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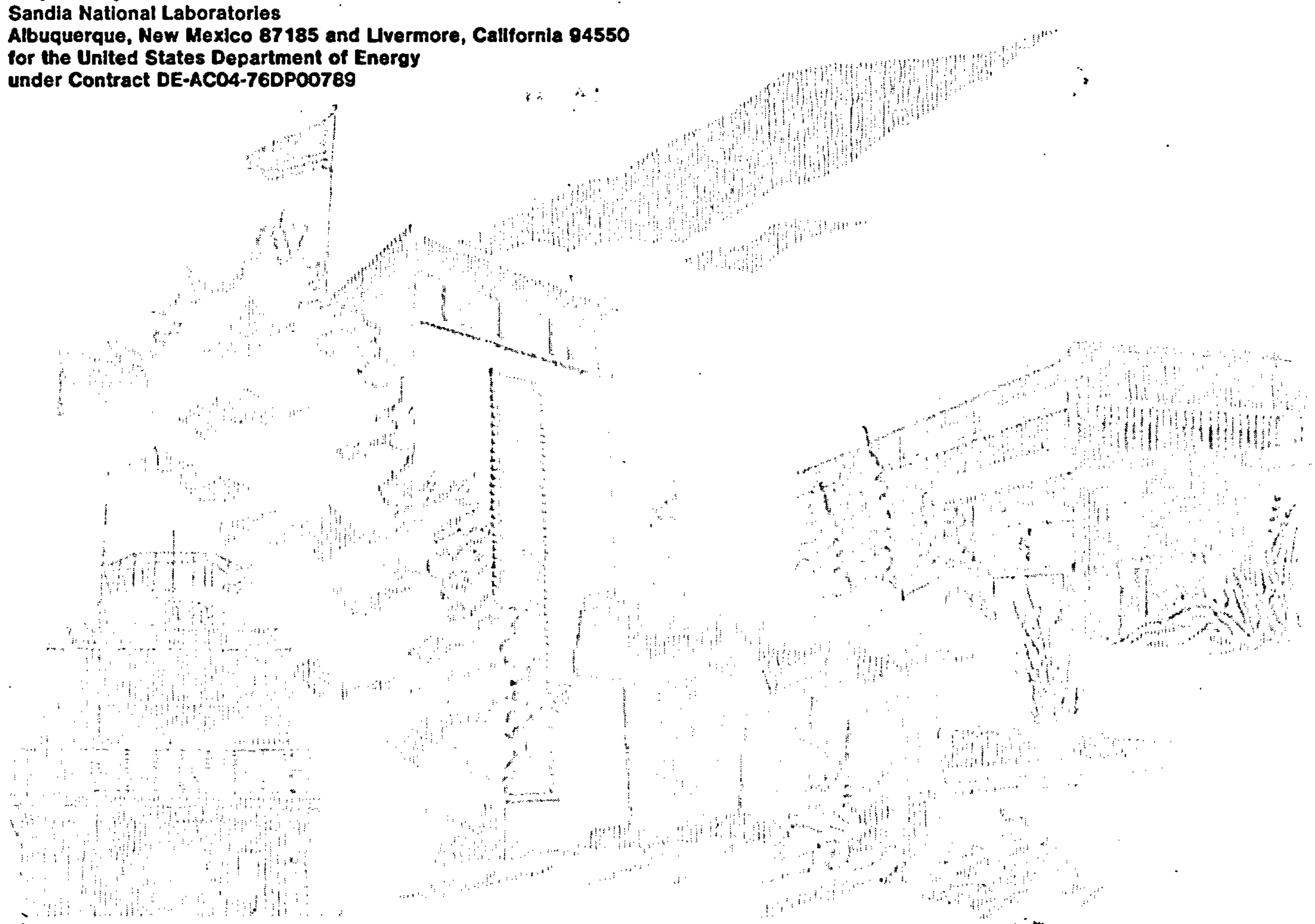
Nevada Nuclear Waste Storage Investigations Project

Site Characterization Plan Conceptual Design Report

Volume 3 Appendices A-E

Compiled by Hugh R. MacDougall, Leo W. Scully,
Joe R. Tillerson

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789



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Compiled by

H. R. MacDougall, L. W. Scully, and J. R. Tillerson
Nevada Nuclear Waste Storage Investigations Department
Sandia National Laboratories
Albuquerque, New Mexico 87185

Engineering design information provided by

Bechtel National, Inc.
San Francisco, California 94119

and

Parsons Brinckerhoff Quade & Douglas, Inc.
San Francisco, California 94109

ABSTRACT

This document presents a description of a prospective geologic repository for high-level radioactive waste to support the development of the Site Characterization Plan for the Yucca Mountain site. This conceptual design has been developed for the Department of Energy's Nevada Nuclear Waste Storage Investigations Project by Sandia National Laboratories and its supporting contractors.

The site for the prospective repository is located at Yucca Mountain in southwestern Nevada, and the waste emplacement area will be constructed in the underlying volcanic tuffs. The target horizon for waste emplacement is a sloping bed of densely welded tuff more than 650 ft below the surface and typically more than 600 ft above the water table. The conceptual design described in this report is unique among repository designs in that (1) it uses ramps in addition to shafts to gain access to the underground facility, (2) the emplacement horizon is located above the water table, and (3) it is possible that 300- to 400-ft-long horizontal waste emplacement boreholes will be used.

In addition to describing the design and operations, this report summarizes the design bases (site and properties of the waste package), design and performance criteria, and the design analyses performed. The current status of meeting the preclosure performance objectives for licensing and of resolving the repository design and preclosure issues is presented. The repository design presented in this report will be expanded and refined during the advanced conceptual design, the license application design, and the final procurement and construction design phases.

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APPENDIX A

EXPECTED TEMPERATURES FOR BOREHOLE WALLS AND DRIFTS AFTER SPENT FUEL EMPLACEMENT

The calculations in this appendix were completed before the establishment of the Reference Information Base (RIB). These calculations are based on properties available at the time of the Unit Evaluation (Tillerson, J. R., and F. B. Nimick, "Geoengineering Properties of Potential Repository Units at Yucca Mountain, Southern Nevada," SAND84-0221, Sandia National Laboratories, Albuquerque, NM, December 1984). The differences between properties used and the current reference values are small and the major controlling variable, areal power density, was not changed. Therefore, expected temperatures reported here should not differ greatly had the value of thermal properties current in the RIB been used.

KEYSTONE MEMO 6310-85-8

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: April/15/1985

to: R. J. Flores, 6314

from: A. J. Mansure, 6314 Arthur Mansure

subject: Expected Temperatures for Spent Fuel Borehole Walls and Drifts.

There is no comprehensive study of expected underground facility temperatures based upon current properties and design parameters. In general, temperature calculations have been done for specific problems (drift temperature) and for purposes other than determining expected temperatures (choosing standoffs). Furthermore as material properties and the layout have changed, many of the older calculations are no longer current (eg. B.S. Langkopf, 1982).

This memorandum presents the most current and representative temperature calculations for establishing expected temperatures. Waste age and burnup are not considered. Results presented here are intended to be either average or highest expected temperature depending upon the assumptions of each individual calculation.

This memorandum is divided into three parts: Calculational Basis, which summarized the properties and model assumptions used; Borehole and Drift Temperatures, where results are presented; and Further Work where the areas for which additional work is needed are identified.

Calculational Basis

Calculations of temperatures for design purposes have assumed there is only conductive transfer of heat. Vapor phase effects due to boiling and associated forced convection are most important near the emplacement borehole and tend to lower temperatures. These effects should not significantly change drift temperatures and far-field temperatures (further verification of these points is necessary). This approach for design calculations (conductive heat transfer only) has been adopted because of the difficulty in validating the vapor-phase models and guaranteeing vaporization takes place as modeled, and because the approach should be conservative.

Evaporation at the walls of the drift has also not yet been adequately incorporated into the thermal analyses. This effect is not important for unventilated drifts; however, it could be signilicant for ventilated drifts. Ventilation removes heat from the system (underground facility); thus assuming the drifts have not been ventilated results in higher temperatures.

Properties used in thermal analyses to date are those adopted for the unit evaluation (Johnstone, et. al. 1984) and predate the current reference data (Nimick, et. al. 1984). They are

Heat capacity	2.17 MJ/cu.m-oC
Thermal conductivity	1.8 W/m-oC
In situ temperature	26 deg. C

Constraints in establishing thermal loadings have been

Areal Power Density 57 kW/acre
- unit evaluation (Johnstone, 1984)

Rock mass temperature <200 deg. C beyond 1m from borehole
Waste form temperature <350 deg. C
- (Gregg and O'Neal, 1983)

Container dimensions and output (3.0 kW/container) assumed are those given in "Preliminary Reference Waste Descriptions for a Repository at Yucca Mountain, Nevada" (O'Brien, 1984). The waste was assumed to be 10 years out of the reactor and have burnups of 27.5 GWd/MTU for BWR and 32.7 GWd/MTU for PWR.

Thermal decay functions used were defined by Shirley (1983a). Drift and layout dimensions for most calculations have been those defined by Shirley (1983b). The results presented here assume no compressed tuff backfill, no borehole liner for vertical emplacement, but assume there is a borehole liner for horizontal emplacement.

