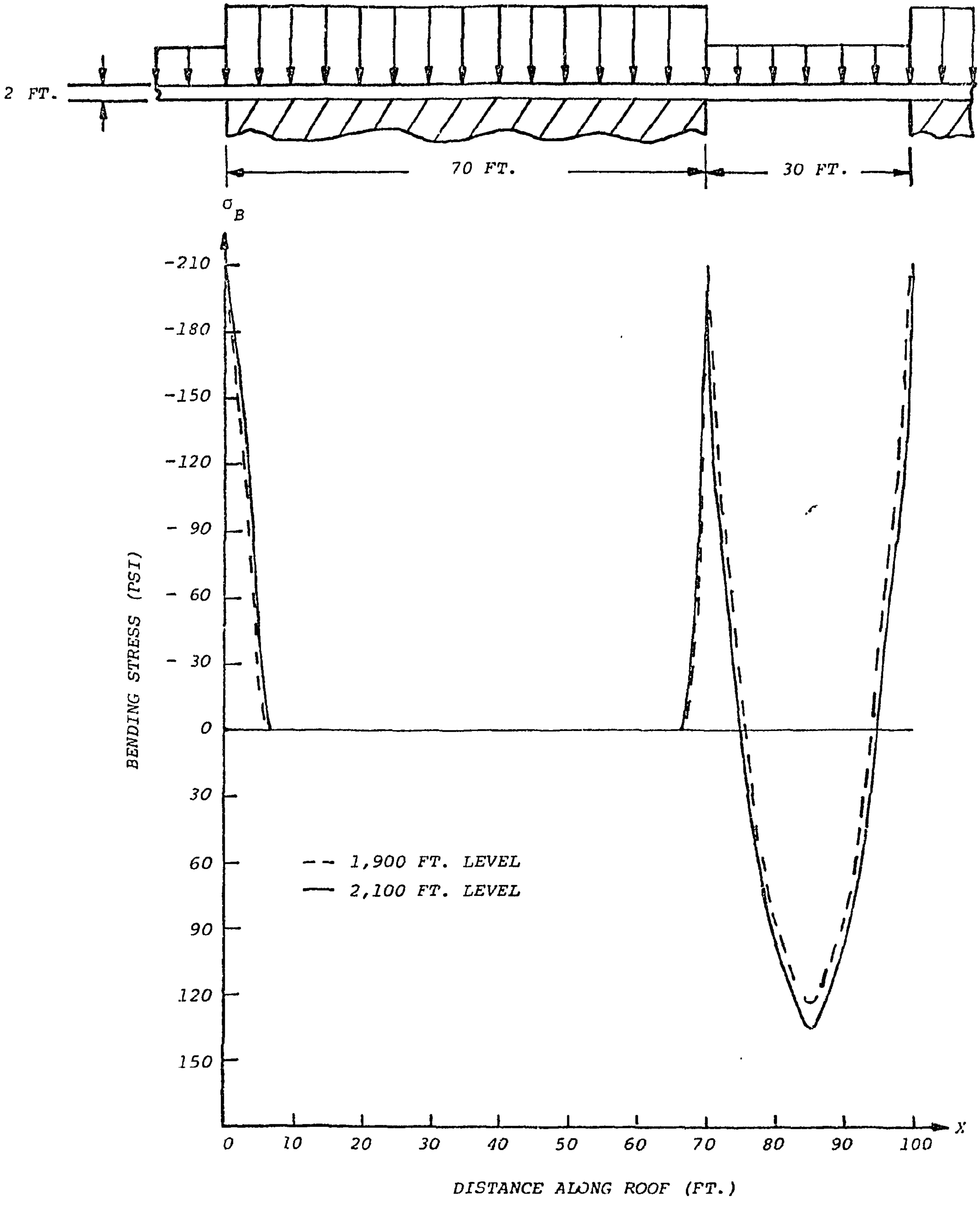

Figure 5.10 Bending Stress Versus Distance Along a 2 Ft. Thick Roof at 1,900 and 2,100 Ft. Levels for a 30 Ft. Room and 70 Ft. Pillar.

CHAPTER 6

SELECTION OF LARGE HOLE DRILLING EQUIPMENT

by

David B. Ellis and William H. Grams

6.1. General Comments on Underground Large Hole Driling

The drilling of large holes in this underground mine is an unusual task, considering the number of holes which will be drilled. Many mines have used large holes for a variety of purposes, such as drainage, ventilation, ore passes, manways, etc. The problem is that these holes were considered special and the equipment was never perfected for efficient and rapid performance. Presently, the use of larger blast holes in large sub-level caving operations is being perfected. The large International Nickel Mine in Sudbury, Ontario, is using new blast hole drills of the 5 to 6 inch diameter class. This is still much smaller than the 20 inch diameter holes required for this project. The large raise boring equipment is certainly capable of drilling the 20 inch diameter holes, but the limited mobility and extensive setup time make raise borers inapplicable to the situation under consideration.

In essence, the availability of equipment to drill these large holes is limited. There are three basic types of equipment which are presently being considered; namely:

(1) Rotary
(2) Core
(3) Bucket excavator

The cutting mechanism for the rotary drilling could be categorized by either standard tri-cone or drag type bits. Furthermore, the mechanism of salt cuttings removal effects the basic construction of the drill rig. The two most common cuttings removal methods would be fluid (air or water) and auger.

The following types of drill rigs are being considered:

(1) Rotary, Tri-cone bit and compressed air cutting removal
(2) Rotary, drag bit, with compressed air cutting removal
(3) Core, compressed air cutting removal
(4) Bucket excavator
(5) Rotary, modified drag bit with auger cutting removal

Of the fifteen major drilling manufacturers contacted, nine have indicated that they have no unit available for our application. The other suppliers are presently preparing proposals as to which of their units would satisfy our requirements and what specific modifications would be needed. General information is given in Sections 6.2. through 6.5. All prices quoted in these brief reviews are estimates. Table 6.1 itemizes the contacts made and indicates whether they are sending detailed information, or if no equipment is available at present.

All information presented here has been obtained from a telephone conversation. The complete analysis will be made when we receive detailed information from the manufacturer.

6.2. Bucket Drill

Calweld Division of Smith International Inc., has a bucket drill rig Model 150-A which utilizes a telescoping kelly. It is powered by a diesel engine. The bit has carbide insert teeth. Utilizing a pull down mechanism, the drill can penetrate rock with a unconfined compressive strength of 12,000 psi, according to a Calweld representative. Figure 6.1 is a graphic illustration of a unit of this type.

The Model 150-A bucket drill could be mounted either on a crawler, on skids, or on hudraulic "walkers". The hudraulic walkers have been used before by Calweld. The drill is 18 feet tall when mounted on skids. It is approximately 9 feet wide. Calweld said that it would not be difficult to shorten the derrick so that the drill would fit in a room with a back

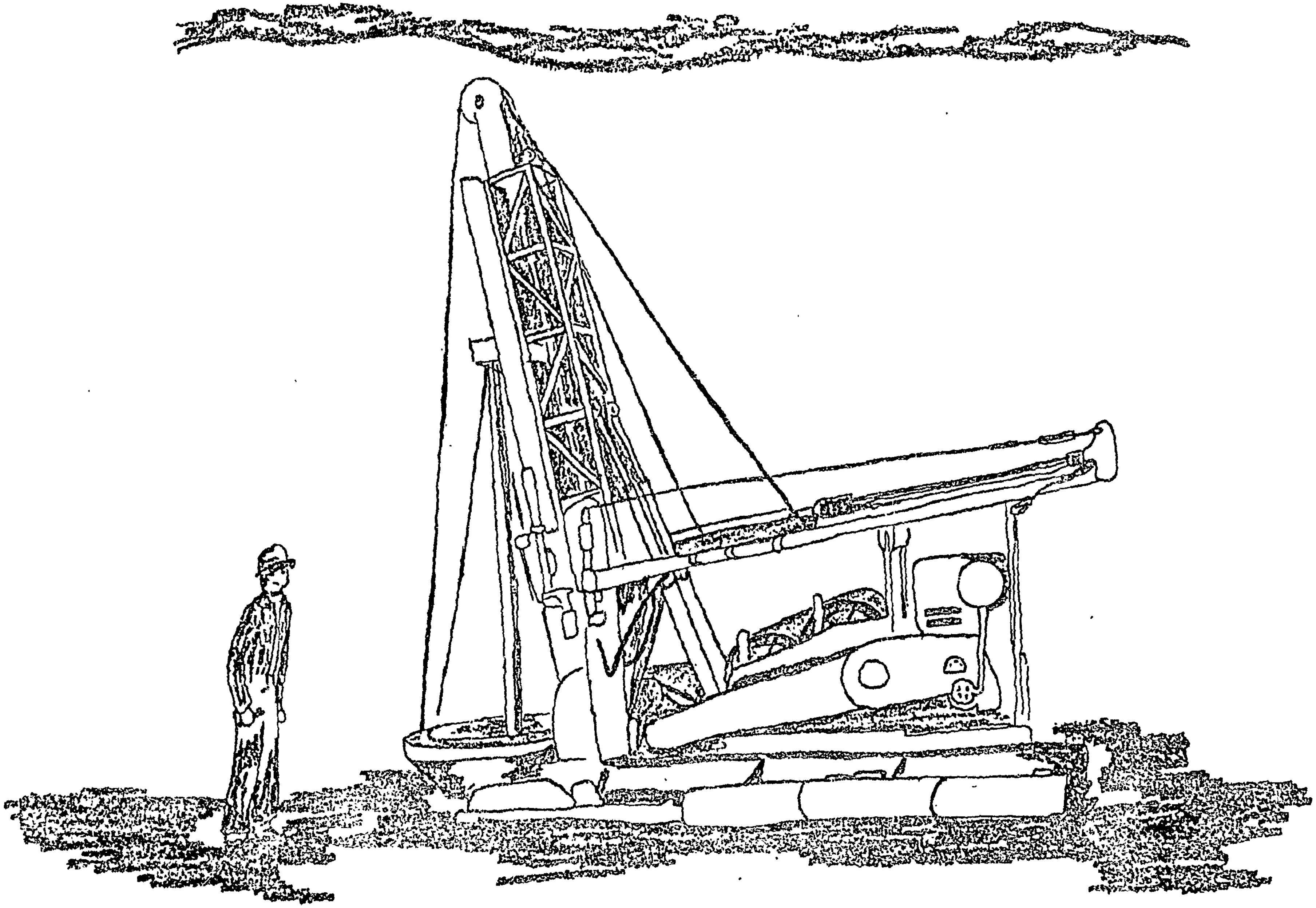

Figure 6.1. Bucket Drill with Telescopic Kelly

(RSI-0024)

height of 16 feet. They also said it would be possible to convert this to electric power. The drilling rate for the electric powered drill is estimated at six holes per shift, but this is only an educated guess from the manufacturer as the proposed use is non-standard for this drill. The bucket drill rig would cost approximately $50,000 if mounted on skids and $60,000 if mounted on walkers.

The Calweld Model 150-A, which is similar to the Model 150-B, except for derrick height, is presently being used by LeFever Foundation Contractors in Chicago, Illinois. They have used the same six Calweld bucket machines for the past en years. The machines has been used in one application to drill holes with a diameter of three feet with a depth of fifteen feet. They have used a modified version of the Model 150-A while drilling in an area with a clearance of 14 feet. Mr. LeFever was very positive about the performance of the Calweld machines.

6.3. Rotary Drill with Drag Bit

The Robbins Company, Seattle, Washington, has a rotary drill Model 11D which they propose using to drive a bit equipped with pick type drag bits. These bits are typically used on cutter chains on rotary head miners used in salt mines. This drill is electrically powered. Figure 6.2 is a graphic illustration of a drill rig of this type.

This drill may be stored on a crawler as supplied by Eimco of Salt Lake City, UT, or could be put on skids. The Model 11D rotary drill mounted on a crawler is less than 11 feet tall. The unit is 7 feet wide and weighs approximately 8 tons. To reduce the annular area between the drill hole gage and the drill rod for better hole cleaning, Robbins suggests the utilization of specially designed drill rod of a much larger diameter than their normal drill rod. The drilling rate for this drill is estimated at about five holes per shift. This is considering an average work shift under-

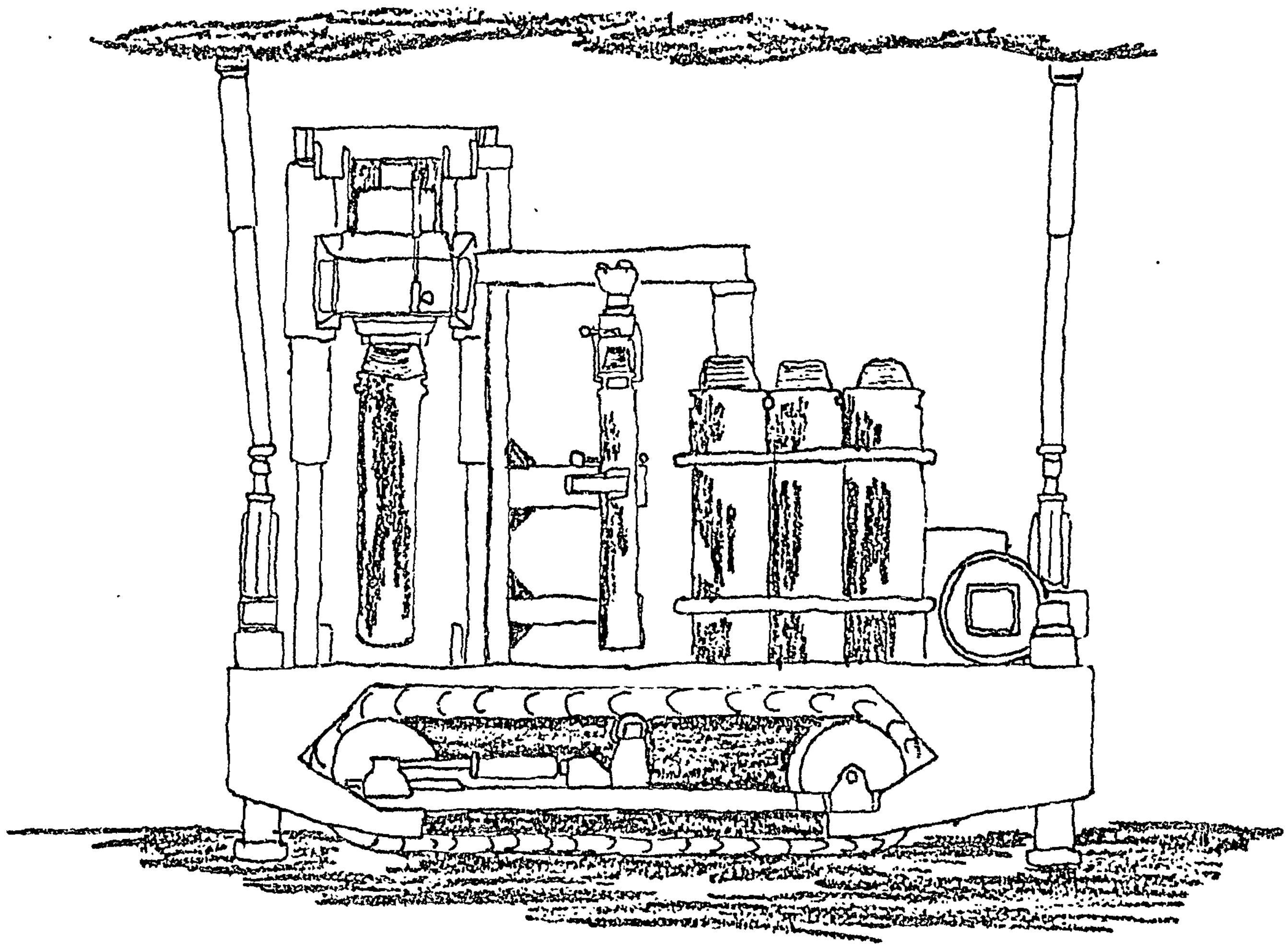

Figure 6.2. Crawler Mounted Rotary Drill with Roof Jacks and Steel Handling Systems

(RSI-0024)

ground of 6½ hours at the face.