The design of the container is still in progress. LLNL has performed some thermal trade-off studies (Stein, et. al., 1984). Their basic design accommodates up to 3 intact or 6 consolidated PWR assemblies, or up to 7 intact or 14 consolidated BWR assemblies. The containers have 6 internal fins for PWR and 9 internal fins for BWR. These designs result in about a 100 deg. C temperature difference between the hottest point within the SF rods and the borehole wall. It has been shown that this temperature difference is dependent upon the number of fins. If the container does not have enough fins or the fins are not properly arranged, this temperature difference would be much higher. If too many fins are added the additional benefit is small and the cost is higher. The basic designs developed by LLNL are believed to be in between not enough fins to get the heat out and the point of diminishing returns. The 100 deg. C temperature difference between the hottest point in the fuel and the borehole wall is about 30% of the temperature difference between the in situ temperature and the waste form temperature constraint. This leaves an adequate temperature difference for heat transfer outside the borehole. Hence, based on the design work by LLNL, thermal analyses have assumed that the borehole wall should not get hotter than about 220 +/-10 deg. C.

There is considerable variability in the thermal output of individual fuel assemblies. This must be considered in the design of the container. The maximum allowable container output has been assumed to be 3.4kW (O'Brien, 1985). The 3.4kW limit has been chosen to keep the waste form temperature limit from being exceeded assuming the afore mentioned basic container designs. This limit could change if the design of the container, especially the number of fins, is changed. The actual limit is also effected by the waste age, burnup, rock thermal properties, and the areal power density. It has been shown that if the container has 14 fins, thermal outputs as high as 3.56kW may be acceptable. (Stein, et. al., 1984)

The average container output if all fuel rods are consolidated is 3.0 kW (O'Brien, 1984). Based on recent waste descriptions (O'Brien, 1985), not all fuel rods can be expected to be consolidated and thus the average container output is 2.3 kW (see Appendix A). One might guess there would be a big difference in temperatures depending upon which container output (3.4kW, 3.0kW, or 2.3kW) is used. However, this is not true because all waste is emplaced at the design basis areal power density. That is the constraint (eg. 57 kW/acre) is more important in determining temperature than the actual container output.

For horizontal emplacement it is fairly easy to understand why, for drift temperatures, the container output is not the critical parameter. In this case the waste is so far away, that for all practical considerations, it can be considered uniformly distributed. Thus the important factor is the areal power density not the output of an individual container.

For horizontal emplacement, heat transfer along the borehole, because of the presence of the liner, should be sufficient to make the rock wall temperature fairly uniform along the borehole wall. Thus the important factor in determining the borehole wall temperature will be the thermal loading (kW per meter) of the borehole. Calculations will be performed to determine the maximum number of kilowatts per meter of borehole for which waste form and rock mass temperature constraints can be met. When higher output containers are received, the containers will have to be spaced out along the borehole to maintain the proper temperatures. If containers of lower output are received, the boreholes can be spaced closer together as long as the maximum APD limit is not exceeded.

For vertical emplacement it has been shown that the important factor in determining temperature is the thermal loading along the drift floor, that is, the output of the container divided by the spacing between containers (St. John, 1985). The acceptable thermal loading is determined by the rock mass temperature constraint and the waste form temperature constraint (temperature at the borehole wall in these calculations). Thus as container output varies, temperatures remain remain essentially the same, if the borehole spacing is varied so that the number of kilowatts per meter of drift is constant. Table 1 compares the borehole temperatures for three different container outputs and shows the peak temperatures are within 15 deg. C when the loading is constant (.612 kW/m was used). Figure 1 displays this same data. Calculations for the table were done using the ARRAYF code.

Table 1: Vertical Emplacement Borehole Wall Temperature for Different Container Outputs, but Constant Kilowatts per Meter of Drift and Areal Power Density

Time (years)	Temperature (deg. C)		
	2.4 kW/container 3.92 m separation	3 kW/container 4.9 m separation	3.4 kW/container 5.55 m separation
5	201	218	230
10	210	226	237
15	212	226	237
20	210	224	234
25	205	220	229
30	200	214	223
50	175	188	196

Since the actual container design has not been established, container, liner, and borehole dimensions are still in a state of flux. These parameters do not significantly effect borehole wall temperatures. Table 2 compares borehole wall temperatures for two different diameter vertical emplacement boreholes. All other input data was the same in these two analyses. The table shows that the borehole wall temperature is not greatly affected by the difference in size of the two boreholes.

Table 2. Borehole Wall Temperature as Effected by Borehole Diameter.

Time (years)	Temperature (deg. C)	
	Diameter .355m	Diameter .395
5	218	212
10	226	221
15	226	222
20	224	220
30	214	211
50	188	186
70	165	163

Borehole and Drift Temperatures

For horizontal emplacement of 10 year old 3.0 kW containers, the emplacement configuration analyzed is 32 containers per 165 meters of borehole (or 0.582kW/m) with the boreholes 33m apart. Table 3 tabulates the temperature in between the boreholes as a function of distance from the center of the borehole. The temperature at 0.395m is the borehole wall. These calculations were made using with ARRAYF computer code (Klett, et. al., 1981).

Table 3. Horizontal Emplacement Rock Temperatures

Time (years)	Distance (meters) 0.395	1.39	2.5	5.0	7.5	10.0	12.5
2.5	192.	132.	104.	72.2	55.4	45.4	39.5
5.0	203.	145.	119.	88.4	71.9	61.7	55.6
7.5	208.	153.	128.	99.0	83.2	73.5	67.7
10.	211.	159.	135.	107.	91.9	82.7	77.2
20.	211.	168.	148.	125.	113.	105.	101.
30	205.	169.	153.	133.	123.	117.	113.
40.	198.	167.	153.	136.	128.	122.	119.
50.	189.	163.	151.	137.	129.	124.	121.
75.	171.	151.	142.	132.	126.	123.	121.
100.	156.	141.	134.	125.	121.	118.	116.

For vertical emplacement of 10 year old 3.0 kW containers, the emplacement configuration analyzed is boreholes separated by 4.9 meters (or .612 kW per meter of drift length) with drifts separated by 32.6m. The top of the containers has been assumed to be 3 meters below the floor of the drift. Clearly for vertical emplacement both borehole wall and drift temperatures depend upon this assumption. Work is presently underway to determine the ventilation and structural significance of this assumption. Table 4 tabulates rock temperatures as a function of distance from the center of the borehole in a plane at the mid-height of the container and perpendicular to the axis of the borehole. The borehole wall is at 0.355 meters. These temperatures were calculated using the ARRAYF computer code (Klett, et. al., 1981). ARRAYF solves for the temperature using an analytic solution. It does not take into account effects of the drift on temperatures.

Table 4. Vertical Emplacement Rock Temperatures Calculated Using ARRAYF

Time (years)	Distance (meters) Toward next borehole 0.355	Toward next borehole 1.355	Perpendicular to drift 1.355	Perpendicular to drift 15.3
2.5	207.	141.	135.	33.3
5.	218.	155.	149.	45.5
7.5	223.	163.	158.	56.6
10.	226.	169.	163.	66.0
15.	226.	175.	170.	80.6
20.	224.	177.	173.	90.7
30.	214.	175.	171.	102.
50.	188.	159.	157.	106.
100	141.	124.	122.	92.2

Figure 2 shows finite element temperature calculations of borehole wall temperature for vertical emplacement (St. John, 1985). Data reported in this figure is based upon a slightly different number of kW per meter of drift (.75 kW/m) than than that reported in Table 4. The container was approximated by a rectangular hole in these calculations. This approximation has negligible effect on drift temperature but may have a slight effect on temperatures near the container because the rectangular hole has about 12% more area to dissipate heat.

The top curve on Figure 2 ignores the presence of the drift and thus corresponds to calculations done using ARRAYF. The second curve on Figure 2 (numerical-unventilated) includes the effects of an unventilated drift. This curve shows that convection and radiation across the drift increases heat transfer causing the borehole wall temperature to be lower. The difference in the top two curves shows that ignoring the presence an unventilated drift leads to an over estimation of borehole wall temperature by about 10 deg C. The third curve on Figure 2 (numerical-ventilated) assumed that the drift wall was held at a constant 30 deg. C to simulate ventilation of the drift. This curve shows that ventilation can significantly cool the borehole wall (about 25 deg. C).

Finite element analyses have not been performed for the current design to determine drift temperatures for horizontal emplacement, but calculations have been made using ARRAYF. The ARRAYF calculations do not include drift effects on the temperature field; however, for horizontal emplacement, the drift is far enough away from the containers that the temperature difference across the drift will be very small. Thus the differences in the temperature field because of the presence of the drift should not be great. Figure 3 shows the temperature expected as a function of time for horizontal emplacement. For horizontal emplacement drift temperatures are dependent upon the standoff between the waste and the drift. The standoff has been selected to be 35m so that at 50 years the temperature in the drift remains below 50 deg. C. Table 5 gives unventilated drift temperatures for horizontal emplacement as a function of time and standoff.

Table 5. Drift Temperatures (deg. C) for a Unventilated Horizontal Emplacement Drift

Time (years)	Standoff Distance 15 meters	25 meters	35 meters
5	29.6	26.8	26.1
10	36.2	29.9	27.2
20	48.4	38.3	32.0
30	57.8	46.2	37.8
40	64.7	52.7	43.3
50	69.9	58.0	48.2
75	77.8	67.0	57.3
100	81.7	72.1	63.0

For the 35m standoff case, horizontal-emplacement drift-temperature calculations have been carried out through 800 years to determine the maximum temperature in the drift. This temperature, 90 deg. C occurred at 720 years. If the standoff were reduced the maximum temperature would be higher and would occur earlier in time.

Finite element calculations of the emplacement drift wall temperature have been made for vertical emplacement assuming .75 kW/m of drift (St. John, 1985). These calculations have simulated radiative and convective heat transfer across the drift by using an equivalent conductivity in the drift. This approach and the diffusivity value used (50 m2/yr) are consistent with that used by other investigators (Eaton, 1982; and Butkovich and Montan 1980). As with vertical emplacement borehole wall temperatures, the emplacement drift temperatures are dependent upon the loading under the drift (kilowatts per meter) and the standoff between the drift and the container. Figure 4 shows vertical emplacement drift temperatures as a function of time for an unventilated drift. Data for Figure 4 is summarized in Table 6.

Table 6. Drift Temperatures (deg. C) for a Unventilated Vertical Emplacement Drift

Time (years)	Center of Drift	Floor	Wall	Roof
5	72.7	94.3	71.1	49.5
10	89.7	110.2	88.2	65.6
20	107.1	124.8	105.9	85.0
30	115.8	130.8	114.8	96.3
40	120.2	133.2	119.4	103.2
50	122.4	133.7	121.7	107.4
75	123.5	131.8	122.9	112.1
100	122.5	129.2	122.0	113.3

For vertical emplacement, in addition to emplacement drifts, there are access drifts. It is a design objective that, like the emplacement drifts for the horizontal configuration, the access drifts for the vertical configuration should remain below 50 deg. C at 50 years. Table 7 shows the drift-wall temperature increase, for vertical access drifts, due to the heat that travels through the rock and due to the heat that comes from the emplacement drift bulkhead. The heat that travels through the rock has been calculated using ARRAYF and assumes a standoff of 34.15 meters between the access drift and the first borehole in the emplacement drift.

The bulkhead contribution to the drift temperature was calculated using ARRAFY by assuming a heat source of .0171 kW/m of access drift. This value was picked because when the temperature contribution (4.5 deg. C) of this heat source is added to the in situ temperature (26 deg. C) and the temperature contribution of the heat conduction through the rock (18.3 deg. C) the resulting drift temperature is 50 deg. C (cf. Table 7). Thus the assumed heat source (.0171 kW/m) represents the maximum amount of heat the bulkhead can leak without the drift temperature being too high.

Table 7. Unventilated Vertical Access Drift Temperature Increases

Time (years)	Temperature Increase (deg. C) Conduction through rock	Bulkhead contribution
5	.2	2.8
10	1.2	3.4
20	5.1	3.9
30	9.7	4.2
40	14.2	4.4
50	18.3	4.5
75	26.5	4.8
100	32.2	5.0

The assumed .0171 kW/m heat source corresponds to .56 kW for each bulkhead. If the temperature on the emplacement side of the bulkhead is assumed to be 110 deg. C (cf. table 6), the bulkhead thermal resistance would have to be at least 2040 oC-sq.m/kW in order to prevent more than .56 kW from leaking through the bulkhead. This is considerably more resistance than supplied by convection and radiation off of the bulkhead, but is about equivalent to 3 inches of glass wool.

Future Work

Future work on evaluating expected temperatures will include revising thermal properties to be consistent with reference data, evaluating the significance of uncertainty in thermal properties by sensitivity studies, evaluating the effect of lithophysae, reevaluating vertical emplacement borehole wall and emplacement drift temperatures using finite element calculations with the current thermal loading and reference geometry, and determining if the effects of boiling and vapor transport have been adequately considered especially for vertical emplacement where the 100 deg. C isotherm intersects the drift.

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References:

Butkovich, T. R. and D. N. Montan, 1980, "A Method for Calculating Internal Radiation and Ventilation with ADINA Heat Flow Code", UCRL-52918, Lawrence Livermore National Laboratory, Livermore CA

Eaton, R. R. and D. C. Reda, 1982, "The Influence of Convective-Energy Transfer on Calculated Temperature Distributions in Proposed Hard-Rock Nuclear Waste Repositories", Radioactive Waste Management Vol 2(4) June 1982 pp.343-361

Gregg, D. W. and W. C. O'Neal, 1983, "Initial Specifications for Nuclear Waste Package External Dimensions and Materials", UCID-19926, Lawrence Livermore Laboratory, Livermore CA

Johnstone, J. K., R. R. Peters, and P. F. Gnirk, 1984, "Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation", SAND83- 0372, Sandia National Laboratory, Albuquerque NM

Klett, R. D., E. S. Hertel, and M. A. Ellis, 1981, "Systems Engineering Programs for Geologic Nuclear Waste Disposal," SAND80-0440, Sandia National Laboratory, Albuquerque NM

Langkopf, B. S., 1982, "Thermal Analysis of Nuclear Waste Emplacement in Welded Tuff," SAND80-2639

Nimick, F. B., S. J. Bauer, and J. R. Tillerson, 1984 "Recommended Matrix and Rock-Mass Bulk, Mechanical and Thermal Properties for Thermomechanical Stratigraphy of Yucca Mountain," Keystone Document 6310-85-1, Sandia National Laboratory, . Albuquerque NM

O'Brien, P. D., 1984, "Preliminary Reference Waste Descriptions for a Repository at Yucca Mountain, Nevada", SAND83-1805, Sandia National Laboratory, Albuquerque NM

O'Brien, P. D., 1985, "Reference Nuclear Waste Descriptions for a Geologic Repository at Yucca Mountain, Nevada", SAND84-1848, Sandia National Laboratory, Albuquerque NM

Shirley, C. G., 1983a, "Reference Commercial Nuclear Waste Thermal Power and Energy Functions," Keystone Memorandum 6310-83-2, Sandia National Laboratory, Albuquerque NM

Shirley, C.G., 1983b, "Reference Waste Emplacement Geometries," Keystone Memorandum 6310-83-1, Sandia National Laboratories, Albuquerque, NM

St. John, C., 1985, "Thermal Analysis of Spent Fuel Disposal in Vertical Emplacement Boreholes in a Welded Tuff Repository," SAND84-7207, Sandia National Laboratory, Albuquerque, NM

Stein, W., J.N. Hockman, and W.C. O'Neal, 1984, "Thermal Conceptual Waste Package Designs," UCID-20091, Lawrence Livermore National Laboratory, Livermore CA

APPENDIX A

Determination of average container size.

PWR

41686MTU * .5085kW/assembly / (.4614MTU/assembly) = 45941 kW

BWR

26499MTU * .1667kW/assembly / (.1833MTU/assembly) = 24099 kW

Average output

70,040kW / (30634 containers) = 2.29 kW/container

....

All data from O'Brien 1985.