The price of the modified Model 11D would be about $118,000. The special drill rod would be approximately $30,000 and the bit would cost approximately $5,000. An air powered transport trailer would be about $60,000. A dust collection system would cost approximately $40,000. Total cost would be approximately $193,000, if the unit was placed on skids; it would be $253,000 if placed on a crawler.

In addition to manufacturing a special 20 inch pipe, the Robbins drill would require modification in the frame, back plate, and cross head in order to accommodate the special drill rod. According to the manufacturer, these modifications are minor, but would increase the base price of the unit by about 50 percent.

The Robbins Model 11D is presently being used by Ecstall Mining Limited, of Timmins, Ontarion. They said moving and positioning the unit, setting up, and rod handling were time consumming. They had major problems anchoring the unit to the floor. They were apparently not using roof jacks. Their carrier was overloaded and they had maintenance problems with the connections between the power package and the drill unit.

6.4. Rotary Drill with Tri-Cone Bit

Robbins Drill Division of Joy Manufacturing sells a rotary drill Model RR105. It is diesel driven and usually mounted on a caterpillar D8-36A or D9-49A. The drill develops up to 65,000 pounds of pressure at the bit. The bit would be a large tri-cone bit as manufactured by a variety of manufacturers and would be driven by a ten inch drill rod with standard API theads.

This drill is 34½ feet long and 11 feet wide. The mast increases its height from 10 to 20 feet. They are not certain if they could decrease the mast height. The drilling unit weighs approximately 50 tons. Joy Manufacturing said it would be possible to convert the machine to electric operation much like their Model RR11E. The standard model of the RR105 sells for approximately $170,000. The modified unit is expected to be less than $300,000.

The Robbins Drill is presently being used by the Vinnell Corporation in Saudia Arabia to drill 25 inch diameter holes to depths of 20 to 25 feet in hard sandstone. Vinnell is using a tri-cone bit manufactured by Reed Tool Company.

6.5. Core Drill

The LeRoy Division of Dresser Industries manufactures a coring drill called the BBS-15. The drill has an optional electric drive. LeRoy also manufactures speciality coring bits up to 30 inches in diameter. Figure 6.3 is a graphic illustration of this drill rig.

This drill is a standard core drill not manufactured for rapid excavation, and hole production may be quite low. An additional problem would be the removal of the large sections of core, not only from the hole, but from the repository. The cost of this machine, exclusive of the specially manufactured bit, would be approximately $16,000.

This drill is presently being used by Boyle Brothers in Allentown, Pennsylvania to drill 18 inch diameter holes to a depth of 20 feet in slate.

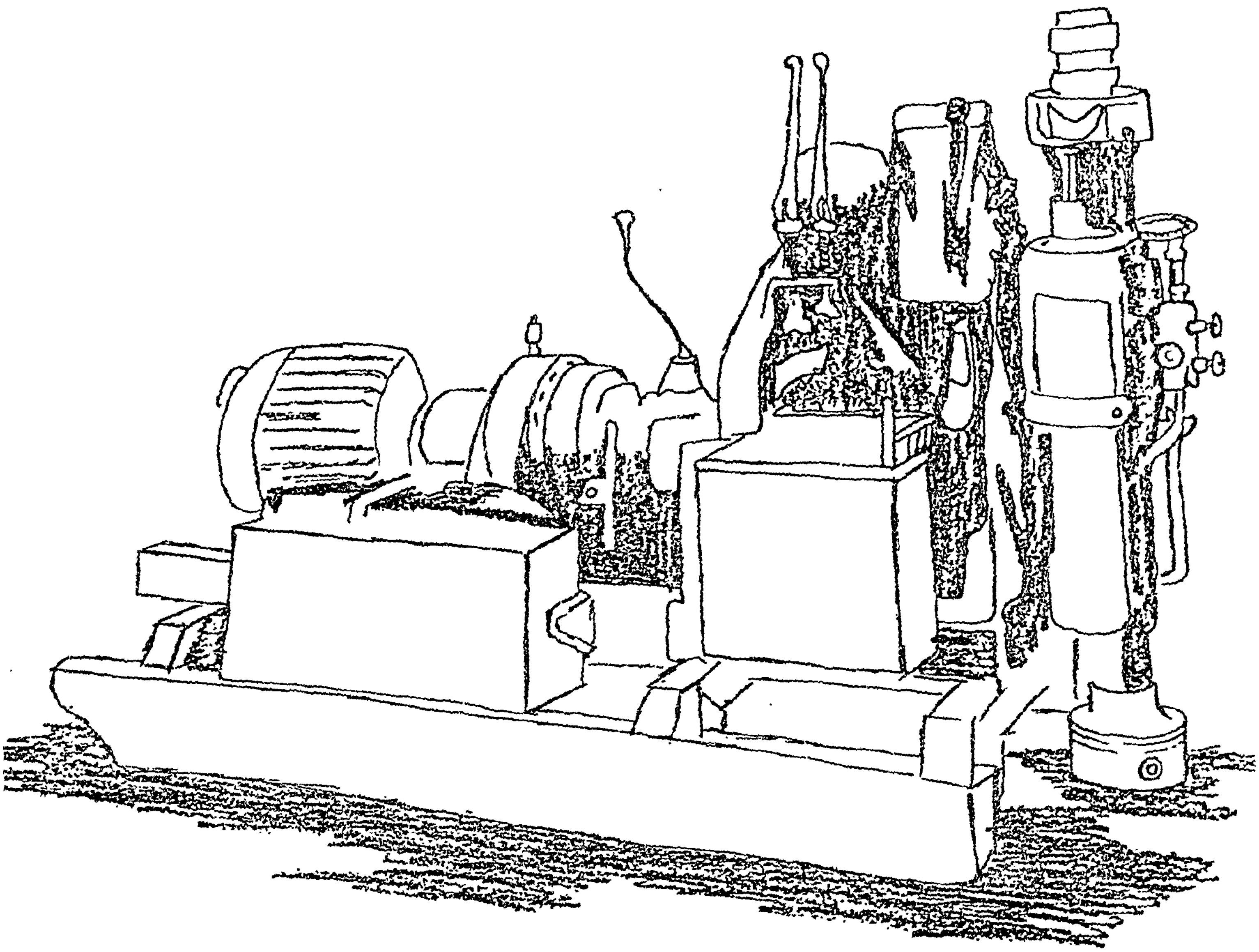

Figure 6.3 Electrically Driven, Skid Mounted Core Drill

TABLE 6.1

Drill Manufacturers Contacted and Their Reply as Regards the Large Hole Drilling Task

Company Name	Company Location	Machine Available	Preparing Proposal On
Calweld Division of Smith International, Inc.	Santa Fe Springs, California	yes	Bucket Drill
LeRoy Division of Dresser Industries and Boyle Brothers	Salt Lake City, Utah Orillia, Ontario	yes	Coring Drill
Robbins Drill Division of Joy Manufacturing	Birmingham Alabama	yes	Rotary Drill with Tri-Cone Bit
Hughes Tools	Houston, Texas	no	
The Robbins Company	Seattle, Washington	yes	Rotary Drill with Special Drag Bit
Atlas-Copco	Wayne, New Jersey	maybe	No Specific Ideas at this Time
Reed Tool Company	Sherman, Texas	no	
Gardner-Denver Company	Dallas, Texas	maybe	No Specific Ideas at this Time
Ingersoll-Rand	Denver, Colorado	no	
Long-Airdox	Oak Hill, W. Virginia	no	
Jeffery Mining	Columbus, Ohio	no	
EIMCO	Salt Lake City, Utah	no	
Acker Drill Company	Clark Summit, Pennsylvania	no	
Salem Tool Company	Salem, Ohio	no	
Smith Tool Company	Ervine, California	no	

CHAPTER 7

EXCAVATION/HAULAGE SYSTEMS

By

Thomas J. Zeller and William H. Grams

7.1. Mining Equipment Status

Mining equipment for salt mines in general has been found to be readily available from manufacturers. Most equipment can be adapted to this particular salt mine application without modification. A number of equipment systems are being considered in light of information received from manufacturers.

7.2. Excavation Systems

The four types of basic excavation systems considered and a selection of the manufacturers of equipment in this category are as follows:

(1) Continuous Miner: Coal Type -- Rotary Drum (as illustrated by Figure 7.1)

- (a) Atlas-Copco Inc.
- (b) Jeffery Mining Machinery Company
- (c) Joy Manufacturing Company
- (d) Lee-Norse Company

(2) Continuous Miner: Impulse Type (as illustrated by Figure 7.2)

- (a) Ingersoll Rand Company
- (b) Lee-Norse Company

(3) Continuous Miner: Boom Type (as illustrated by Figure 7.3)

- (a) Alpine Equipment Corporation

(4) Conventional Mining Equipment

- (a) Atlas-Copco Inc.
- (b) Ingersoll Rand Company
- (c) Joy Manufacturing Company
- (d) Long-Airdox Company
- (e) Schroeder Brothers Corporation

In addition to equipment manufacturers, Dupont has been contacted concerning blasting requirements.