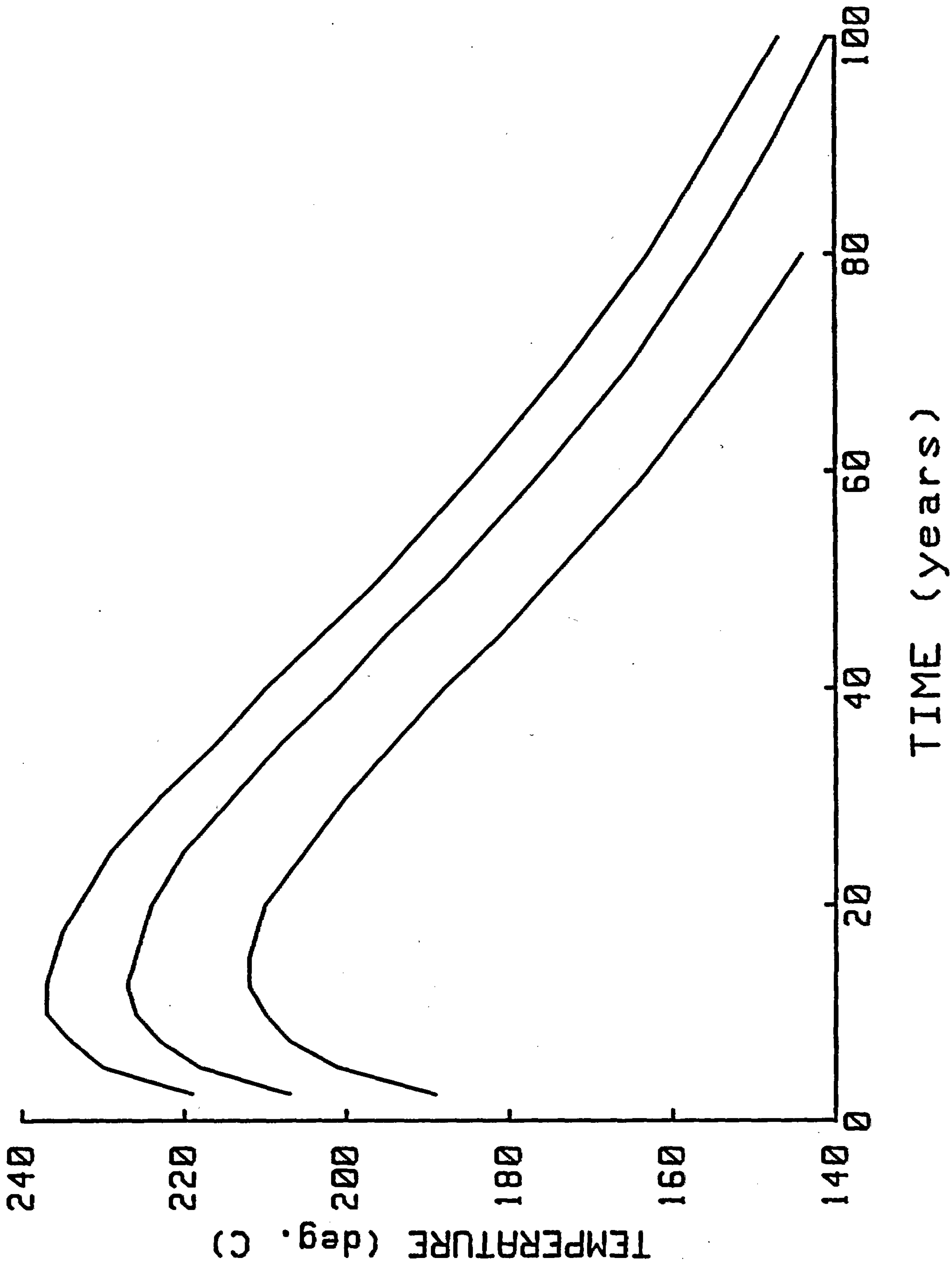

Figure 1. Vertical Emplacement Borehole Wall Temperature for Different Container Outputs, but Constant Kilowatts per Meter of Drift and Areal Power Density

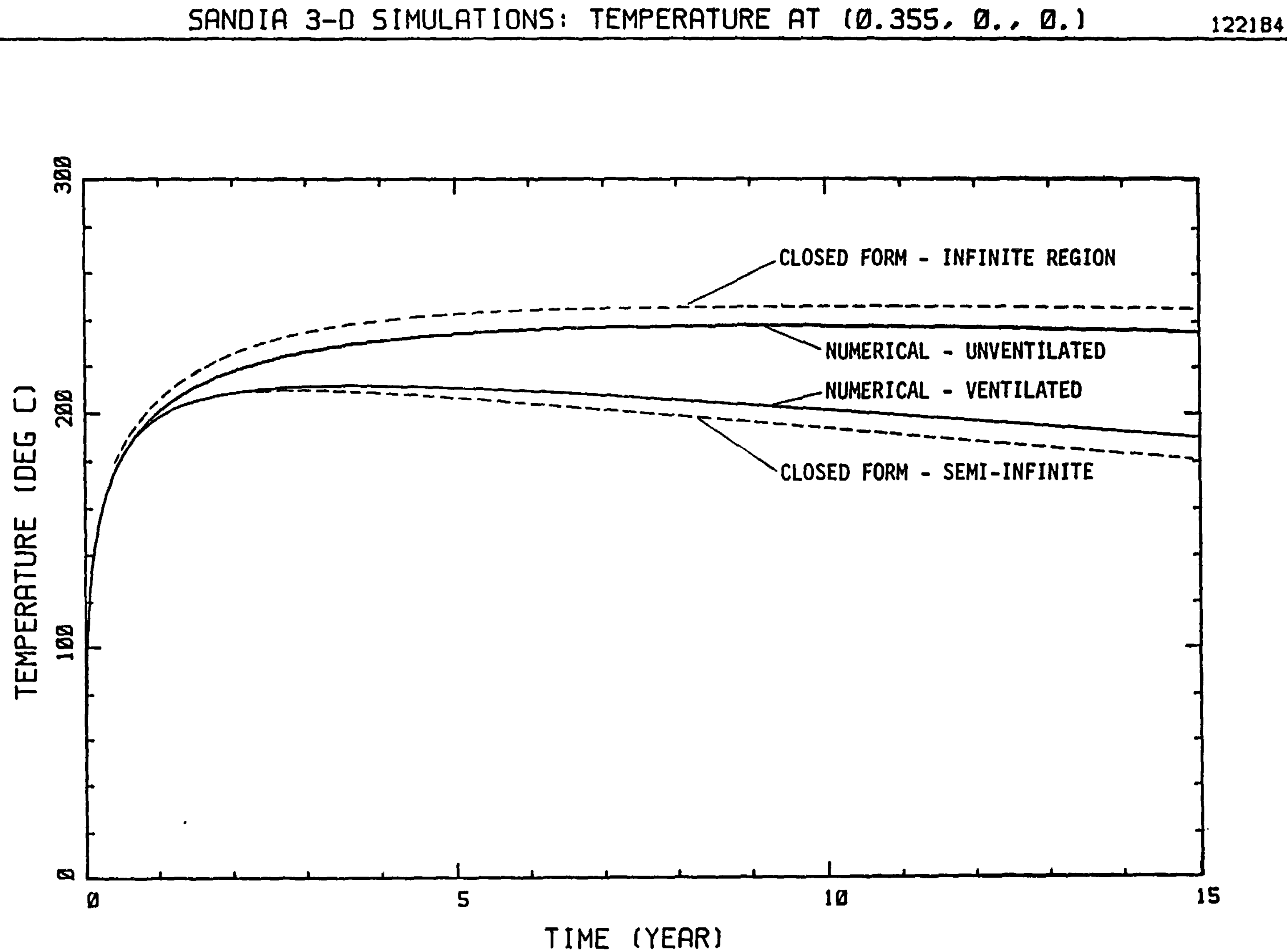

Figure 2. A Comparison of the Temperature History of a Point on the Wall of a Vertical Emplacement Borehole, Obtained Using Several Different Three Dimensional Models Each with a Different Approach to Representing Ventilation in the Drift.

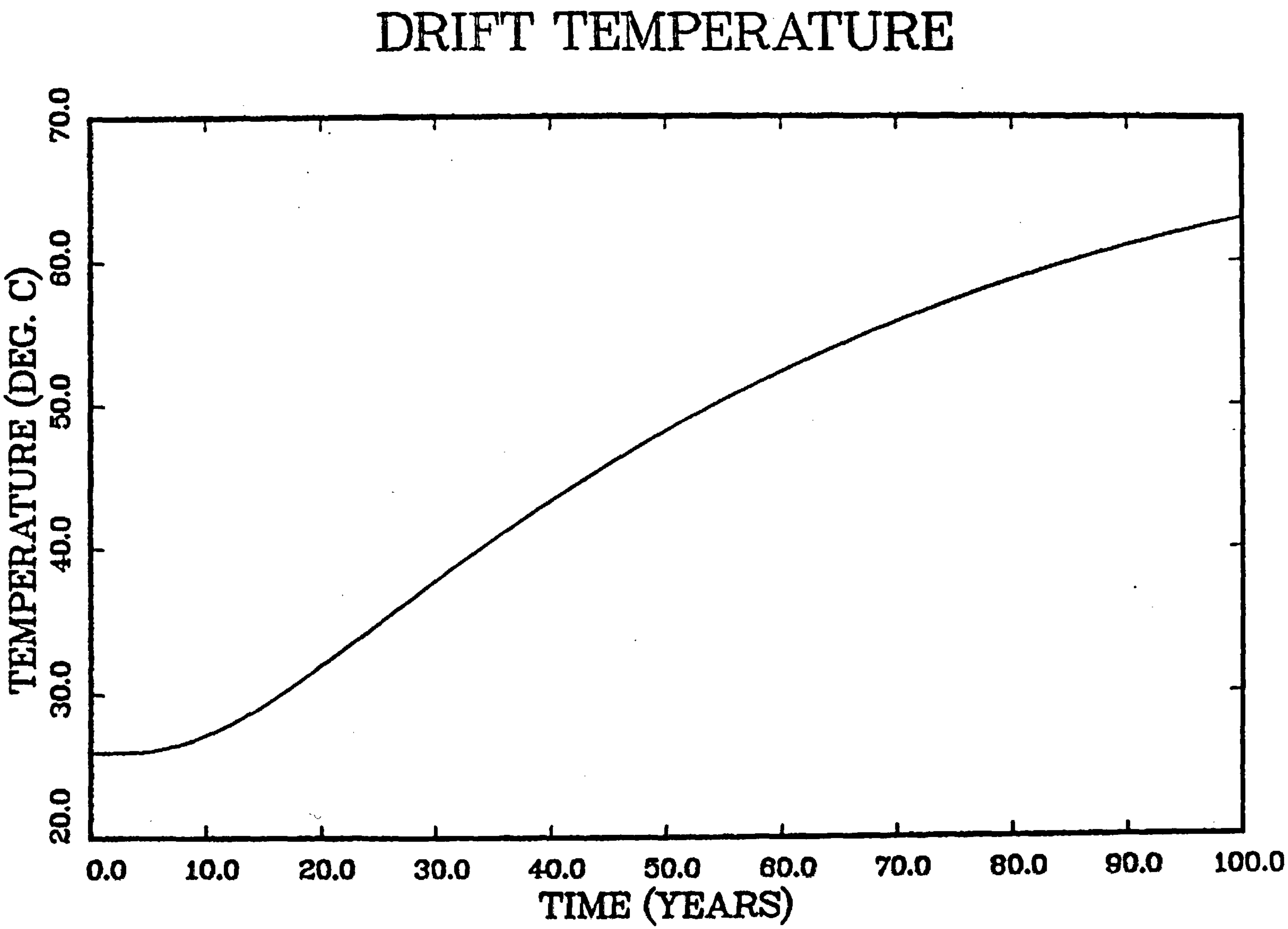

Figure 3. Average drift Temperatures (deg. C) for an Unventilated Horizontal Emplacement Drift (35 m standoff case).

PORFLOW SIMULATIONS: UNVENTILATED CASE - TIME HISTORY OF TEMPERATURE 72284

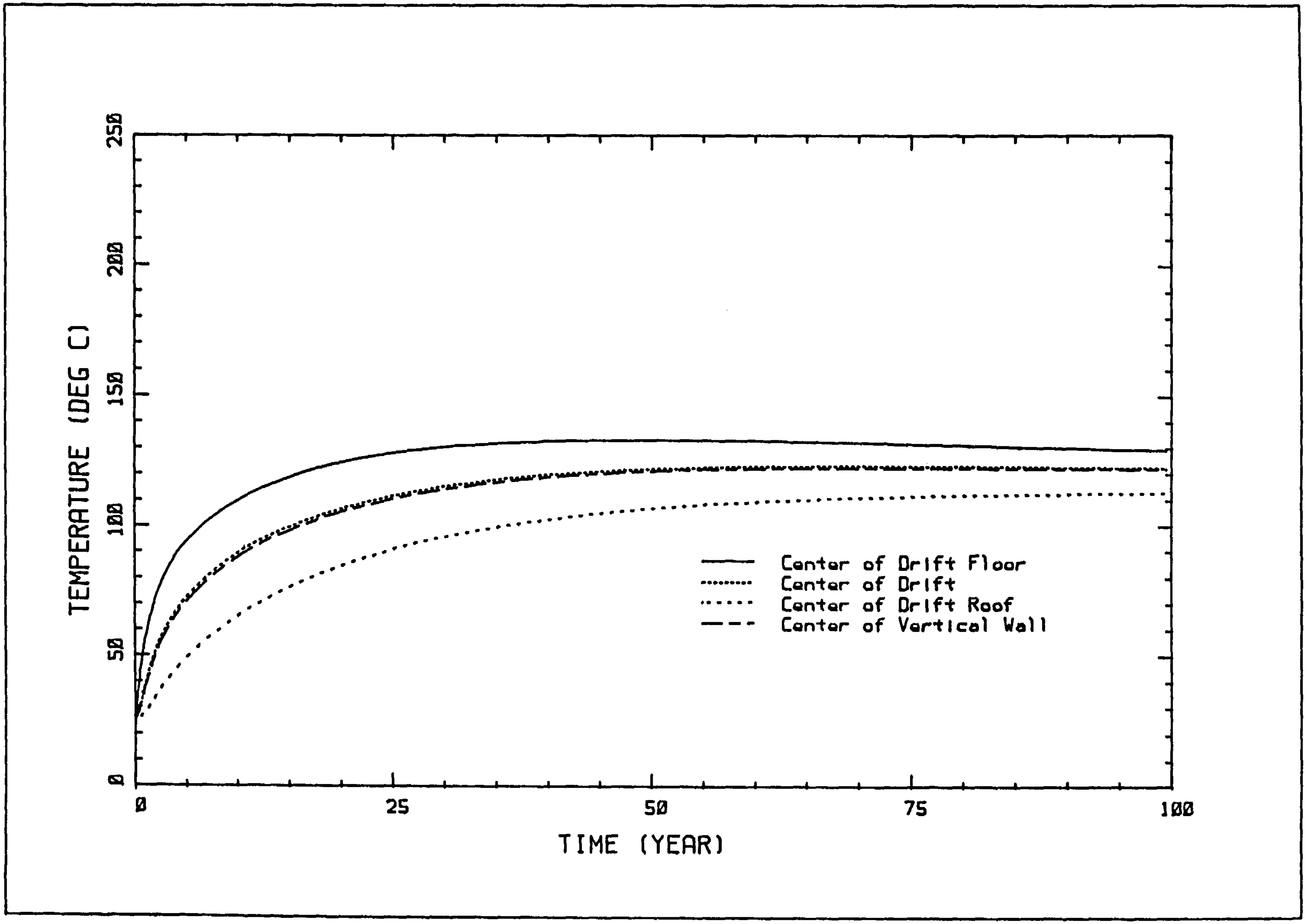

Figure 4. Vertical Emplacement Drift Temperatures for an Unventilated Drift

ADDENDUM TO APPENDIX A

1. The curves of Figure 1 should be labeled as follows: for the top curve, 3.4 kW/container; the middle curve, 3.0 kW/container; and the bottom curve, 2.4 kW/container.

2. Subsequent to this report two sets of reference calculations have been made.

   For emplacement drift conditions the reader should refer to C.M. St. John, "Reference Thermal and Thermal/Mechanical Analyses of Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff," SAND86-7005, Sandia National Laboratory, Albuquerque, NM, May, 1987.

   For horizontal emplacement borehole conditions the reader should refer to K. Arulmoli and C.M. St. John, "Analyses of Horizontal Waste Emplacement Boreholes of a Repository in Tuff," SAND 86-7133, Sandia National Laboratory, Albuquerque, NM, 1987.

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APPENDIX B

PRELIMINARY LINER STRESS ANALYSES

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Appendix B

PRELIMINARY LINER STRESS ANALYSIS

Introduction:

In addition to a vertical emplacement concept, the Nevada Nuclear Waste Storage Investigations (NNWSI) Project staff at Sandia National Laboratories are investigating horizontal emplacement of waste. The horizontal emplacement concept offers various potential cost and performance advantages (CDR Appendix E). To ensure that the emplaced waste will be retrievable as required by 10 CFR 60 (NRC, 1986), the current design for horizontal emplacement includes the use of a liner in the emplacement boreholes. This preliminary scoping analysis has been performed for two reasons: (1) to determine whether the liner can survive the anticipated rockfall loading and (2) to determine the amount of sacrificial material available for corrosion damage.

Approach:

Many different types of analysis techniques were considered for this preliminary scoping analysis (e.g., beam on elastic foundation analysis, finite element analysis, surface analysis, and ring loading analysis). A ring loading analysis was selected because it is considered to provide sufficient accuracy with a minimum level of effort and to produce conservative results. As shown in Figure B-1, a 1-in. section of the liner was isolated. The loading configuration for the resulting ring is shown in Figure B-2. The concept of superposition was used to develop the proper loading configuration. As shown in Figure B-3, by combining three loading configurations for which the solutions are known (Roark and Young, 1975), the loading arrangement shown in Figure B-2 can be modeled. The stresses in the liner resulting from the loads were predicted using the computer code PLOT_LOAD. This code predicts the bending stress at specific locations along the circumference of the liner. The results are presented as a plot of bending stress from the top of the liner (Point A) to the bottom (Point C). Verification of the computer code used for this analysis is contained in Attachment 1. A copy of the computer code is provided in Attachment 2.

Assumptions:

The following assumptions have been made for this analysis:

1. Only loading due to rockfall has been considered. The loads imparted by the waste package and the actual weight of the liner are not insignificant and will be considered in future work.

2. Axial loads have not been considered. The two possible sources for axial loading are (1) residual loads as a result of emplacement of the liner and (2) thermally induced axial stress. For this analysis, it has been assumed that the liner is free to move within the borehole.

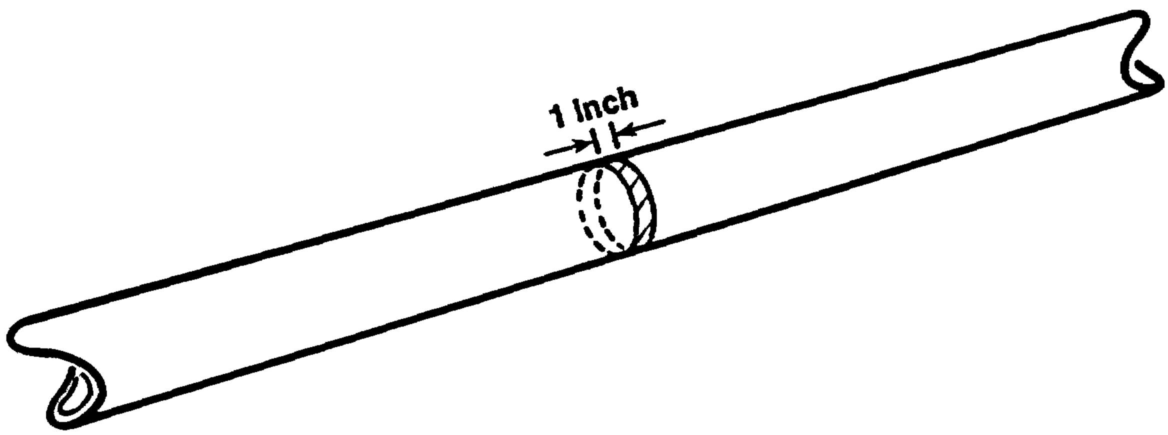


Figure B-1. Representative 1-in. Section for Ring Loading Analysis

3. Only bending stress has been considered. As a result of the imposed rockfall loading, bending, hoop, and shear stresses will be present. As shown in Attachment 3, the hoop and shear stresses are negligible in contrast to the bending stress.