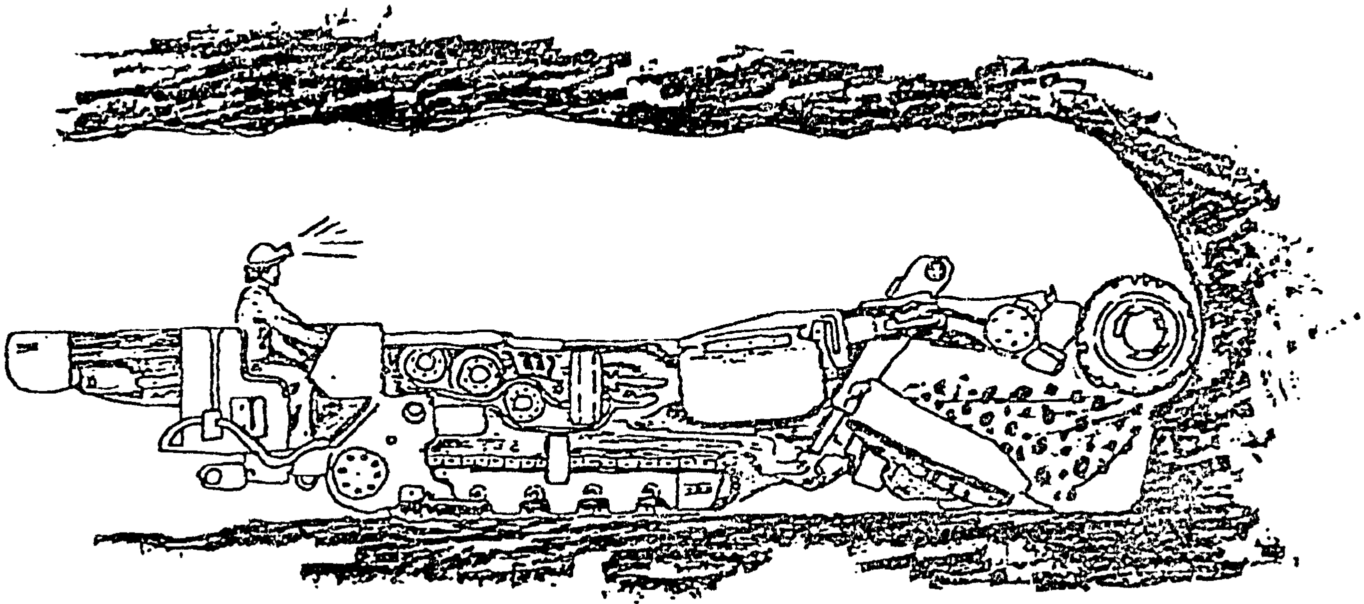

Figure 7.1. Continuous Miner - Rotary Drum

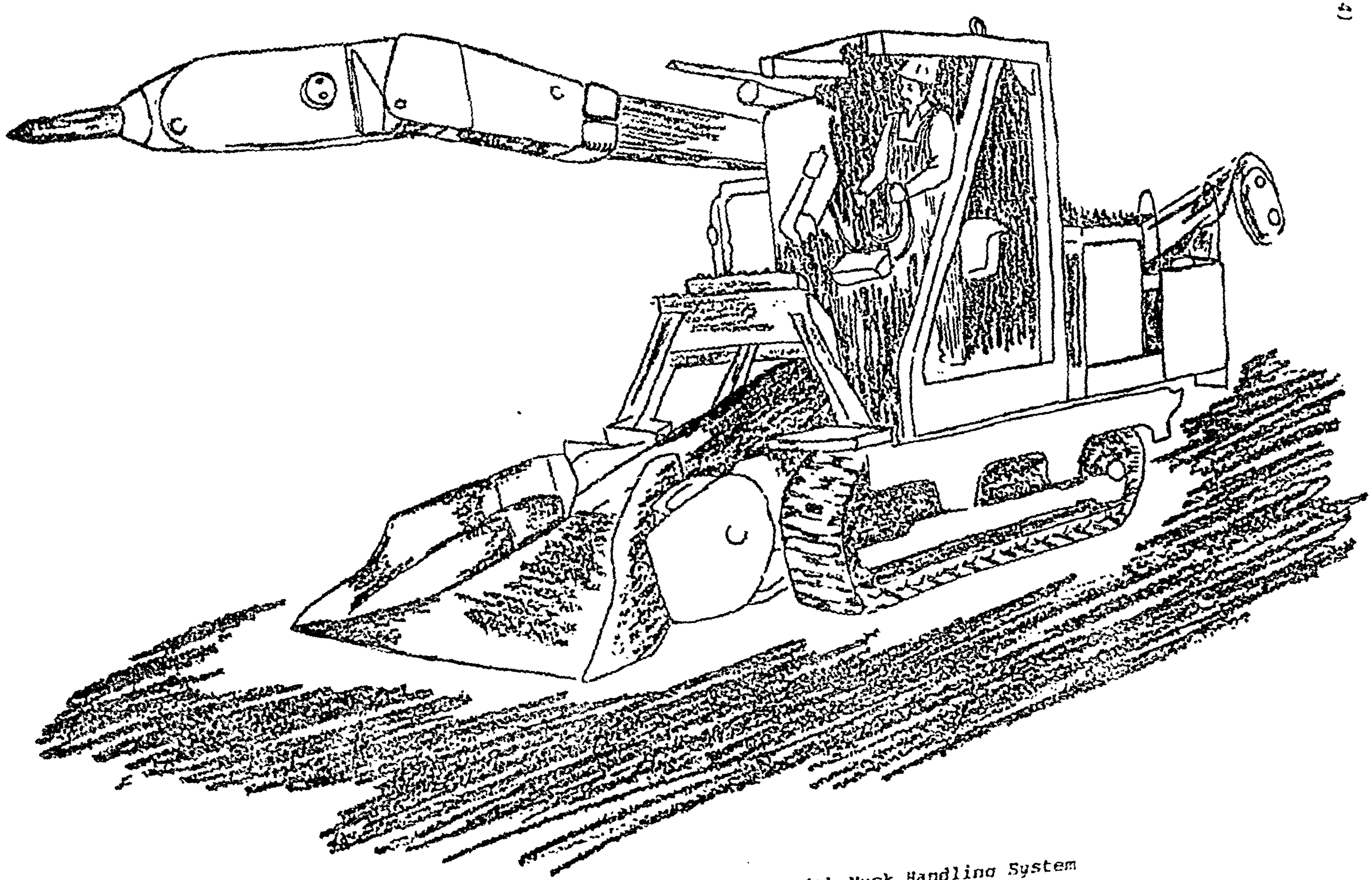

Figure 7.2. Impulse Type Continuous Miner with Muck Handling System

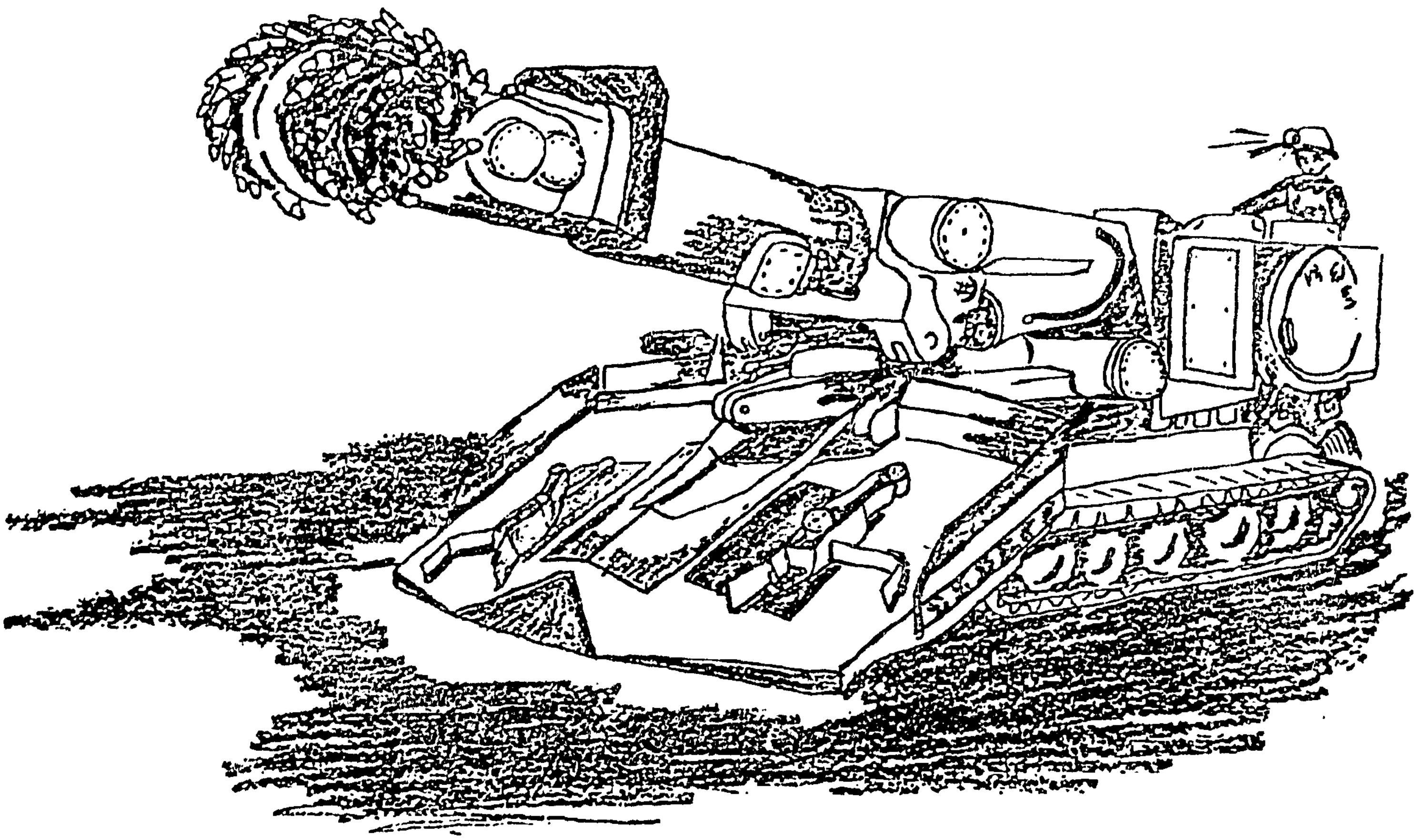

Figure 7.3. Continuous Miner, Boom Mounted Pineapple Cutter and Gathering Arm Muck Handling System

7.3. Haulage Systems and Auxiliary Equipment

Haulage system equipment has been defined as any equipment used in the mine other than that used directly on the face of the mine heading. This would include equipment such as loaders, load haul dump units, roof bolters, shuttle cars, feeder breakers, belt conveyors, and rail equipment. Manufacturers of haulage equipment other than rail equipment, which have been contacted are:

(a) Atlas Copco Inc.
(b) Envirotech Corporation
(c) Fairchild Equipment and Supply Company
(d) FMC Corporation
(e) Joy Manufacturing Company
(f) Lee-Norse Company
(g) Long-Airdox Company
(h) National Mine Service
(i) Schroeder Brothers Corporation
(j) Wagner

Rail equipment manufacturers contacted include:

(a) ACF Industries
(b) Card Corporation
(c) Difco, Inc.
(d) Jeffery Mining Machinery Company
(e) Lakeshore, Inc.
(f) Plymouth Locomotive
(g) West Virginia Armature

7.4. Problem Areas

Problems which may prove to be unique to this mine may cause design modifications in equipment or restrictions on what components may be used in the mining process. Some of the problems which may be anticipated in the equipment selection process are:

(1) Ventilation requirements due to the special nature of alpha waste repositories may preclude the use of diesel powered equipment. The mine could possibly be classified as gassy which would also limit the equipment to electric or air powered. This will mean that extra emphasis will be given to investigation of an all electric system. This would also keep noise levels and ventilation requirements to a minimum.

(2) Continuous mining equipment is basically designed to cut up to only 12 feet in height. This would mean that a 16-foot high mine heading would have to be cut by double benching.

(3) Roof bolters and auger face drills are not normally designed to cover 16 feet in vertical range. However, most manufacturers feel this is a small problem that can be easily overcome with a slight modification of present equipment.

7.5. Conventional vs. Continuous Mining

In the analysis of mining methods, there will be several trade-offs which will have to be researched before a decision can be made as to the optimum set of mining equipment components. From preliminary analysis of continuous and conventional mining methods, the following advantages and disadvantages have been determined:

Advantages of Conventional Mining Methods:

(1) High rate of production
(2) Multiple headings can be mined with the same equipment
(3) Entire heading can be mined with one pass
(4) Low maintenance, highly durable equipment
(5) Significant background in salt mines with conventional equipment

Disadvantages of Conventional Mining Methods:

(1) Blasting may fracture surrounding rock, weakening pillar and roof structures
(2) Floor may be relatively rough
(3) More pieces of equipment are required with conventional mining than with continuous mining techniques.
(4) Blasting may subject miners to excessive noise and possibly noxious fumes which would present additional ventilation requirements.

Advantages of Continuous Mining Equipment:

(1) Continuous operation of equipment
(2) Will not fracture surrounding rock
(3) Noise levels and fumes are held to acceptable levels
(4) Smooth floor for operating equipment

Disadvantages of Continuous Mining Equipment:

(1) Would probably have to be special equipment, extra heavy
(2) Little background on continuous mining in salt
(3) Would have to cut in two passes
(4) If continuous miner goes down for maintenance, all other production stops
(5) High capital outlay in relation to production requirements
(6) Would require more than one machine to work multiple headings

7.6. Concluding Remarks

The aforementioned problems, and the advantages and disadvantages of different mining methods, will be further researched to determine the optimum mining method within the given set of parameters. Further refinement of equipment requirements will come with the determination of excavation rates which are based on canister size and number of canisters per hole.

CHAPTER 8

SUMMARY OF APPLICABLE MESA AND OSHA SAFETY REQUIREMENTS

by

William H. Grams

8.1 General Remarks

The health and safety standards and regulations of general concern are governed by both OSHA and MESA. The OSHA regulations were obtained from the Federal Register Vol. 39, No. 122, Monday, June 24, 1974. The MESA regulations were obtained from the Metal and Non-Metal Mine Health and Safety Standards and Regulations, a guide to 30 CFR, Chapter 1, Parts 55, 56, 57, and 58.

OSHA is concerned with underground construction, in general, tunnelling. Therefore, many of the rules and regulations established by OSHA could be applicable to the low level repository. At present, no correspondence has been made with the OSHA personnel to determine if any or all of the OSHA standards will have to be considered.

MESA standards most certainly will have to be met, and hopefully exceeded.

The discussion herewith will concern itself only with those rules and regulations which would tend to affect the scope of the present contract for the initial investigation of the low level alpha waste repository.

8.2 Applicable MESA Requirements

The sections of particular interest as regards the MESA regulations are as follows:

(1) Section 57.3: Ground Control. In particular, paragraphs 57.3-29 concern the shaft pillar and would be of concern.

(2) Section 57.5: Air Quality, Ventilation, Radiation, and Physical

Agents. Paragraphs 57.5-37 through 42 concern radiation. This may be of concern, although it is set up for uranium mining. Paragraph 57.5-50 concerns physical agents, and the sections regarding dust and noise are of particular interest.

(3) Section 57.7: Drilling. This section deals mainly with safe drilling practices, but paragraph 57.7-13 states that large holes which could present a physical hazard must be covered.

(4) Section 57.11: Travelways and Escapeways. This section states the rules and regulations for safety in the areas where people are moving.

(5) Sections 57.21 through 57.25: Gassy Mines. These sections concern the mining practices in a mine that contains a flammable gas. Of particular interest is Section 57.21 on ventilation. Paragraph 46 states that crosscuts must be made between entries and rooms at an interval not in excess of 100 feet.

8.3. Applicable OSHA Rules

The sections of particular interest as regards the OSHA regulations are as follows:

(1) Subpart D: Occupational Health and Environmental Controls Section 1926.52 of the subpart deals with the Occupational Noise Exposure, and delineates acceptable sound pressure levels and the maximum working times allowable for a particular noise level.

(2) Subpart S: Tunnels and Shafts, Caissons, Cofferdams, and Compressed Air. The section of general concern to this project is 1926.800 or tunnels and shafts.

METAL AND NONMETAL MINE HEALTH AND SAFETY STANDARDS AND REGULATIONS

A Guide to
30 CFR, Chapter I
Parts 55, 56, 57 and 58

Promulgated under provisions of
Public Law 89-577
the
Federal Metal and Nonmetallic Mine
Safety Act

Mining Enforcement and Safety
Administration

(RSI-0024)

57.3-20 *Mandatory.* Ground support shall be used if the operating experience of the mine, or any particular area of the mine, indicates that it is required. If it is required, support, including timbering, rock bolting, or other methods shall be consistent with the nature of the ground and the mining method used.

57.3-21 Men should be trained in the proper methods of testing for, taking down, and supporting loose ground.

57.3-22 *Mandatory.* Miners shall examine and test the back, face, and ribs of their working places at the beginning of each shift and frequently thereafter. Supervisors shall examine the ground conditions during daily visits to insure that proper testing and ground control practices are being followed. Loose ground shall be taken down or adequately supported before any other work is done. Ground conditions along haulageways and travelways shall be examined periodically and scaled or supported as necessary.

57.3-23 A scaling bar of proper length and blunt on one end should be provided at each working face.

57.3-24 Picks or other short tools that would place the user in danger of falling rock should not be used for barring down.

57.3-25 Timbers should be blocked tightly.

57.3-26 Damaged or dislodged timbers which create a hazardous condition should be repaired or replaced promptly.

57.3-28 When necessary, permanent, or temporary ground support should be installed near enough to the bottom of the shaft during shaft sinking to prevent falls of rocks from the sides of the shaft.

57.3-29 Shaft pillars should have sufficient strength to protect operating shafts.

57.3-30 Rock-bolt installations should be installed in a manner to provide safe and effective ground support.

57.3-31 Rock-bolting materials should meet the applicable standards of the United States of America Standards Institute.

57.3-32 When needed, rock bolts should be installed as soon as possible after an area is exposed.

57.3-33 Torque meters or torque wrenches should be available at mines where rock bolts are used for ground support. Periodic tests should be made to determine if bolts meet recommended torque.

§ 57.5 Air quality, ventilation, radiation, and physical agents.

GENERAL—SURFACE AND UNDERGROUND

57.5-1 *Mandatory.* Except as permitted by § 57.5-5: (a) Except as provided in paragraph (b), the exposure to airborne contaminants shall not exceed, on the basis of a time weighted average, the threshold limit values adopted by the American Conference of Governmental Industrial Hygienists, as set forth and explained in the 1973 edition of the Conference's publication, entitled "TLV's Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973," pages 1 through 54, which are hereby incorporated by reference and made a part hereof. This publication may be obtained from the American Conference of Governmental Industrial Hygienists by writing to the Secretary-Treasurer, P.O. Box 1937, Cincinnati, Ohio 45201, or may be examined in any Metal and Nonmetal Mine Health and Safety District or Subdistrict Office of the Mining Enforcement and Safety Administration. Excursions above the listed thresholds shall not be of a greater magnitude than is characterized as permissible by the Conference.

(b) The 8-hour time weighted average airborne concentration of asbestos dust to which employees are exposed shall not exceed 5 fibers per milliliter greater than 5 microns in length, as determined by the membrane filter method at 400–450 magnification (4 millimeter objective) phase contrast illumination. No employee shall be exposed at any time to airborne concentrations of asbestos fibers in excess of 10 fibers longer than 5 micrometers, per milliliter of air, as determined by the membrane filter method over a minimum sampling time of 15 minutes. "Asbestos" is a generic term for a number of hydrated silicates that, when crushed or processed, separate into flexible fibers made up of fibrils. Although there are many asbestos minerals, the term "asbestos" as used herein is limited to the following minerals; chrysotile, amosite, crocidolite, anthophylite asbestos, tremolite asbestos, and actinolite asbestos.

(c) Employees shall be withdrawn from areas where there is present an airborne contaminant given a "C" designation by the Conference and the concentration exceeds the threshold limit value listed for that contaminant.

57.5-2 *Mandatory.* Dust, gas, mist, and fume surveys shall be conducted as frequently as necessary to determine the adequacy of control measures.

57.5-3 *Mandatory.* Holes shall be collared and drilled wet, or other efficient dust-control measures shall be used when drilling non-water-soluble material. Efficient dust-control measures shall be used when drilling water-soluble materials.

57.5-4 Muckpiles, haulage roads, rock transfer points, crushers, and other points where dust is produced in amounts sufficient to cause a health or safety hazard should be wetted down as often as necessary, unless the dust is controlled adequately by other methods.

57.5-5 *Mandatory.* Control of employees exposure to harmful airborne contaminants shall be, insofar as feasible, by prevention of contamination, removal by exhaust ventilation, or by dilution with uncontaminated air. However, where accepted engineering control measures have not been developed or when necessary by the nature of the work involved (for example, while establishing controls or occasional entry into hazardous atmospheres to perform maintenance or investigation), employees may work for reasonable periods of time in concentrations of airborne contaminants exceeding permissible levels if they are protected by appropriate respiratory protective equipment. Whenever respiratory protective equipment is used a program for selection, maintenance, training, fitting, supervision, cleaning, and use shall meet the following minimum requirements:

(a) Mining Enforcement and Safety Administration approved respirators which are applicable and suitable for the purpose intended shall be furnished, and employees shall use the protective equipment in accordance with training and instruction.

(b) *A respirator program consistent with* the requirements of ANSI Z88.2-1969, published by the American National Standards Institute and entitled "American National Standards Practices for Respiratory Protection ANSI Z88.2 1969," approved August 11, 1969, which is hereby incorporated by reference and made a part hereof. This publication may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018, or may be examined in any Metal and Nonmetal Mine Health and Safety District or Subdistrict Office of the Mining Enforcement and Safety Administration.

(c) When respiratory protection is used in atmospheres immediately harmful to life, the presence of at least one other person with backup equipment and rescue capability shall be required in the event of failure of the respiratory equipment.

UNDERGROND ONLY

57.5-15 Atmospheres in all active areas should contain at least 20 percent oxygen.

VENTILATION

UNDERGROUND ONLY

57.5-21 Main fans should be installed on the surface; if it is necessary to locate them underground, they should be in fire-resistant areas and should be provided with remote controls.

57.5-22 *Mandatory.* Fan housings and air ducts connecting main fans to underground openings shall be fire-resistant.

57.5-23 Separate mine openings should be provided for main intake- and return-air currents except during early stages of development. A multiple compartment shaft is a single opening for the purpose of this standard.

57.5-25 Main fans should be inspected and maintained properly.

57.5-26 Instruments should be provided to test the mine atmosphere quantitatively for carbon monoxide, nitrogen dioxide, and other gases that occur in the mine. Tests should be conducted as frequently as necessary to assure that the required quality of air is maintained.

57.5-27 Flame safety lamps or other suitable devices should be used to test for acute oxygen deficiency.

57.5-28 *Mandatory.* Unventilated areas shall be sealed, or barricaded and posted against entry.

57.5-29 When used, ventilation tubing should be installed so that the air current sweeps the face areas effectively. Maximum distance of the end of the tubing from the face generally should be 30 feet for blowing and 6 feet for exhausting.

57.5-30 Ventilation doors not operated mechanically should be designed and installed so that they are self-closing and will remain closed regardless of the direction of the air movement.

RADIATION

UNDERGROUND ONLY

57.5-37 *Mandatory.* Mine atmospheres shall be sampled to determine if hazardous concentrations of radon daughters are present. Where potentially hazardous concentrations are found, or known sources of radon exist, each active work area shall be sampled as often as necessary by a qualified person.

57.5-38 *Mandatory.* No employee shall be permitted to receive an exposure of more than 6 WLM (working level months) in any consecutive 3-month period and no more than 12 WLM in any consecutive 12-month period. *Superseded**

57.5-39 *Mandatory.* If samples show an atmospheric concentration of radon daughters of more than 1.0 working level, but less than 2.0 working levels, immediate corrective action shall be taken or the men shall be withdrawn. When concentrations higher than 2.0 working levels are found, the men shall be withdrawn from the area until corrective action is taken and the radon-daughter atmospheric concentrations are reduced to 1.0 working level or less.

57.5-40 *Mandatory.* (a) Where uranium is mined, if measurements in areas indicate exposure to concentrations of radon daughters in excess of 0.3 working level, complete individual exposure records shall be kept for all employees entering these areas.

(b) * * *

57.5-41 *Mandatory.* Smoking shall be prohibited where uranium is mined.

57.5-42 *Mandatory.* If levels of permissible exposures to concentrations of radon daughters different from those prescribed in 57.5-38 are recommended by the Environmental Protection Agency and approved by the President, no employee shall be permitted to receive exposures in excess of those levels after the effective dates established by the Agency.

*As provided in 57.5-42, permissible annual radiation-exposure levels of no more than 4 WLM were recommended by the Environmental Protection Agency and approved by the President, effective July 1, 1971.

PHYSICAL AGENTS

GENERAL—SURFACE AND UNDERGROUND

57.5-50 *Mandatory.* (a) No employee shall be permitted an exposure to noise in excess of that specified in the table below. Noise level measurements shall be made using a sound level meter meeting specifications for type 2 meters contained in American National Standards Institute (ANSI) Standard S1.4-1971, "General Purpose Sound Level Meters," approved April 27, 1971, which is hereby incorporated by reference and made a part hereof, or by a dosimeter with similar accuracy. This publication may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018, or may be examined in any Metal and Nonmetal Mine Health and Safety District or Subdistrict Office of the Mining Enforcement and Safety Administration.

PERMISSIBLE NOISE EXPOSURES

Duration per day, hours of exposure:	*Sound level dBA, slow response*
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

No exposure shall exceed 115 dBA. Impact or impulsive noises shall not exceed 140 dB, peak sound pressure level.

NOTE. When the daily exposure is composed of two or more periods of noise exposure at different levels, their combined effect shall be considered rather than the individual effect of each.

If the sum $\frac{C_1}{T_1}+\frac{C_2}{T_2}+\ldots\frac{C_n}{T_n}$ exceeds unity,

then the mixed exposure shall be considered to exceed the permissible exposure. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level. Interpolation between tabulated values may be determined by the following formula:

$$\log T=6.322-0.0602\ SL$$

Where T is the time in hours and SL is the sound level in DBA.

(b) When employees' exposure exceeds that listed in the above table, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce exposure to within permissible levels, personal protection equipment shall be provided and used to reduce sound levels to within the levels of the table.

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§ 57.7 Drilling.

SURFACE ONLY

57.7-1 Equipment that is to be used during a shift should be inspected each shift by a competent person. Equipment defects affecting safety should be reported.

57.7-2 *Mandatory.* Equipment defects affecting safety shall be corrected before the equipment is used.

57.7-3 *Mandatory.* The drilling area shall be inspected for hazards before starting the drilling operations.

57.7-4 *Mandatory.* Men shall not be on a mast while the drill-bit is in operation unless they are provided with a safe platform from which to work and they are required to use safety belts to avoid falling.

57.7-5 *Mandatory.* Drill crews and others shall stay clear of augers or drill stems that are in motion. Persons shall not pass under or step over a moving stem or auger.

57.7-6 Receptacles or racks should be provided for drill steel stored on drills.

57.7-7 Tools and other objects should not be left loose on the mast or drill platform.

57.7-8 *Mandatory.* When a drill is being moved from one drilling area to another, drill steel, tools, and other equipment shall be secured and the mast placed in a safe position.

57.7-9 The drill helper, when used, should be in sight of the operator at all times while the drill is being moved to a new location.

57.7-10 *Mandatory.* In the event of power failure, drill controls shall be placed in the neutral position until power is restored.

57.7-11 *Mandatory.* The drill stem shall be resting on the bottom of the hole or on the platform with the stem secured to the mast before attempts are made to straighten a crossed cable on a reel.

57.7-12 *Mandatory.* While in operation, drills shall be attended at all times.

57.7-13 *Mandatory.* Drill holes large enough to constitute a hazard shall be covered or guarded.

57.7-14 Men operating or working near jackhammers or jackleg drills and other drilling machines should position themselves so that they will not be struck or lose their balance if the drill steel breaks or sticks.

57.7-15 Men should not drill from positions that hinder their access to the control levers, or from insecure footing or staging, or from atop equipment not designed for this purpose.

57.7-16 Bit wrenches or bit knockers should be used to remove detachable bits from drill steel.

57.7-17 Starter steels should be used when collaring holes with handheld drills.

57.7-18 *Mandatory.* Men shall not hold the drill steel while collaring holes, or rest their hands on the chuck or centralizer while drilling.

57.7-19 Air should be turned off and bled from the hose before handheld drills are moved from one working area to another.

(RSI-0024)

UNDERGROUND ONLY

57.7-25 Men operating or working near drilling machines should position themselves so that they will not be struck or lose their balance if the steel breaks or sticks.

57.7-26 Men should not attempt to operate drills from positions that hinder their access to the control levers.

57.7-27 Drilling should not be attempted from insecure footing or staging, or from atop equipment not designed for this purpose.

57.7-28 Men should not hold the drill steel while collaring holes, or rest their hands on the chuck or centralizer while drilling.

57.7-29 Air should be turned off before moving portable drills from one face to another.

57.7-30 Receptacles or racks should be provided for drill steel stored on jumbos.

57.7-31 Before drilling cycle is started, warning should be given to men working below jumbo decks.

57.7-32 Drills on columns should be anchored firmly before drilling is started and should be retightened frequently thereafter.

§ 57.11 Travelways and escapeways.

TRAVELWAYS

GENERAL—SURFACE AND UNDERGROUND

57.11-1 *Mandatory.* Safe means of access shall be provided and maintained to all working places.

57.11-2 *Mandatory.* Crossovers, elevated walkways, elevated ramps, and stairways shall be of substantial construction, provided with handrails, and maintained in good condition. Where necessary, toeboards shall be provided.

57.11-3 *Mandatory.* Ladders shall be of substantial construction and maintained in good condition.

57.11-4 Portable straight ladders should be provided with nonslip bases, should be placed against a safe backing, and set on secure footing.

57.11-5 *Mandatory.* Fixed ladders shall be anchored securely and installed to provide at least 3 inches of toe clearance.

57.11-6 *Mandatory.* Fixed ladders shall project at least 3 feet above landings, or substantial handholds shall be provided above the landings.

57.11-7 Wooden members of ladders should not be painted.

57.11-8 Ladderways, stairways, walkways, and ramps should be kept free of loose rock and extraneous materials.

57.11-9 *Mandatory.* Walkways with outboard railings shall be provided wherever persons are required to walk alongside elevated conveyor belts. Inclined railed walkways shall be nonskid or provided with cleats.

57.11-10 Vertical clearance above stair steps should be a minimum of 7 feet or adequate warning should be provided to indicate an impaired clearance.

57.11-11 Men climbing or descending ladders should face the ladders and have both hands free for climbing.

57.11-12 *Mandatory.* Openings above, below, or near travelways through which men or materials may fall shall be protected by railings, barriers, or covers. Where it is impractical to install such protective devices, adequate warning signals shall be installed.

57.11-13 *Mandatory.* Crossovers shall be provided where it is necessary to cross conveyors.

57.11-14 *Mandatory.* Moving conveyors shall be crossed only at designated crossover points.

57.11-15 Slippery walkways should be provided with cleats and handrails and/or ropes.

57.11-16 *Mandatory.* Regularly used walkways and travelways shall be sanded, salted, or cleared of snow and ice as soon as practicable.

57.11-17 Fixed ladders should not incline backwards at any point unless provided with backguards.

SURFACE ONLY

57.11-25 Fixed ladders should be offset and have substantial railed landings at least every 30 feet unless backguards are provided.

57.11-26 Steep fixed ladders (70° to 90° from the horizontal) 30 feet or more in length, should be provided with backguards, cages, or equivalent protection, starting at a point not more than 7 feet from the bottom of the ladder.

57.11-27 *Mandatory.* Scaffolds and working platforms shall be of substantial construction and provided with handrails and maintained in good condition. Floorboards shall be laid properly and the scaffolds and working platform shall not be overloaded. Working platforms shall be provided with toeboards when necessary.

UNDERGROUND ONLY

57.11-35 Flexible ladders should be used only where rigid ladders may be impractical.

57.11-36 *Mandatory.* Trap doors or adequate guarding shall be provided in ladderways at each level. Doors shall be kept operable.

57.11-37 The minimum, unobstructed cross-sectional opening in ladderways should be 24 inches by 24 inches.

57.11-38 Warning should be given and acknowledged before entering a manway above or below where men are working.

57.11-39 Working floors in square-set stopes should be lagged closely and securely, and open sets should be equipped with guardrails.

57.11-40 Travelways steeper than 30° from the horizonal should be provided with ladders or stairways.

57.11-41 Ladders with an inclination of more than 70° off the horizontal should be offset and have landing gates, backguards or substantial landings at least every 30 feet.

ESCAPEWAYS

UNDERGROUND ONLY

57.11-50 *Mandatory.* Every mine shall have two separate properly maintained escapeways to the surface which are so positioned that damage to one shall not lessen the effectiveness of the other, or a method of refuge shall be provided when only one opening to the surface is possible.

57.11-51 *Mandatory.* Escape routes shall be:

(a) Inspected at regular intervals and maintained in safe, travelable condition.