Input Data:

The following input data have been used for this analysis:

Borehole radius	= 18.5 in.
Rock specific gravity	= 2.34
Liner radius (R)	= 18.0 in.
Liner thickness (t)	= 0.5 in.
Rock load angle (2a)	= 60°
Base reaction angle (2b)	= 20°

Rockfall Load Calculation:

This calculation utilizes the concept of a failure zone. The concept assumes that the rock within a zone of failure has fallen upon the liner. Two worst-case loading concepts, triangular and radial, were considered for this analysis. The triangular concept is suggested in "Field Investigation of Keyblock Stability," (Yow, 1985) and is shown in Figure B-4. Using an apex angle of 60°, the resulting rockfall load is 19.8 lb. The radial failure concept shown in Figure B-5 has been developed using engineering judgment. This concept assumes that 9.84 in. (0.25 m) of rock has failed in a zone that extends over a

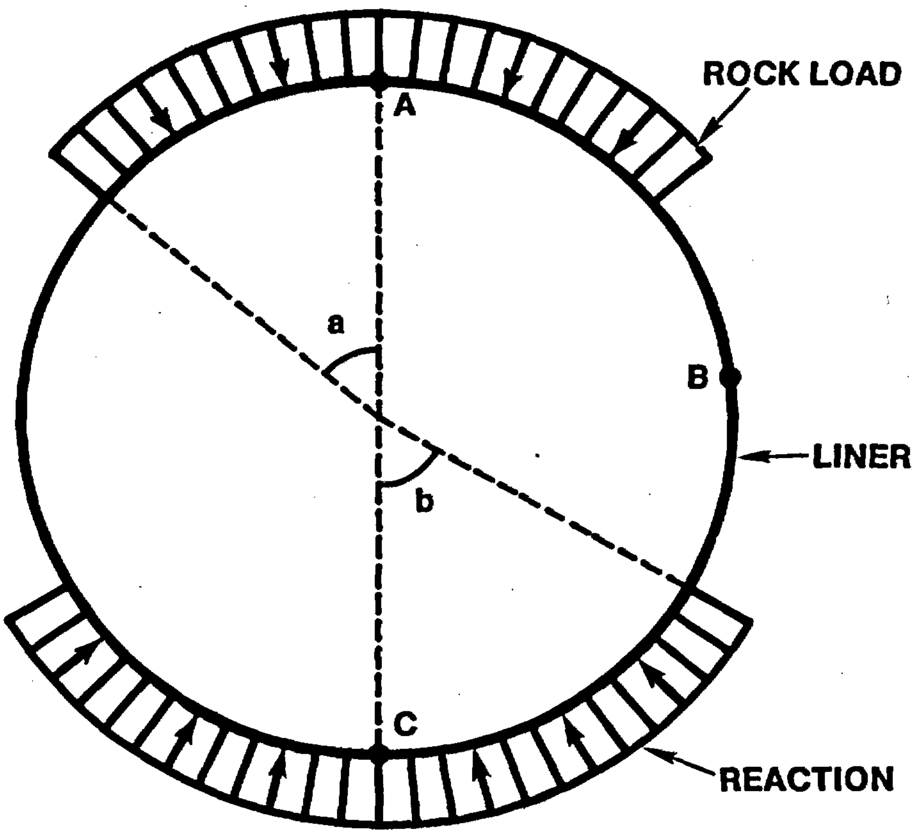


Figure B-2. Borehole Liner Load Diagram

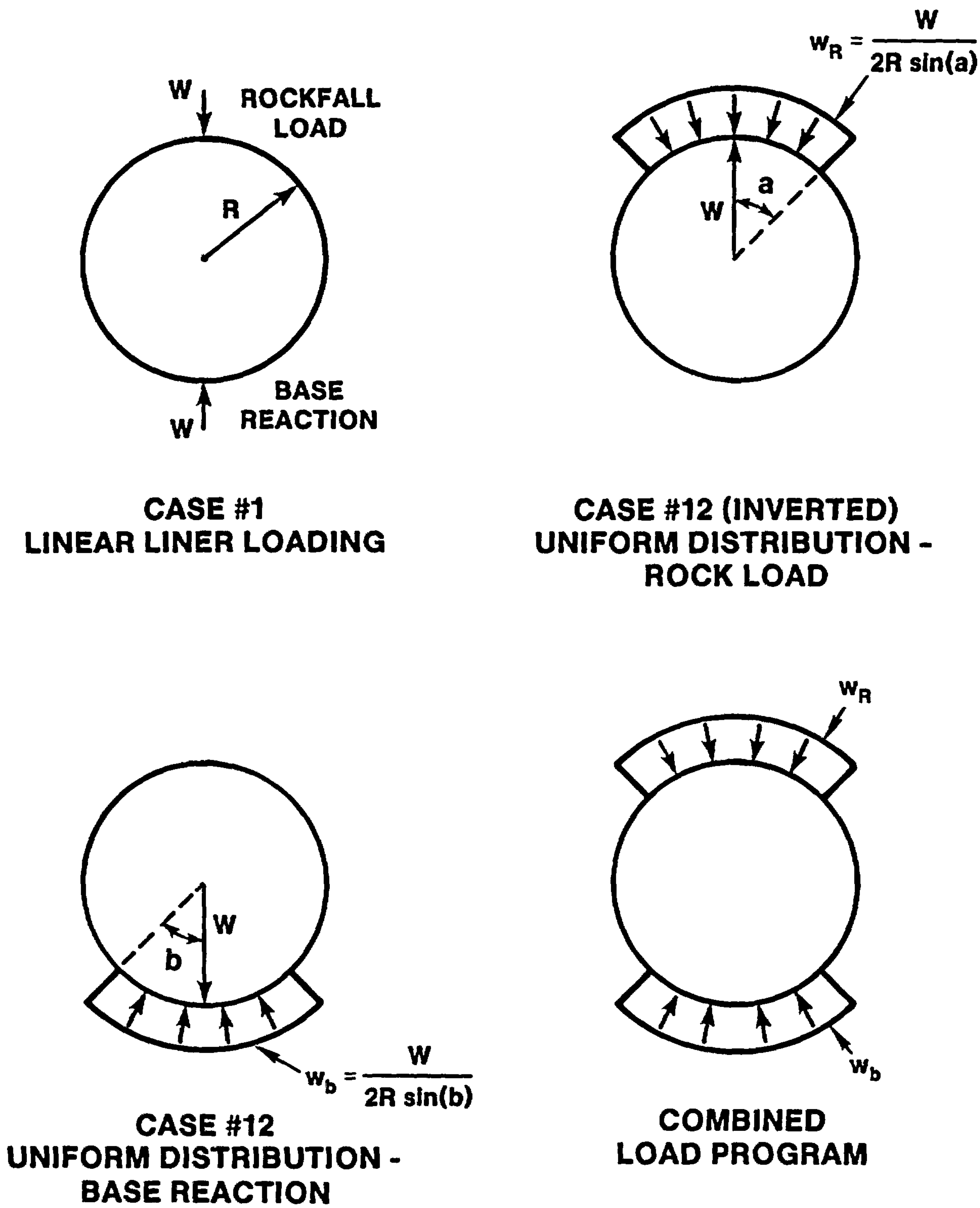
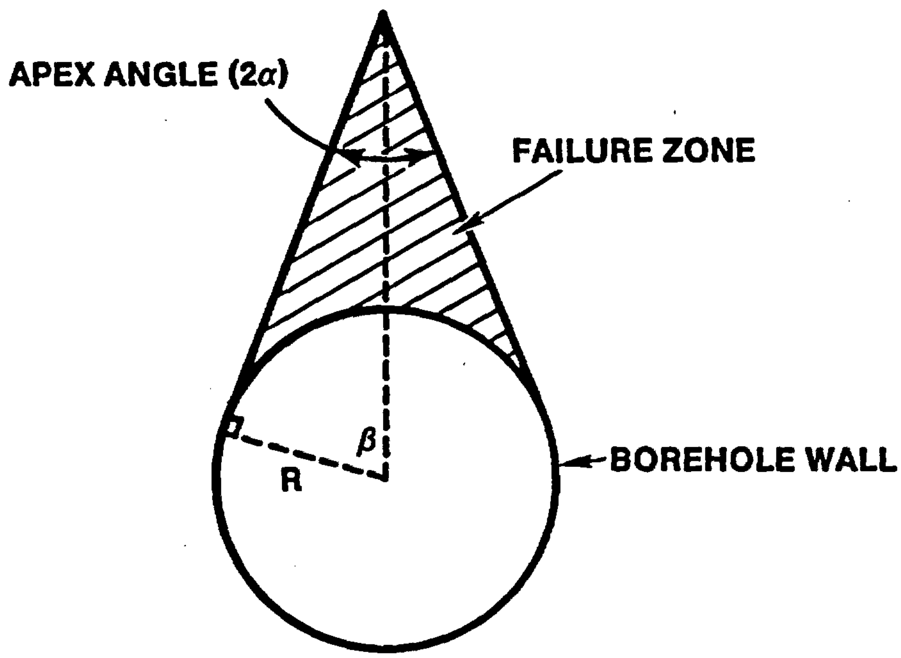