(b) Marked with conspicuous and easily read direction signs that clearly indicate the ways of escape.

57.11-52 *Mandatory.* Refuge areas shall be:

(a) Of fire-resistant construction, preferably in untimbered areas of the mine.

(b) Large enough to accommodate readily the normal number of men in the particular area of the mine.

(c) Constructed so they can be made gas-tight.

(d) Provided with compressed air lines, waterlines, suitable handtools, and stopping materials.

57.11-53 *Mandatory.* A specific escape and evacuation plan and revisions thereof suitable to the conditions and mining system of the mine and showing assigned responsibilities of all key personnel in the event of an emergency shall be developed by the operator and set out in written form. Within 45 calendar days after promulgation of this standard a copy of the plan and revisions thereof shall be available to the Secretary or his authorized representative. Also copies of the plans and revisions thereof shall be posted at locations convenient to all persons on the surface and underground. Such a plan shall be updated as necessary and shall be reviewed jointly by the operator and the Secretary or his authorized representative at least once every six months from the date of the last review. The plan shall include:

(a) Mine maps or diagrams showing directions of principal air flow, location of escape routes and locations of existing telephones, primary fans, primary fan controls, fire doors, ventilation doors, and refuge chambers. Appropriate portions of such maps or diagrams shall be posted at all shaft stations and in underground shops, lunchrooms, and elsewhere in working areas where men congregate.

(b) Procedures to show how the miners will be notified of emergency.

(c) An escape plan for each working area in the mine to include instructions showing how each working area should be evacuated. Each such plan shall be posted at appropriate shaft stations and elsewhere in working areas where men congregate.

(d) A fire fighting plan.

(e) Surface procedure to follow in an emergency, including the notification of proper authorities, preparing rescue equipment, and other equipment which may be used in rescue and recovery operations.

(f) A statement of the availability of emergency communication and transportation facilities, emergency power and ventilation and location of rescue personnel and equipment.

57.11-54 *Mandatory.* Telephone or other voice communication shall be provided between the surface and refuge chambers and such systems shall be independent of the mine power supply.

57.11-55 *Mandatory.* Designated escapeways inclined more than 30° from the horizontal shall be equipped with stairways, ladders, cleated walkways, or emergency hoisting facilities.

57.11-56 Emergency hoisting facilities should conform to the extent possible to safety requirements for other man hoists, should be adequate to remove the men from the mine with a minimum of delay, be maintained in ready condition, and be tested at least every 30 days; records should be kept of these tests.

57.11-58 *Mandatory*. Each operator of an underground mine shall establish a check-in and check-out system which shall provide an accurate record of persons in the mine. These records shall be kept on the surface in a place chosen to minimize the danger of destruction by fire or other hazards. Every person underground shall carry a positive means of being identified.

§ 57.21 Gassy mines.

Gassy mines shall be operated in accordance with all mandatory standards in this part. Such mines shall also be operated in accordance with the mandatory standards in this section. The standards in this section apply *only* to underground operations.

MINE CLASSIFICATION

57.21-1 *Mandatory*. A mine shall be deemed gassy, and thereafter operated as a gassy mine, if:

(a) The State in which the mine is located classifies the mine as gassy; or

(b) Flammable gas emanating from the orebody or the strata surrounding the orebody has been ignited in the mine; or

(c) A concentration of 0.25 percent or more, by air analysis, of flammable gas emanating only from the orebody or the strata surrounding the orebody has been detected not less than 12 inches from the back, face, or ribs in any open workings; or

(d) The mine is connected to a gassy mine.

57.21-2 *Mandatory*. Flammable gases detected while unwatering mines and similar operations shall not be used to class a mine gassy.

Fire Prevention and Control

57.21-10 *Mandatory.* Men shall not smoke or carry smoking materials, matches, or lighters underground. The operator shall institute a reasonable program to ensure that persons entering the mine do not carry smoking materials, matches, or lighters.

57.21-11 *Mandatory.* Except when necessary for welding or cutting, open flames shall not be used in other than fresh air or in places where flammable gases are present or may enter the air current.

57.21-12 *Mandatory.* Welding or cutting with arc or flame underground in other than fresh air or in places where flammable gases are present or may enter the air current shall be under the direct supervision of a qualified person who shall test for flammable gases before and frequently during such operations.

57.21-13 *Mandatory.* Welding or cutting shall not be performed in atmospheres, containing more than 1.0 percent of flammable gases.

Ventilation

57.21-20 *Mandatory.* Main fans shall be:

(a) Installed on the surface.

(b) Powered electrically from a circuit independent of the mine power circuit. Internal combustion engines shall be used only for standby power, or where electrical power is not available.

(c) Installed in fireproof housing provided with fireproof air ducts.

(d) Offset not less than 15 feet from the nearest side of the mine opening and equipped with ample means of pressure relief unless:

(1) The opening is not in direct line with forces which would come out of the mine should an explosion occur; and

(2) Another opening not less than 15 feet nor more than 100 feet from the fan opening is equipped with a weak-wall stopping or explosion doors in direct lines with the forces which would come out of the mine should an explosion occur.

(e) Installed to permit prompt reversal of airflow.

(f) Attended constantly, or provided with automatic devices to give alarm when the fans slow down to stop. Such devices shall be placed so they will be seen or heard by responsible persons.

57.21-21 Main fans should be:

(a) Operated continuously except when the mine is shut down for an extended period.

(b) Provided with pressure-recording gages.

(c) Inspected daily and records kept of such inspections and of fan maintenance.

57.21-22 The main intake and return air currents in mines should be in separate shafts, slopes, or drifts.

57.21-23 *Mandatory.* When single shafts are used for intake and return the curtain wall or partition shall be constructed of reinforced concrete or equivalent and provided with pressure relief devices.

57.21-24 *Mandatory.* When a main fan fails or stops and ventilation is not restored in a reasonable time, action shall be taken to cut off the power to the areas affected and to withdraw all men from such areas.

57.21-25 When there has been a failure of ventilation and ventilation has been restored in a reasonable time, all places where flammable gas may have accumulated should be examined by a qualified person and determined to be free of flammable gas before power is restored and work resumed.

57.21-26 *Mandatory.* When ventilation is not restored in a reasonable time, all men shall be removed from the areas affected, and after ventilation has been restored, the areas affected shall be examined by qualified persons for gas and other hazards and made safe before power is restored and before men, other than the examiners and other authorized persons, return to the areas affected.

57.21-27 *Mandatory.* When the main fan or fans have been shut down with all men out of the mine, no person, other than those qualified to examine the mine, or other authorized persons, shall go underground until the fans have been started and the mine examined for gas and other hazards and declared safe.

57.21-28 *Mandatory.* Booster fans shall be:

(a) Operated by permissible drive units maintained in permissible condition.

(b) Operated only in air containing not more than 1.0 percent flammable gas.

57.21-29 *Mandatory.* A booster fan shall be:

(a) Equipped with an automatic device to give alarm when the fan slows or stops, or equipped with a device that automatically cuts off the power in the area affected if the fan slows or stops.

(b) Provided with air locks, the doors of which open automatically if the fan stops.

57.21-30 *Mandatory.* Auxiliary fans shall be:

(a) Operated by permissible drive units maintained in permissible condition.

(b) Operated only in air containing not more than 1.0 percent flammable gas.

57.21-31 Auxiliary fans should be inspected by competent persons at least twice each shift.

57.21-32 *Mandatory.* Men shall be withdrawn from areas affected by auxiliary or booster fans when such fans slow down or stop.

57.21-33 *Mandatory.* The volume and velocity of the current of air coursed through all active areas shall be sufficient to dilute and carry away flammable gases, smoke and fumes.

57.21-34 *Mandatory.* The quantity of air coursed through the last open crosscut in pairs or sets of entries or through other ventilation openings nearest the face, shall be at least 6,000 cubic feet a minute.

57.21-35 *Mandatory.* At least once each week, a qualified person shall measure the volume of air entering the main intakes and leaving the main returns, the volume of the intake and return of each split, and the volume through the last open crosscuts or other ventilation openings nearest the active faces. Records of such measurements shall be kept in a book on the surface.

57.21-36 Permanently installed battery-charging and transformer stations should be ventilated by separate spilts of air conducted directly to return-air courses.

57.21-37 Electrically operated pumps, compressors, and portable substations should be in intake air.

57.21-38 *Mandatory.* Changes in ventilation that materially affect the main air current or any split thereof and may affect the safety of persons in the mine shall be made only when the mine is idle. Only those persons engaged in making such changes shall be permitted in the mine during the change. Power shall be removed from the areas affected by the change before work starts and not restored until the effect of the change has been ascertained and the affected areas determined to be safe by a qualified person.

57.21-39 *Mandatory.* If flammable gas in excess of 1.0 percent by volume is detected in the air not less than 12 inches from the back, face, and rib of an underground working place, or in air returning from a working place or places, adjustments shall be made in the ventilation immediately so that the concentration of flammable gas in such air is reduced to 1.0 percent or less.

57.21-40 *Mandatory.* If 1.5 percent or higher concentration of flammable gas is detected in air returning from an underground working place or places, the men shall be withdrawn and the power cut off to the portion of the mine endangered by such flammable gas until the concentration of such gas is reduced to 1.0 percent or less.

57.21-41 *Mandatory.* Air that has passed by an opening of any unsealed abandoned area and contains 0.25 percent or more of flammable gas shall not be used to ventilate working areas. Examinations of such air shall be conducted during the preshift examinations required by 57.21-59.

57.21-42 *Mandatory.* Air that has passed through an abandoned panel or area which is inaccessible or unsafe for inspection shall not be used to ventilate any working place in such mine. No air which has been used to ventilate an area from which the pillars have been removed shall be used to ventilate any working place in such mine, except that such air, if it does not contain 0.25 volume per centum or more of methane, may be used to ventilate enough advancing working places immediately adjacent to the line of retreat to maintain an orderly sequence of pillar recovery on a set of entries.

57.21-43 *Mandatory.* Abandoned areas shall be sealed or ventilated; areas that are not sealed shall be barricaded and posted against unauthorized entry.

57.21-44 *Mandatory.* Seals shall be of substantial construction. Exposed surfaces shall be made of fire-resistent material or, if the commodity mined is combustible, seals shall be made of incombustible material.

57.21-45 *Mandatory.* One or more seals of every sealed area shall be fitted with a pipe and a valve or cap to permit sampling of the atmosphere and measurement of the pressure behind such seals.

57.21-46 *Mandatory.* Crosscuts shall be made at intervals not in excess of 100 feet between entries and between rooms.

57.21-47 Crosscuts should be closed where necessary to provide adequate face ventilation.

57.21-48 *Mandatory.* Line brattice or other suitable devices shall be installed from the last open crosscut to a point near the face to assure positive air flow to the face of every active underground working place, unless the Secretary or his authorized representative permits an exception to this requirement.

57.21-49 Brattice cloth should be of flame-resistant material.

57.21-50 *Mandatory.* Damaged brattices shall be repaired promptly.

57.21-51 Crosscuts should be provided, where practicable, at or near the faces of entries and rooms before they are abandoned.

57.21-52 *Mandatory.* Entries or rooms shall not be started off entries beyond the last open crosscuts, except that room necks and entries not to exceed 18 feet in depth may be turned off entries beyond the last open crosscuts if such room necks or entries are kept free of accumulations of flammable gas by us of line brattice or other adequate means.

57.21-53 Stoppings in crosscuts between intake and return airways, on entries other than room entries, should be built of solid, substantial material; exposed surfaces should be made of fire-resistant material or, if the material mined is combustible, stoppings should be made of incombustible material.

57.21-54 Stoppings should be reasonably airtight.

57.21-55 *Mandatory.* The main ventilation shall be so arranged by means of air locks, overcasts, or undercasts that the passage of trips or persons does not cause interruptions of air currents. Where air locks are impracticable, single doors may be used if they are attended constantly while the areas of the mine affected by the doors are being worked, unless they are operated mechanically or are self-closing.

57.21-56 *Mandatory.* Air locks shall be ventilated sufficiently to prevent accumulations of flammable gas inside the locks.

57.21-57 *Mandatory.* Doors shall be kept closed except when men or equipment are passing through the doorways.

57.21-58 Overcasts and undercasts should be:

(a) Constructed tightly of incombustible material.

(b) Of sufficient strength to withstand possible falls from the back.

(c) Kept clear of obstructions.

57.21-59 *Mandatory.* Preshift examinations shall be made of all working areas by qualified persons within 3 hours before any workmen, other than the examiners, enter the mine.

57.21-61 *Mandatory.* Only qualified examiners and persons authorized to correct the dangerous conditions shall enter places or areas where danger signs are posted.

57.21-62 *Mandatory.* Danger signs shall not be removed until the dangerous conditions have been corrected.

57.21-65 Examinations for dangerous conditions, including tests for flammable gas with a device approved by the Secretary should be made at least once each week, and at intervals of not more than 7 days, by the mine foreman or other designated mine official, except during weeks in which the mine is idle for the entire week. The foreman or other designated mine official should:

(a) Examine and make tests:

(1) In the return of each split where it enters the main return,

(2) On accessible pillar falls,

(3) At seals,

(4) In the main return,

(5) In at least one entry of each intake and return airway in its entirety,

(6) In idle workings,

(7) In abandoned workings, insofar as conditions permit.

(b) Mark his initials and the date at the places examined;

(c) Report dangerous conditions promptly to the mine operator or other designated person;

(d) Record the results of his examination with ink or indelible pencil in a book kept for that purpose at a designated place on the surface of the mine.

57.21-66 The mine foreman or other designated mine official should read and countersign promptly the reports of daily and weekly examinations by qualified persons and should take prompt action to have dangerous conditions corrected.

EQUIPMENT

57.21-76 *Mandatory.* Diesel-powered equipment shall not be taken into or operated in places where flammable gas exceeds 1.0 percent at any point not less than 12 inches from the back, face, and rib.

57.21-77 *Mandatory.* Trolley wires and trolley feeder wires shall be on intake air and shall not extend beyond the last open crosscut or other ventilation opening. Such wires shall be kept at least 150 feet from pillar workings.

57.21-78 *Mandatory.* Only permissible equipment maintained in permissible condition shall be used beyond the last open crosscut or in places where dangerous quantities of flammable gases are present or may enter the air current.

57.21-79 *Mandatory.* Only permissible distribution boxes shall be used in working places and other places where dangerous quantities of flammable gas may be present or may enter the air current.

57.21-81 *Mandatory.* No electric equipment shall be taken into or operated in places where flammable gas can be detected in the amount of 1.0 percent or more at any point not less than 12 inches from the back, face, and rib.

ILLUMINATION

57.21-90 *Mandatory.* Only permissible electric lamps shall be used for portable illumination underground.

EXPLOSIVES

57.21-95 *Mandatory.* Explosives not designated as permissible by the Bureau of Mines or the Mining Enforcement and Safety Administration shall not be used in any underground gassy mine until the Mining Enforcement and Safety Administration and State Inspector of Mines have given written approval for each such specific explosive to be used.

57.21-96 *Mandatory.* The Mining Enforcement and Safety Administration and the State Inspector of Mines, in granting approval referred to in standard 57.21-95, shall provide the operator with a written list of conditions for using the specific explosives covered by the approval and adapted to the mining operation.

57.21-97 *Mandatory.* Blasts in gassy mines shall be initiated electrically, and multiple-shot blasts shall be initiated only with millisecond-delay detonators. Permissible blasting units of capacity suitable for the number of holes in a round to be blasted shall be used unless the round is fired from the surface when all men are out of the mine.

57.21-98 *Mandatory.* Boreholes shall be stemmed as prescribed for the explosives used.

57.21-99 *Mandatory.* Examinations for gas shall be made immediately before and after firing each shot or round.

57.21-100 *Mandatory.* Shots or rounds shall not be fired in places where flammable gas can be detected with a permissible flame safety lamp, or where 1.0 percent or more of flammable gas can be detected by any other Bureau of Mines or the Mining Enforcement and Safety Administration approved device or method, at a point not less than 12 inches from the back, face, and rib.

57.21-101 Shots and rounds should be fired by qualified persons.

§ 57.24 Variances—General.

57.24-1 *Except as provided in* § 57.24-7, the Administrator, Mining Enforcement and Safety Administration, may, in accordance with the provisions of this § 57.24, permit a variance from a mandatory standard in this part other than those relating to exposure to concentrations of radon daughters. The Administrator may permit such a variance only by means of a written decision specifically describing the variance permitted and the restrictions and conditions to be observed and finding that, in the circumstances, the health and safety of all persons which the mandatory standard is designed to protect *will be no less assured* under the variance permitted. The Administrator may, in writing delegate the authority conferred by this § 57.24 to the Deputy Administrator, Mining Enforcement and Safety Administration, the Assistant Administrator, Metal and Nonmetal Mine Health and Safety, and the Metal and Nonmetal Mine Health and Safety District Managers.

57.24-2 An application for a variance must be in writing and filed with the Administrator, Mining Enforcement and Safety Administration, Department of the Interior, Washington, D.C. 20240. A copy of the application must be mailed or otherwise delivered to the District Manager of the Metal and Nonmetal Mine Health and Safety District of the Mining Enforcement and Safety Administration in which the mine is located and a copy must be mailed or otherwise delivered to the State agency responsible for health and safety in the mine.

57.24-3 Before an application for a variance is filed, the person making such application shall give notice of the contents of the application to all persons employed in the area of the mine that would be affected by the variance if granted. Such notice may be given by the delivery of a copy to each such employee individually; or by the delivery of a copy of the application to an organization, agency, or individual authorized by the employees to represent them; or by posting a copy on a bulletin board at the m[illegible] office or in some other appropriate pla[illegible] at the mine adequate to give notice to the employees. An application will be rejected if it does not show that the notice required by this subsection has been given.

57.24-4 An application for a variance must:

(a) Specify the mandatory standard or standards from which the variance is requested:

(b) Describe the variance requested:

(c) Identify the areas of the mine that would be affected by the variance;

(d) Give the reasons why the standard or standards cannot or should not be strictly complied with;

(e) Specify the time period for which the variance is requested;

(f) Describe the work assignments of persons employed in affected areas of the mine, specifying the number of persons having each work assignment;

(g) Explain how the health and safety of persons employed in the affected areas of the mine will be no less assured if the requested variance is granted than through strict compliance with the standard or standards;

(h) Indicate the authority of the person signing the application;

(i) Include a statement describing how, and on what dates, the notice required in subsection 57.24-3 was given.

57.24-5 For a period of 15 days following the date on which an application for a variance is filed, any interested person may submit to the Administrator, Mining Enforcement and Safety Administration, written data, views, or arguments, respecting the application. Copies of such comments shall be mailed or otherwise delivered to the District Manager of the Health and Safety District of the Mining Enforcement and Safety Administration in which the mine is located, to the State agency responsible for health and safety in the mine, and to the person making the application. The Administrator may hold a public hearing if he determines that such a hearing would contribute to his consideration of the application. The Administrator shall issue a decision on an application promptly following the expiration of the period of 15 days and the conclusion of a hearing, if any.

57.24-6 Notwithstanding the provisions of subsection 57.24-5, a temporary variance from a mandatory standard may be approved before the expiration of the 15-day period for a specified time not to exceed 45 calendar days after receipt of the application, if the application is for a variance that would, in the judgment of the Administrator, clearly provide a level of health and safety to the persons employed in the areas of the mine that would be affected thereby no less than would be provided by compliance with a particular mandatory standard.

57.24-7 This § 57.24 does not authorize the Administrator to permit a variance from any mandatory standard relating to exposure to airborne contaminants. A variance from mandatory standards relating to exposure to radon daughters may be granted in accordance with the provisions of § 57.25.

§ 57.25 Variances—Radon daughter standards.

UNDERGROUND ONLY

57.25-1 The Administrator, Mining Enforcement and Safety Administration, in accordance with the provisions of this §57.25 is authorized to permit a variance from standard 57.5-5 in this Part 57 relating to the use of respirators in lieu of environmental controls in mines subject to standards relating to exposures to radon daughters. The Administrator may permit such a variance only by means of a written decision specifically describing the variance permitted and the restrictions and conditions to be observed. The Administrator may, in writing, delegate the authority conferred by this § 57.25 to the Deputy Administrator, Mining Enforcement and Safety Administration, the Assistant Administrator, Metal and Nonmetal Mine Health and Safety, and the Metal and Nonmetal Mine Health and Safety District Managers.

57.25-2 (a) No variance shall be granted to the provisions of § 57.5-5 which permits any person to receive a cumulative exposure in excess of 4 WLM per year.

(b) No variance shall be granted for a period of time longer than that necessary for the operator to establish environmental controls and to achieve conditions in the mine which will assure that individuals employed in any capacity in such mine will not receive an exposure in excess of 4 WLM per year. The period of time for which a variance may be permitted shall not exceed six (6) months: *Provided, however,* That two extensions, not to exceed 6 months each, may be granted if the terms, conditions, and other provisions of the variance as approved have been met and the holder of the variance establishes that he has exercised his best efforts to achieve conditions which will make respiratory protection unnecessary to avoid overexposure.

(c) A written application for an extension of a variance must be received by the Administrator at least 30 days prior to the expiration or termination of the existing variance. The applicant for an extension of a variance shall comply with the filing and notice requirements provided in §§ 57.25-3 and 57.25-4.

57.25-3 An application for a variance or an extension of a variance must be in writing and filed with the Administrator, Mining Enforcement and Safety Administration, Department of the Interior, Washington, D.C. 20240. A copy of the application must be mailed or otherwise delivered to the District Manager of the Metal and Nonmetal Mine Health and Safety District of the Mining Enforcement and Safety Administration in which the mine is located and a copy must be mailed or otherwise delivered to the State agency responsible for health and safety in the mine.

57.25-4 Before an application for a variance or an extension of a variance is filed, the person making such application shall give notice of the contents of the application to all persons employed in the mine that would be affected by the variance if granted. Such notice may be given by the delivery of a copy to each such employee individually: or by the delivery of a copy of the application to an organization, agency, or individual authorized by the employees to represent them; or by posting a copy on a bulletin board at the mine office; or in some other appropriate place at the mine adequate to give notice to the employees. An application will be rejected if it does not show that such notice has been given.

57.25-5 An application for a variance shall include:

(a) The name and address of the applicant and of the mine for which the variance is requested.

(b) A statement that the application is a request for a variance from mandatory standard 57.5-5.

(c) A statement that the applicant is unable to establish environmental controls and achieve conditions in the mine which will make respiratory protection unnecessary to avoid overexposure and shall set forth the reasons therefor.

(d) A plan which, on approval, shall become a condition of the variance if granted which specifies the actions to be taken which will assure that when the plan has been completed no employee in the mine will receive an exposure in excess of 4 WLM per year.

(e) A program for respiratory protection of all employees likely to receive exposure to radon daughters in excess of 4 WLM per year based on current measurements of radon daughter concentrations and prior recordkeeping. In order to receive approval the program shall meet the following conditions and requirements:

(1) The program shall provide that employees shall wear protective equipment which has been approved by the Bureau of Mines under Bureau of Mines Schedule 21B, "Filter-type Dust, Fume, and Mist Respirators" (see 30 CFR Part 14, revised edition January 1, 1972; 30 F.R. 616, January 19, 1965, as amended at 34 F.R. 9617, June 19, 1969); or approved under Title 30, Code of Federal Regulations, Part 11—"Respiratory Protective Devices; Tests for Permissibility; Fees," promulgated in 37 F.R. 6244, March 25, 1972, and employees shall be protected by the use of such equipment so that their annual exposure shall not exceed 4 WLM.

(2) The program shall describe the protective equipment to be employed, including the efficiency of the equipment for radon daughters. Approved respirators of the types described as follows may be used in the manner and circumstances as follows:

(i) Approved dust respirtors may be used for protection in radon daughter concentrations up to 1 WL. The protection factor for approved dust respirators shall be 0.2, that is, such respirators shall be capable of removing 80 percent of the radon daughters from the respired air.

(ii) Respirators approved for protection against radon daughters and those approved for protection against radioactive aerosols up to 10 times the MPC may be used for protection in radon daughter concentrations up to 3 WL. The protection factor for such approved respirators shall be 0.1, that is, the respirator shall be capable of removing 90 percent of the radon daughters from the respired air.

(iii) Approved powered air-purifying respirators when equipped with a high efficiency filters or with a filter approved for use with radon daughters may be used for protection in radon daughter concentrations up to 10 WL. The protection factor for such approved respirators shall be 0.03, that is, the respirator shall be capable of removing 97 percent of the radom daughters from the respired air.

(iv) Approved continuous flow air line respirators or pressure demand type self-contained breathing apparatus shall be used for protection in radon daughter concentrations above 10 WL.

(3) The program shall provide that respirators shall be selected, fitted, used, and maintained in accordance with the provisions of the American National Standard Z88.1 "Safety Guide for Respiratory Protection against Radon Daughters," or Z88.2 "Practices for Respiratory Protection," obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

(4) The program shall prescribe procedures governing the use of protective equipment, including supervisory procedures, and the approximate length of time the equipment will be used by individuals in each work week. The proposed periods of use of such equipment by an individual should not be of such duration as will discourage observance by the individual of the established procedures, nor should respirators be used under conditions where they may otherwise be detrimental to safety and health of employees.

(5) Filters on reusable respirators shall not be used longer than one shift (8 hours) before changing, and filters shall be changed at the beginning of each shift regardless of the length of time used on the previous shift.

(6) The program may consist of the use of respirators in combination with work rotation procedures or other methods of protection.

(7) The program shall set forth average concentration of radon daughters present in

the areas of mine occupied by the affected employees.

(8) The program shall contain a summarization of the exposure of affected employees for the 12-month period preceding the application by showing on a quarterly basis the number of workers exceeding 1, 2, 3, etc., working level months.

(9) The program shall contain a description of the work assignments of affected employees, specifying the number of persons having each work assignment.

(f) Specify the time period for which the variance is requested.

(g) Indicate the authority of the person signing the application.

(h) A statement describing how, and on what dates, the notice required by § 57.25-4 was given.

57.25-6 While a variance is in effect, in addition to any other requirements of this part and as a condition of the variance the operator shall comply with the following:

(a) Mine atmospheres shall be sampled to determine the concentrations of radon daughters.

(1) Sampling shall be in accordance with the procedures contained in American National Standards Institute N 7.1a-1969, "Supplement to radiation protection in uranium mines and mills (concentrators)," except that the sampling frequency for primary air courses not using vent tubing shall be at least monthly and the sampling frequency for areas ventilated by secondary systems or through vent tubing shall be at least weekly. Where samples are required to be taken weekly, such samples shall be taken randomly throughout the week in any given work place, for example, if a work place is sampled on Thursday at 10 a.m. 1 week, it shall not be sampled on Thursday at 10 a.m. the following week, but rather it shall be sampled on another day at another time of the day.

(2) Samples used for exposure determinations shall be taken as near as possible to the breathing zone of workers in each work place.

(3) Sampling shall be done during the course of a regular work shift.

(b) Exposure records for each employee exposed to radon daughters shall be kept in accordance with American National Standards Institute N 7.1a-1969, "Supplement to radiation protection in uranium mines and mills (concentrators)," except that the interval for calculating cumulative exposure shall be monthly.

(c) Clear and legible forms containing the same information as given in Appendix C of American National Standards Institute N 7.1a-1969 shall be used for recordkeeping. Occupancy time shall be recorded to the nearest half-hour. Periods of respirator use shall be clearly indicated on the form including the protection factor for each respirator used. Annual exposure shall be kept on a calendar year basis. The annual period shall start on the first Sunday of the year and end on the Saturday preceding the first Sunday of the following year. If existing timekeeping or recordkeeping procedures make this impractical, another period may be used that starts as soon after the first day of the calendar year as practical and that continues to an equivalent day of the succeeding year so that all days are covered.

(d) All sampling and exposure records required to be kept by this § 57.25-6, or any provision of the variance, shall be open for inspection by all affected employees, representatives of employees, State agencies, and authorized representatives of the Secretary of the Interior.

(e) American National Standards Institute N 7.1a-1969, "Supplement to radiation protection in uranium mines and mills (concentrators)", is obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

57.25-7 (a) For a period of 15 days following the date on which an application for a variance or extension is filed, any interested person may submit to the Administrator, Mining Enforcement and Safety Administration, written data, views, objections, or arguments respecting the application. Copies of such comments shall be mailed or otherwise delivered to the District Manager of the Metal and Nonmetal Mine Health and Safety District of the Mining Enforcement and Safety Administration in which the mine is located, and to the State agency responsible for health and safety in the mine. The Administrator may forward copies of such data, views, objections, or arguments to the applicant after removing any identification of the source of such comments, if requested to do so by the person filing such comments and such person is an employee in the mine for which the variance or extension is requested.

(b) Upon the written request of an affected party, made and filed with the Administrator within 15 days following the date on which an application for a variance or extension is filed, the Administrator shall hold a public hearing to consider the application. The Administrator on his own initiative may hold a public hearing on the application. A notice of the time and place of such hearing shall be published in the FEDERAL REGISTER as soon as practicable after receipt of the request.