Figure B-3. Loading Configuration



$$\text{AREA} = R^2 \left(\frac{\cos \alpha}{\sin \alpha} - \beta \right) = R^2(\cot \alpha + \alpha_R - \pi/2)$$

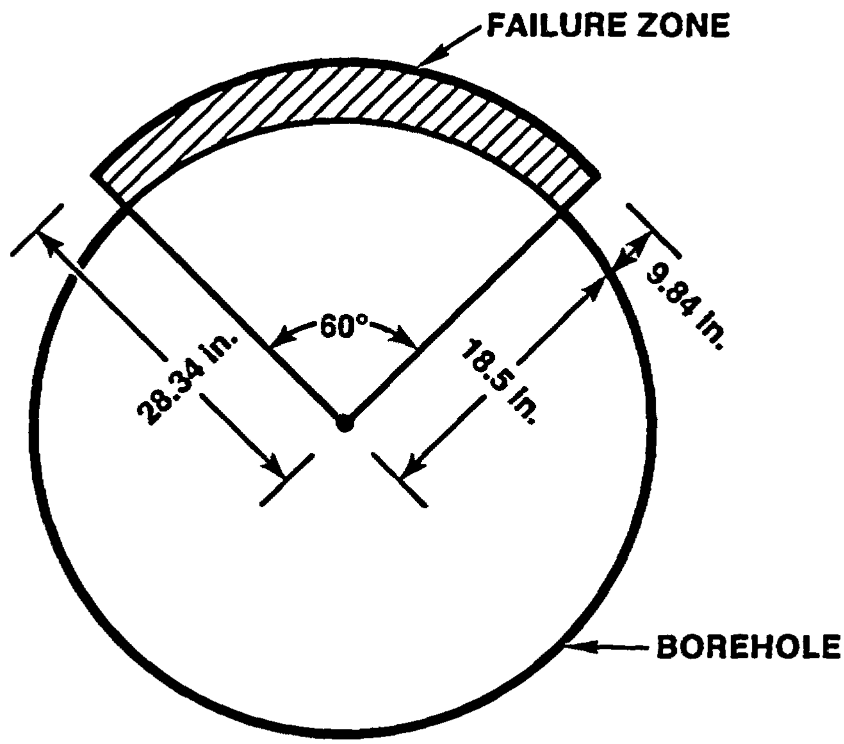
$$\text{AREA} = (18.5 \text{ in.})^2 \, [\cot(30°) + (30°)_R - \pi/2] = 234 \text{ in.}^2$$

$$\text{LOAD}^* = (\text{DENSITY})(\text{AREA})(1 \text{ in.}) = (0.0845 \text{ lb/in.}^3)(234 \text{ in.}^2)(1 \text{ in.})$$

$$\text{LOAD} = 19.8 \text{ lb}$$

*NOTE: THE LOAD IS BASED UPON A 1-in. RING

Figure B-4. Triangular Concept



$$\text{AREA} = \frac{\pi}{6}\left[(28.34\ \text{in.})^2 - (18.5\ \text{in.})^2\right] = 241.3\ \text{in.}^2$$

$$\text{LOAD}^* = (\text{DENSITY})(\text{AREA})(1\ \text{in.}) = (0.0845\ \text{lb/in.}^3)(241.3\ \text{in.}^2)(1\ \text{in.})$$

$$\text{LOAD} = 20.4\ \text{lb}$$

*NOTE: THE LOAD IS BASED UPON A 1-in. RING

Figure B-5. Radial Failure Concept

60° angle. The resulting rockfall load is 20.4 lb for the 1-in. ring length. The radial loading concept will be used for this analysis because it results in a larger load on the liner.

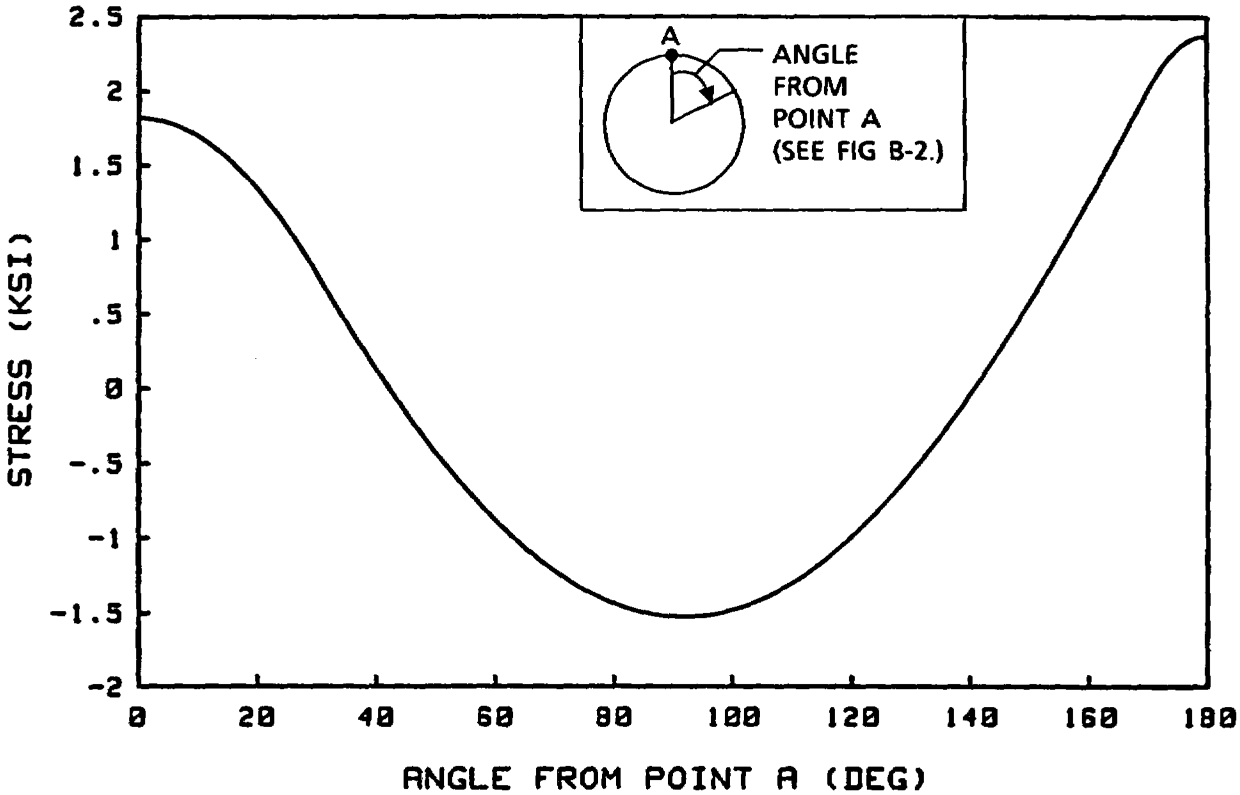
Results:

Four series of computer runs were made for this analysis. The first run was a verification run (presented in Attachment 3). This run confirmed that the computer code was solving the modeling equations correctly.

The second run computed the stress on the liner for the assumed input conditions and rockfall loading. The results are presented in Figure B-6. These results indicate that the maximum bending stress on the liner occurs at the bottom of the liner and is approximately +2,400 psi. (Note: the positive sign indicates that the bending is outward.) This stress level is negligible in comparison to the yield strength of low carbon steel of at least 30 Ksi.

The third run varied the rockfall and base reaction load angles to investigate the change in resulting liner stress predictions. As shown in Figures B-6 through B-8, the shape of the stress plots is affected only minimally by the variance of the rockfall load angle from 50° to 30°. The major effect was a variance of the stress at the top of the liner of approximately 500 psi. A similar response was observed by varying the base angle from 30° to 50° as shown in Figures B-9 through B-11.

The fourth computer run varied the liner thickness to simulate the possible effect of corrosion of the liner. As shown in Figures B-11 through B-19, the stress in the liner does not become significant (compared to the liner yield stress of at least 30 Ksi, assuming low carbon steel) until the thickness is reduced to 0.2 inches (a 60% reduction in thickness). With current projections of corrosion rates on the order of 2 mpy (mills per year) (NACE, 1974), sufficient sacrificial material should be present for the 0.5-in.-thick liner to survive the 84-yr expected lifetime.