Requests for hearings shall be addressed to the Administrator and copies shall be mailed or otherwise delivered to the District Manager, the State agency responsible for health and safety in the mine, and the applicant. The request for hearing shall include a concise statement of facts showing how the person requesting the hearing would be affected by the variance or extension, if granted, and shall also specify any statement or representation in the application for variance or extension which is denied or contested, and a concise summary of the evidence that will be adduced in support of such denial or contest, and any views or arguments on any issue of fact or law presented.

(c) The Administrator may cause radiation surveys to be made at the mine when he deems such necessary to assist him in his consideration of the application for a variance or extension.

(d) The Administrator shall issue a decision on the application as soon as practicable following the expiration of the period of 15 days, or the conclusion of any hearing held, or completion of radiation surveys which may be conducted.

57.25-8 Notwithstanding the provisions of § 57.25-7, the Administrator may issue a temporary variance, specifying the conditions thereof, for a period of time, not to exceed 60 days, necessary to permit his full consideration of an application made under the provisions of § 57.25.

57.25-9 (a) The Administrator may make such changes and impose such conditions in the applicant's plans for establishment of environmental controls, program of respiratory protection, sampling procedures and recordkeeping, and other matters, as he may deem appropriate before granting a variance.

(b) The Administrator may at any time while a variance is in effect cancel, revoke, or make revisions in the terms and conditions of the variance if he finds that the plans or programs which have been instituted are not accomplishing the expected results, or changed mine conditions prevent the plans and programs from functioning as intended, or the operator fails to observe the terms and conditions of the variance.

(RSI-0024)

§ 57.26 Procedures.

NOTIFICATION OF COMMENCEMENT OF OPERATIONS AND CLOSING OF MINES

57.26-1 *Mandatory.* The owner, operator, or person in charge of any metal and nonmetal mine shall notify the nearest Mining Enforcement and Safety Administration Metal and Nonmetal Mine Health and Safety subdistrict office or the State agency if the mine is located in a State which has a State Plan Agreement in effect, before starting operations, of the approximate or actual date mine operation will commence. The notification shall include the mine name, location, the company name, mailing address, person in charge, and whether operations will be continuous or intermittent.

When any mine is closed, the person in charge shall notify the nearest subdistrict office or State agency as provided above and indicate whether the closure is temporary or permanent.

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DEPARTMENT OF LABOR

Occupational Safety and Health Administration

CONSTRUCTION SAFETY AND HEALTH REGULATIONS

Title 29—Labor

CHAPTER XVII—OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION, DEPARTMENT OF LABOR

PART 1926—OCCUPATIONAL SAFETY AND HEALTH REGULATIONS FOR CONSTRUCTION

Pursuant to authority in sections 6 and 8(g) of the Williams-Steiger Occupational Safety and Health Act of 1970 (84 Stat. 1593, 1600 (29 U.S.C. 655, 657)), in Secretary of Labor's Order No. 12-71 (36 FR 8754), and in Section 107 of the Contract Work Hours and Safety Standards Act, as amended (83 Stat. 96; 40 U.S.C. 333), Part 1926 of Title 29 Code of Federal Regulations is hereby republished in its entirety. The purpose of this republication is to update the present occupational safety and health standards for construction by incorporating all changes made up to June 3, 1974, and thereby improve their usefulness and facilitate their enforcement.

Since this republication does not make any substantive change in the standards, it is not necessary to provide notice of proposed rulemaking, opportunity for public participation therein, nor any delay in the effective date under either section 6(b) of the Williams-Steiger Occupational Safety and Health Act of 1970 or 5 U.S.C. 553. For the same reason, good cause is found for not following the regular procedure for rulemaking and for making this republication effective immediately.

Signed at Washington, D.C. this 28th day of May, 1974.

John Stender,
Assistant Secretary of Labor.

PART 1926—SAFETY AND HEALTH REGULATIONS FOR CONSTRUCTION

(f) The telephone numbers of the physicians, hospitals, or ambulances shall be conspicuously posted.

§ 1926.51 Sanitation.

(a) *Potable water.* (1) An adequate supply of potable water shall be provided in all places of employment.

(2) Portable containers used to dispense drinking water shall be capable of being tightly closed, and equipped with a tap. Water shall not be dipped from containers.

(3) Any container used to distribute drinking water shall be clearly marked as to the nature of its contents and not used for any other purpose.

(4) The common drinking cup is prohibited.

(5) Where single service cups (to be used but once) are supplied, both a sanitary container for the unused cups and a receptacle for disposing of the used cups shall be provided.

(b) *Nonpotable water.* (1) Outlets for nonpotable water, such as water for industrial or firefighting purposes only, shall be identified by signs meeting the requirements of Subpart G of this part, to indicate clearly that the water is unsafe and is not to be used for drinking, washing, or cooking purposes.

(2) There shall be no cross-connection, open or potential, between a system furnishing potable water and a system furnishing nonpotable water.

(c) *Toilets at construction jobsites.* (1) Toilets shall be provided for employees according to the following table:

TABLE D-1

Number of employees	*Minimum number of facilities*
20 or less	1.
20 or more	1 toilet seat and 1 urinal per 40 workers.
200 or more	1 toilet seat and 1 urinal per 50 workers.

(2) Under temporary field conditions, provisions shall be made to assure not less than one toilet facility is available.

(3) Job sites, not provided with a sanitary sewer, shall be provided with one of the following toilet facilities unless prohibited by local codes:

(i) Privies (where their use will not contaminate ground or surface water);

(ii) Chemical toilets;

(iii) Recirculating toilets;

(iv) Combustion toilets.

(4) The requirements of this paragraph (c) for sanitation facilities shall not apply to mobile crews having transportation readily available to nearby toilet facilities.

(d) *Food handling.* All employees' food service facilities and operations shall meet the applicable laws, ordinances, and regulations of the jurisdictions in which they are located.

(e) *Temporary sleeping quarters.* When temporary sleeping quarters are provided, they shall be heated, ventilated, and lighted.

(f) *Washing facilities.* The employer shall provide adequate washing facilities for employees engaged in the application of paints, coating, herbicides, or insecticides, or in other operations where contaminants may be harmful to the employees. Such facilities shall be in near proximity to the worksite and shall be so equipped as to enable employees to remove such substances.

(g) [Revoked]

§ 1926.52 Occupational noise exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table D-2 of this section when measured on the A-scale of a standard sound level meter at slow response.

(b) When employees are subjected to sound levels exceeding those listed in Table D-2 of this section, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment as required in Subpart E, shall be provided and used to reduce sound levels within the levels of the table.

(c) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(d) (1) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

TABLE D-2—PERMISSIBLE NOISE EXPOSURES

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

(2) (i) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. Exposure to different levels for various periods of time shall be computed according to the formula set forth in subdivision (ii) of this subparagraph.

(ii)

$$F_e = \frac{T_1}{L_1} + \frac{T_2}{L_2} + \cdots + \frac{T_n}{L_n}$$

where:

F_e = The equivalent noise exposure factor.

T = The period of noise exposure at any essentially constant level.

L = The duration of the permissible noise exposure at the constant level (from Table D-2).

If the value of F_e exceeds unity (1) the exposure exceeds permissible levels.

(iii) A sample computation showing an application of the formula in subdivision (ii) of this paragraph is as follows. An employee is exposed at these levels for these periods:

110 dbA ¼ hour.
100 dbA ½ hour.
90 dbA 1½ hours.

$$F_e = \frac{1/4}{1/2} + \frac{1/2}{2} + \frac{1\frac{1}{2}}{8}$$

$$F_e = 0.500 + 0.25 + 0.188$$

$$F_e = 0.938$$

Since the value of F_e does not exceed unity, the exposure is within permissible limits.

(e) Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

§ 1926.53 Ionizing radiation.

(a) In construction and related activities involving the use of sources of ionizing radiation, the pertinent provisions of the Atomic Energy Commission's Standards for Protection Against Radiation (10 CFR Part 20), relating to protection against occupational radiation exposure, shall apply.

(b) Any activity which involves the use of radioactive materials or X-rays, whether or not under license from the Atomic Energy Commission, shall be performed by competent persons specially trained in the proper and safe operation of such equipment. In the case of materials used under Commission license, only persons actually licensed, or competent persons under direction and supervision of the licensee, shall perform such work.

§ 1926.54 Nonionizing radiation.

(a) Only qualified and trained employees shall be assigned to install, adjust, and operate laser equipment.

(b) Proof of qualification of the laser equipment operator shall be available and in possession of the operator at all times.

(c) Employees, when working in areas in which a potential exposure to direct or reflected laser light greater than 0.005 watts (5 milliwatts) exists, shall be provided with antilaser eye protection devices as specified in Subpart E of this part.

(d) Areas in which lasers are used shall be posted with standard laser warning placards.

(e) Beam shutters or caps shall be utilized, or the laser turned off, when laser transmission is not actually required. When the laser is left unattended for a substantial period of time, such as during lunch hour, overnight, or at change of shifts, the laser shall be turned off.

(f) Only mechanical or electronic means shall be used as a detector for guiding the internal alignment of the laser.

(g) The laser beam shall not be directed at employees.

(h) When it is raining or snowing, or when there is dust or fog in the air, the operation of laser systems shall be prohibited where practicable; in any event, employees shall be kept out of range of the area of source and target during such weather conditions.

(i) Laser equipment shall bear a label to indicate maximum output.

(j) Employees shall not be exposed to light intensities above:

(1) Direct staring: 1 micro-watt per square centimeter;

(2) Incidental observing: 1 milliwatt per square centimeter;

(3) Diffused reflected light: 2½ watts per square centimeter.

until the members are secured with not less than two bolts, or the equivalent at each connection and drawn up wrench tight.

(b) Open web steel joists shall not be placed on any structural steel framework unless such framework is safely bolted or welded.

(c) (1) In steel framing, where bar joists are utilized, and columns are not framed in at least two directions with structural steel members, a bar joist shall be field-bolted at columns to provide lateral stability during construction.

(2) Where longspan joists or trusses, 40 feet or longer, are used, a center row of bolted bridging shall be installed to provide lateral stability during construction prior to slacking of hoisting line.

(3) No load shall be placed on open web steel joists until these security requirements are met.

(d) Tag lines shall be used for controlling loads.

§ 1926.752 Bolting, riveting, fitting-up, and plumbing-up.

(a) *General requirements.* (1) Containers shall be provided for storing or carrying rivets, bolts, and drift pins, and secured against accidental displacement when aloft.

(2) Pneumatic hand tools shall be disconnected from the power source, and pressure in hose lines shall be released, before any adjustments or repairs are made.

(3) Air line hose sections shall be tied together except when quick disconnect couplers are used to join sections.

(4) Eye protection shall be provided in accordance with Subpart E of this part.

(b) *Bolting.* (1) When bolts or drift pins are being knocked out, means shall be provided to keep them from falling.

(2) Impact wrenches shall be provided with a locking device for retaining the socket.

(c) *Riveting.* (1) Riveting shall not be done in the vicinity of combustible material unless precautions are taken to prevent fire.

(2) When rivet heads are knocked off, or backed out, means shall be provided to keep them from falling.

(3) A safety wire shall be properly installed on the snap and on the handle of the pneumatic riveting hammer and shall be used at all times. The wire size shall be not less than No. 9 (B&S gauge), leaving the handle and annealed No. 14 on the snap, or equivalent.

(d) *Plumbing-up.* (1) Connections of the equipment used in plumbing-up shall be properly secured.

(2) The turnbuckles shall be secured to prevent unwinding while under stress.

(3) Plumbing-up guys related equipment shall be placed so that employees can get at the connection points.

(4) Plumbing-up guys shall be removed only under the supervision of a competent person.

(e) Wood planking shall be of proper thickness to carry the working load, but shall be not less than 2 inches thick full size undressed, exterior grade plywood, at least ¾-inch thick, or equivalent material.

(f) Metal decking of sufficient strength shall be laid tight and secured to prevent movement.

(g) Planks shall overlap the bearing on each end by a minimum of 12 inches.

(h) Wire mesh, exterior plywood, or equivalent, shall be used around columns where planks do not fit tightly.

(i) Provisions shall be made to secure temporary flooring against displacement.

(j) All unused openings in floors, temporary or permanent, shall be completely planked over or guarded in accordance with Subpart M of this part.

(k) Employees shall be provided with safety belts in accordance with § 1926.104 when they are working on float scaffolds.

Subpart S—Tunnels and Shafts, Caissons, Cofferdums, and Compressed Air

§ 1926.800 Tunnels and shafts.

(a) *General.* (1) The specific requirements of this Subpart S, Tunnels, Shafts, Caissons, Cofferdams, and Compressed Air, shall be complied with as well as the applicable provisions of all other subparts of this part.

(2) Safe means of access shall be provided and maintained to all working places.

(3) When ladders and stairways are provided in shafts and steep inclines, they shall meet the requirements of Subparts L and M of this part.

(4) Access to unattended underground openings shall be restricted by gates or doors. Unused chutes, manways, or other openings shall be tightly covered, bulkheaded, or fenced off, and posted. Conduits, trenches, and manholes shall meet the requirements of Subparts M and P of this part.

(5) Subsidence areas that present hazards shall be fenced and posted.

(6) Each operation shall have a check-in and check-out system that will provide positive identification of every employee underground. An accurate record and location of the employees shall be kept on the surface.

(b) *Emergency provisions.* (1) Evacuation plans and procedures shall be developed and made known to the employees.

(2) Emergency hoisting facilities shall be readily available at shafts more than 50 feet in depth, unless hoisting facilities are provided that are independent of electrical power failures. A boatswain's chair shall meet the requirements of Subpart L of this part.

(3) Bureau of Mines approved self-rescuers shall be available near the advancing face to equip each face employee. Such equipment shall be on the haulage equipment and in other areas where employees might be trapped by smoke or gas, and shall be maintained in good condition.

(4) Telephone or other signal communication shall be provided between the work face and the tunnel portal, and such systems shall be independent of the tunnel power supply.

(c) *Air Quality and Ventilation*—(1) *Air quality and quantity.* (i) Instruments shall be provided to test the atmosphere quantitatively for carbon monoxide, nitrogen dioxide, flammable or toxic gases, dusts, mists, and fumes that occur in the tunnel or shaft. Tests shall be conducted as frequently as necessary to assure that the required quality and quantity of air is maintained. A record of all tests shall be maintained and be kept available.

(ii) Field-type oxygen analyzers, or other suitable devices, shall be used to test for oxygen deficiency.

(iii) Respirators shall not be substituted for environmental control measures. However, where environmental controls have not yet been developed, or when necessary by the nature of the work involved (for example, welding, sand blasting, lead burning), an employee may work for short periods of time in concentrations of airborne contaminants which exceed the limit of permissible excursions referred to in subdivisions (iv) and (v) of this subparagraph, if such employee wears a respiratory protective device approved by the Bureau of Mines as protection against the particular hazards involved.

(iv) The exposure to airborne contaminants of an employee working in a tunnel or shaft shall not exceed the threshold limit values adopted by the American Conference of Governmental Industrial Hygienists, as set forth and explained in the 1970 edition of "Threshold Limit Values of Airborne Contaminants."

(v) Employees shall be withdrawn from areas in which there is a concentration of an airborne contaminant which exceeds the threshold limit value listed for that contaminant.

(vi) Atmospheres in all active areas shall contain at least 20 percent oxygen.

(2) *Ventilation.* (i) Tunnels shall be provided with mechanically induced primary ventilation in all work areas. The direction of airflow shall be reversible.

(ii) Ventilation doors, not operated mechanically, shall be designed and installed so that they are self-closing and will remain closed regardless of the direction of the air movement.

(iii) When there has been a failure of ventilation, and ventilation has been restored in a reasonable time, all places where flammable gas may have accumulated shall be examined by a competent person and determined to be free of flammable gas before power is restored and work resumed.

(iv) When the main fan or fans have been shut down with all employees out of the adit, tunnel or shaft, no employee, other than those qualified to examine the adit, tunnel, or shaft, or other authorized employee, shall go underground until the fans have been started, the work areas examined for gas and other hazards, and declared safe.

(v) The supply of fresh air shall not be less than 200 cubic feet per minute for each employee underground. The linear velocity of the air flow in the tunnel bore shall not be less than 30 feet per minute in those tunnels where blasting or rock drilling is conducted or where there are other conditions that are likely to produce dusts, fumes, vapors, or gases in harmful quantities.

(vi) If 1.5 percent or higher concentration of flammable gas is detected in air returning from an underground working place or places, the employees shall be withdrawn and the power cut off to the portion of the area endangered by such flammable gas until the concentration of such gas is reduced to 1 percent or less.

(vii) Internal combustion engines other than mobile diesel shall not be used underground. Mobile diesel-powered equipment used underground shall be certified by the Bureau of Mines, U.S. Department of the Interior according to the Bureau of Mines publication "Mechanical Equipment for Mines—tests for permissibility and suitability, Part 32, Mobile Diesel Power Equipment for Non-Coal Mines, Schedule 24" of March 23, 1965.

(d) *Illumination.* (1) Sufficient lighting shall be provided, in accordance with the requirements of Table D-3 of Subpart D of this part, to permit safe operations at the face as well as in the general tunnel or shaft area and at the employees' workplace.

(e) *Fire prevention and control*—(1) *General.* (i) The requirements for fire prevention and protection specified in Subpart F of this part shall be complied with in all tunnel and shaft operations.

(ii) Signs warning against smoking and open flames shall be posted so that they can be readily seen in areas or places where fire or explosion hazards exist.

(iii) The carrying of matches, lighters, or other flame-producing smoking materials shall be prohibited in all underground operations where fire or explosion hazards exist.

(iv) Not more than a 1 day's supply of diesel fuel shall be stored underground.

(v) Gasoline or liquefied petroleum gases shall not be taken, stored, or used underground.

(vi) Oil, grease, or fuel stored underground shall be kept in tightly sealed containers in fire-resistant areas, at safe distances from explosives magazines, electrical installations, and shaft stations.

(vii) Air that has passed through underground oil or fuel-storage areas shall not be used to ventilate working areas.

(viii) Approved fire-resistant hydraulic fluids shall be used in hydraulically actuated underground machinery and equipment.

(ix) Fires shall not be built underground.

(x) Noncombustible barriers shall be installed below welding or burning operations in or over a shaft or raise.

(xi) Fire extinguishers or equivalent protection shall be provided at the head and tail pulleys of underground belt conveyors and at 300-foot intervals along the belt line.

(xii) At tunnel operations, employing 25 or more employees at one time underground at least two rescue crews (10 employees divided between shifts) shall be trained annually in rescue procedures, in the use, care, and limitations of oxygen breathing apparatus, and the use and maintenance of firefighting equipment. Not less than one crew (5 employees) shall be trained at smaller operations.

(f) *Personal protective equipment.* Protective clothing or equipment shall be worn as specified in Subparts D and E of this part.

(g) *Noise.* (1) Permissible noise exposures shall conform to those specified in Subpart D of this part.

(h) *Ground support*—(1) *Tunnel portal area.* Portals shall be protected and supported where loose soil or rock or fractured material is encountered.

(2) *Tunnel area.* (i) The employer shall examine and test the roof, face, and walls of the work area at the start of each shift and frequently thereafter.

(ii) Loose ground shall be taken down or supported. Ground conditions along haulage ways and travelways shall be examined periodically and scaled or supported as necessary.

(iii) Torque meters and torque wrenches shall be available at tunnels where rock bolts are used for ground support. Frequent tests shall be made to determine if bolts meet the required torque. The test frequency shall be determined by rock conditions and distance from vibration sources.

(iv) Damaged or dislodged tunnel supports, whether steel sets or timber, shall be repaired or replaced. New supports shall be installed whenever possible before removing the damaged supports.

(v) All sets, including horseshoe-shaped or arched rib steel sets, shall be designed and installed so that the bottoms will have required anchorage to prevent pressures from pushing them inward into the excavation. Lateral bracing shall be provided between sets to further stabilize the support.

(3) *Shafts.* (i) Small diameter shafts, which employees are required to enter, shall be provided with a steel casing, concrete pipe, timber, or other material of required strength to support the surrounding earth.

(ii) The casing and bracing shall be provided the full depth of the shaft, or at least 5 feet into solid rock if possible, and shall extend at least 1 foot above ground level.

(iii) All wells or shafts over 5 feet in depth shall be retained with lagging, spiling, or casing.

(iv) In shafts, the employer shall inspect the walls, ladders, timbers, blocking, and wedges of the last set to determine if they have loosened following blasting operations. Where found unsafe, corrections shall be made before shift operations are started.

(v) Safety belts shall be worn on skips and platforms used in shafts by crews when the skip or cage does not occlude the opening to within 1 foot of the sides of the shaft, unless guardrails or cages are provided.

(i) *Drilling.* (1) Equipment that is to be used during a shift shall be inspected each shift by a competent person. Equipment defects affecting safety shall be corrected before the equipment is used.

(2) The drilling area shall be inspected for hazards before starting the drilling operation.

(3) Employees shall not be allowed on a drill mast while the drill bit is in operation.

(4) When a drill is being moved from one drilling area to another, drill steel, tools, and other equipment shall be secured, and the mast placed in a safe position.

(5) Receptacles or racks shall be provided for drill steel stored on jumbos.

(6) Before drilling cycle is started, warning shall be given to men working below jumbo decks.

(7) Drills on columns shall be anchored firmly before drilling is started and shall be retightened frequently thereafter.

(8) The employer shall provide mechanical means for lifting drills, roof bolts, mine straps, and other unwieldy heavy material to the top decks of jumbos over 10 feet in height.

(9) The employer shall provide stair access to jumbo decks wide enough to accomodate two persons if the deck is over 10 feet in height.

(10) On jumbo decks over 10 feet in height, guardrails which are removable (pipe in sockets with chain handrail), or equal, shall be provided on all sides and back platforms.

(11) Scaling bars shall be in good condition at all times, and blunted and severely worn bars shall not be used.

(12) When jumbos are being moved, riders will not be allowed on the jumbo unless they are assisting the driver.

(13) Before commencing the drill cycle, the face and lifters shall be examined for misfires (residual explosives) and, if found, they shall be removed before drilling commences at the face. Lifters shall not be drilled through blasted rock (muck) or water.

(14) Air lines that are buried in the invert shall be identified by signs posted nearby, warning all personnel.

(j) *Blasting.* All blasting and explosives-handling operations shall be conducted in compliance with Subpart U of this part.

(k) *Haulage.* (1) Equipment that is to be used during a shift shall be inspected by a competent person each shift. Equipment defects affecting safety shall be corrected before the equipment is used.

(2) Powered mobile equipment shall be provided with adequate brakes.

(3) Powered mobile haulage equipment shall be provided with audible warning devices. Lights shall be provided at both ends.

(4) Cab windows shall be of safety glass, or equivalent, in good condition, and shall be kept clean.

(5) Adequate backstops or brakes shall be installed on inclined conveyor drive units to prevent conveyors from running in reverse and creating a hazard to employees.

(6) No employee shall be permitted to ride a power-driven chain, belt, or bucket conveyor, unless the conveyor is specifically designed for the transportation of employees.

(7) The employer shall not permit employees to ride in dippers, shovel buckets, forks, clamshells, or in the beds of dump trucks, or on haulage equipment not specifically designed or adapted for the transportation of employees.

(8) Electrically powered mobile equipment shall not be left unattended unless the master switch is in the off position, all operating controls are in the neutral position, and the brakes are set, or other equivalent precautions are taken against rolling.

(9) When dumping cars by hand, the car dumps shall be provided with tiedown chains or bumper blocks to prevent cars from overturning.

(10) Rocker-bottom or bottom-dump cars shall be equipped with positive locking devices.

(11) Equipment which is to be hauled shall be so loaded and protected as to prevent sliding or spillage.

(12) Parked railcars shall be blocked securely.

(13) Berms, bumper blocks, safety hooks, or similar means shall be provided to prevent overtravel and overturning at dumping locations.

(14) Where necessary, bumper blocks, or the equivalent, shall be provided at all track dead ends.

(15) Supplies, materials, and tools, other than small handtools, shall not be transported with employees in mantrip cars.

(l) *Electrical equipment.* (1) Electrical equipment shall conform to the requirements of Subpart K of this part.

(2) Powerlines shall be well separated or insulated from waterlines, telephone lines, and airlines.

(3) Oil-filled transformers shall not be used underground unless they are located in a fire-resistant enclosure and surrounded by a dike to contain the contents of the transformers in event of a rupture.

(m) *Hoisting.* (1) Hoisting machines, either powered or hand operated, shall be worm-geared or powered both ways. The design must be such that when the power is stopped, the load cannot move.

(2) Controls for powered hoists shall be of the deadman type with a nonlocking switch or control.

(3) A device to shut off the power shall be installed ahead of the operating control.

(4) Hand-operated release mechanisms, which can permit the load to descend faster than the speed rating, shall not be used.

(5) Hoist machines with cast metal parts shall not be used.

(6) Every hoist shall be tested with twice the maximum load before being put into operation, and annually thereafter.

(7) All anchorages of hoists shall be inspected at the beginning of each shift.

(8) An enclosed covered metal cage shall be used to raise and lower persons in the shaft [illegible] shall be designed with a safety [illegible] f 4 and shall be load-tested p[illegible]. The exterior of the cage sh[illegible] of projections or sharp corne[illegible]osed shackles shall be used in the [illegible] rigging.

(9) If the cage is equipped with a door, a positive locking device shall be installed to prevent the door from opening accidentally while the cage is being lowered or raised while hoisting or lowering employees.

§ 1926.801 *Caissons.*

(a) Wherever, in caisson work in which compressed air is used, and the working chamber is less than 11 feet in length, and when such caissons are at any time suspended or hung while work is in progress so that the bottom of the excavation is more than 9 feet below the deck of the working chamber, a shield shall be erected therein for the protection of the employees.

(b) Shafts shall be subjected to a hydrostatic or air-pressure test, at which pressure they shall be tight. The shaft shall be stamped on the outside shell about 12 inches from each flange to show the pressure to which they have been subjected.

(c) Whenever a shaft is used, it shall be provided, where space permits, with a safe, proper, and suitable staircase for its entire length, including landing platforms, not more than 20 feet apart. Where this is impracticable, suitable ladders shall be installed with landing platforms located about 20 feet apart to break the climb.

(d) All caissons having a diameter or side greater than 10 feet shall be provided with a man lock and shaft for the exclusive use of employees.

(e) In addition to the gauge in the locks, an accurate gauge shall be maintained on the outer and inner side of each bulkhead. These gauges shall be accessible at all times and kept in accurate working order.

(f) In caisson operations where employees are exposed to compressed air working environments, the requirements contained in § 1926.803 shall be complied with.

§ 1926.802 *Cofferdams.*

(a) If overtopping of the cofferdam by high waters is possible, means shall be provided for controlled flooding of the work area.

(b) Warning signals for evacuation of employees in case of emergency shall be developed and posted.

(c) Cofferdam walkways, bridges, or ramps with at least two means of rapid exit shall be provided with guardrails as specified in Subpart M of this part.

(d) Cofferdams located close to navigable shipping channels shall be protected from vessels in transit, where possible.

§ 1926.803 *Compressed air.*

(a) *General provisions.* (1) There shall be present, at all times, at least one competent person designated by and representing the employer, who shall be familiar with this subpart in all respects, and responsible for full compliance with these and other applicable subparts.

(2) Every employee shall be instructed in the rules and regulations which concern his safety or the safety of others.

(b) *Medical attendance, examination, and regulations.* (1) There shall be retained one or more licensed physicians familiar with and experienced in the physical requirements and the medical aspects of compressed air work and the treatment of decompression illness. He shall be available at all times while work is in progress in order to provide medical supervision of employees employed in compressed air work. He shall himself be physically qualified and be willing to enter a pressurized environment.

(2) No employee shall be permitted to enter a compressed air environment until he has been examined by the physician and reported by him to be physically qualified to engage in such work.

(3) In the event an employee is absent from work for 10 days, or is absent due to sickness or injury, he shall not resume work until he is reexamined by the physician, and his physical condition reported, as provided in this paragraph, to be such as to permit him to work in compressed air.

(4) After an employee has been employed continuously in compressed air for a period designated by the physician, but not to exceed 1 year, he shall be reexamined by the physician to determine if he is still physically qualified to engage in compressed air work.

(5) Such physician shall at all times keep a complete and full record of examinations made by him. The physician shall also keep an accurate record of any decompression illness or other illness or injury incapacitating any employee for work, and of all loss of life that occurs in the operation of a tunnel, caisson, or other compartment in which compressed air is used.

(6) Records shall be available for the inspection of the Secretary or his representatives, and a copy thereof shall be forwarded to OSHA within 48 hours following the occurrence of the accident, death, injury, or decompression illness. It shall state as fully as possible the cause of said death or decompression illness, and the place where the injured or sick employee was taken, and such other relative information as may be required by the Secretary.

(7) A fully equipped first aid station shall be provided at each tunnel project regardless of the number of persons employed. An ambulance or transportation suitable for a litter case shall be at each project.

(8) Where tunnels are being excavated from portals more than 8 road miles apart, a first aid station and transportation facilities shall be provided at each portal.

(9) A medical lock shall be established and maintained in immediate working order whenever air pressure in the working chamber is increased above the normal atmosphere.