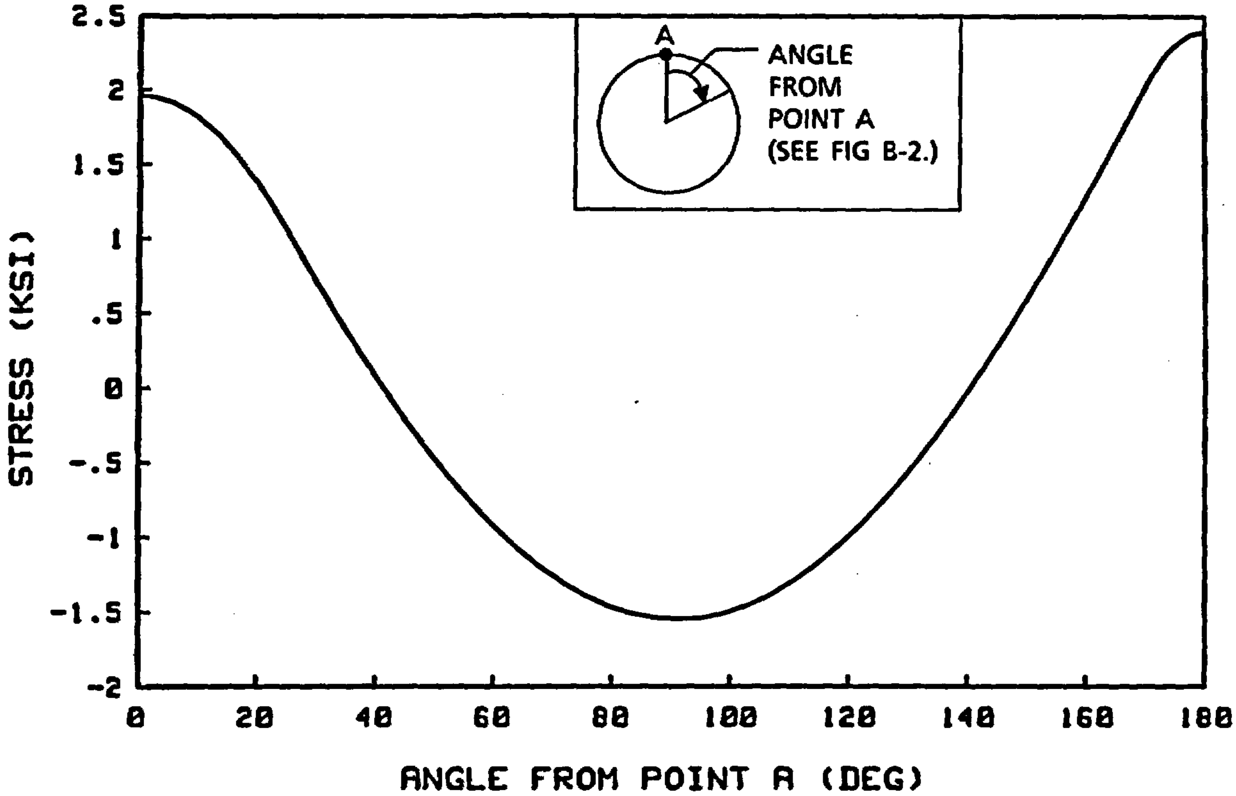
INPUT DATA

LINER RADIUS	=	18.0 INCHES
LINER THICKNESS	=	.500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING	=	20.4 LBS/IN
ROCK LOAD ANGLE	=	60 DEGREES
BASE LOAD ANGLE	=	20 DEGREES

Figure B-6. Liner Stress Due to Rockfall Loading



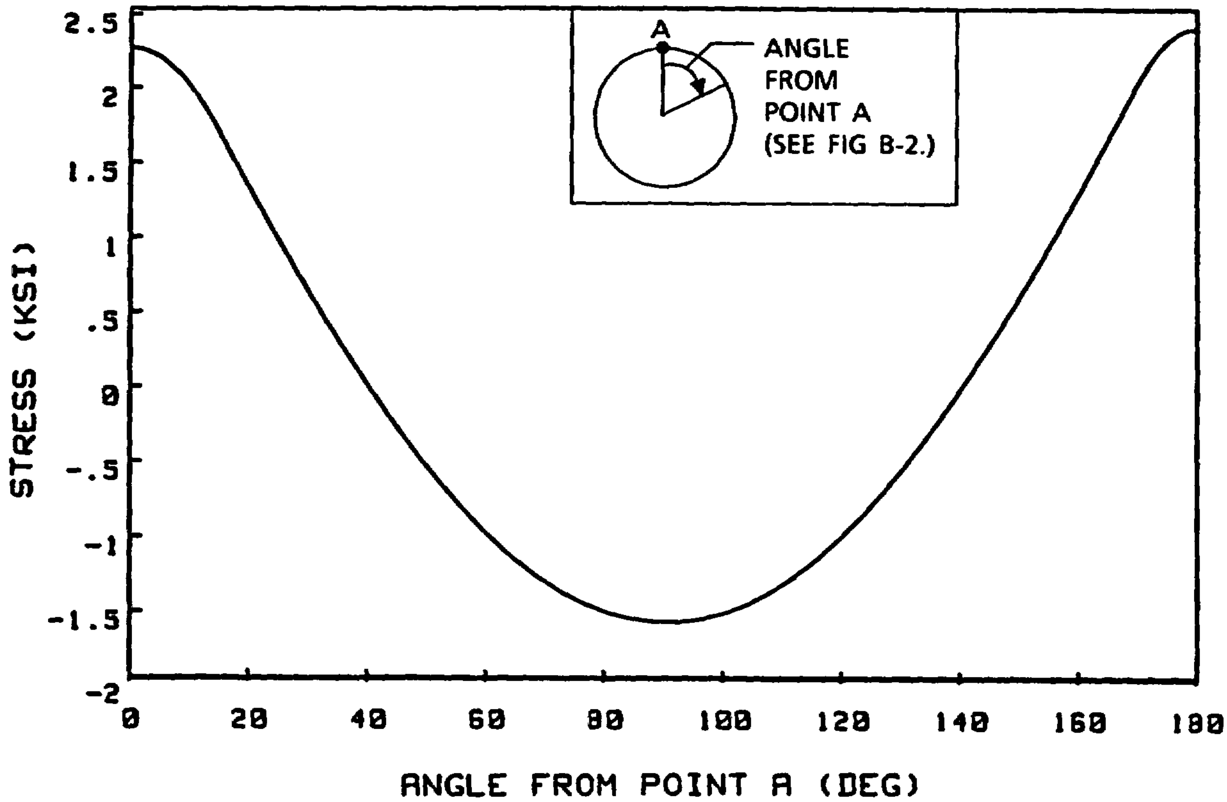
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 50 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-7. Liner Stress - Effect of Varying Rock Load Angle (50°)



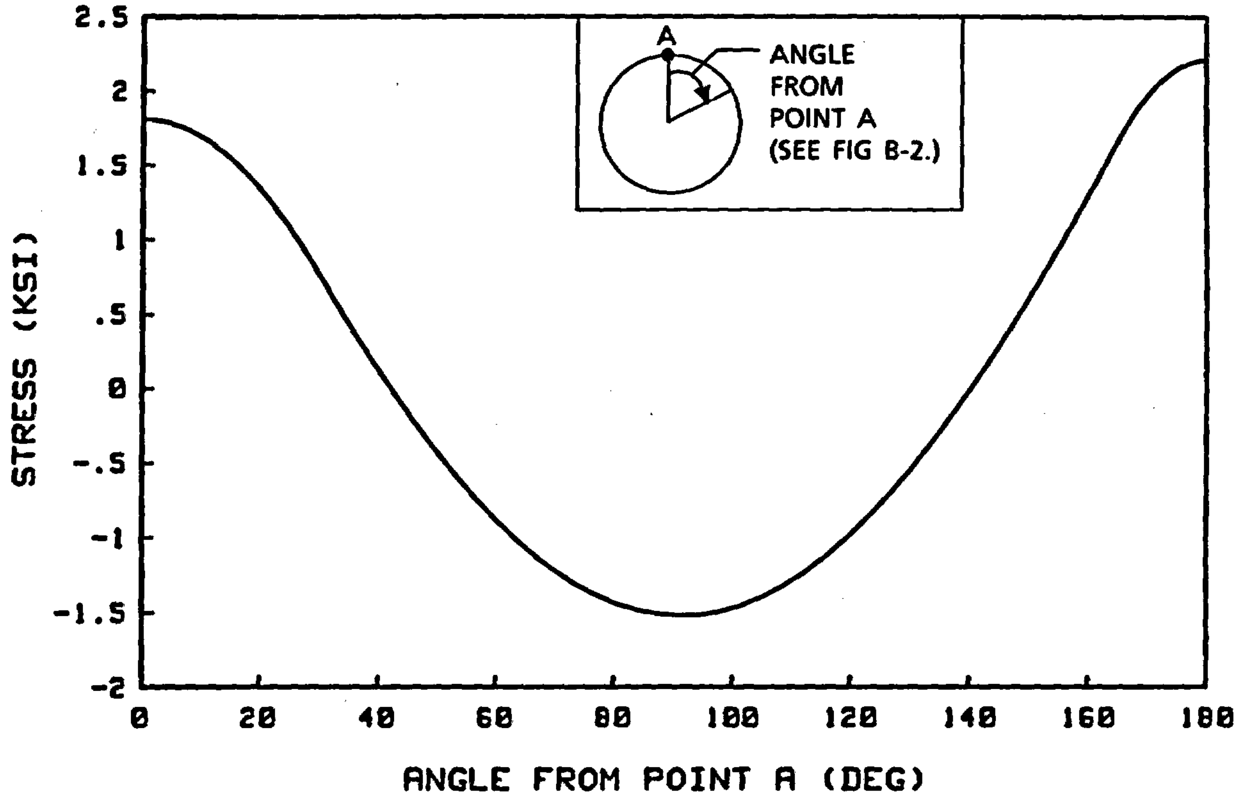
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 30 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-8. Liner Stress - Effect of Varying Rock Load Angle (30°)



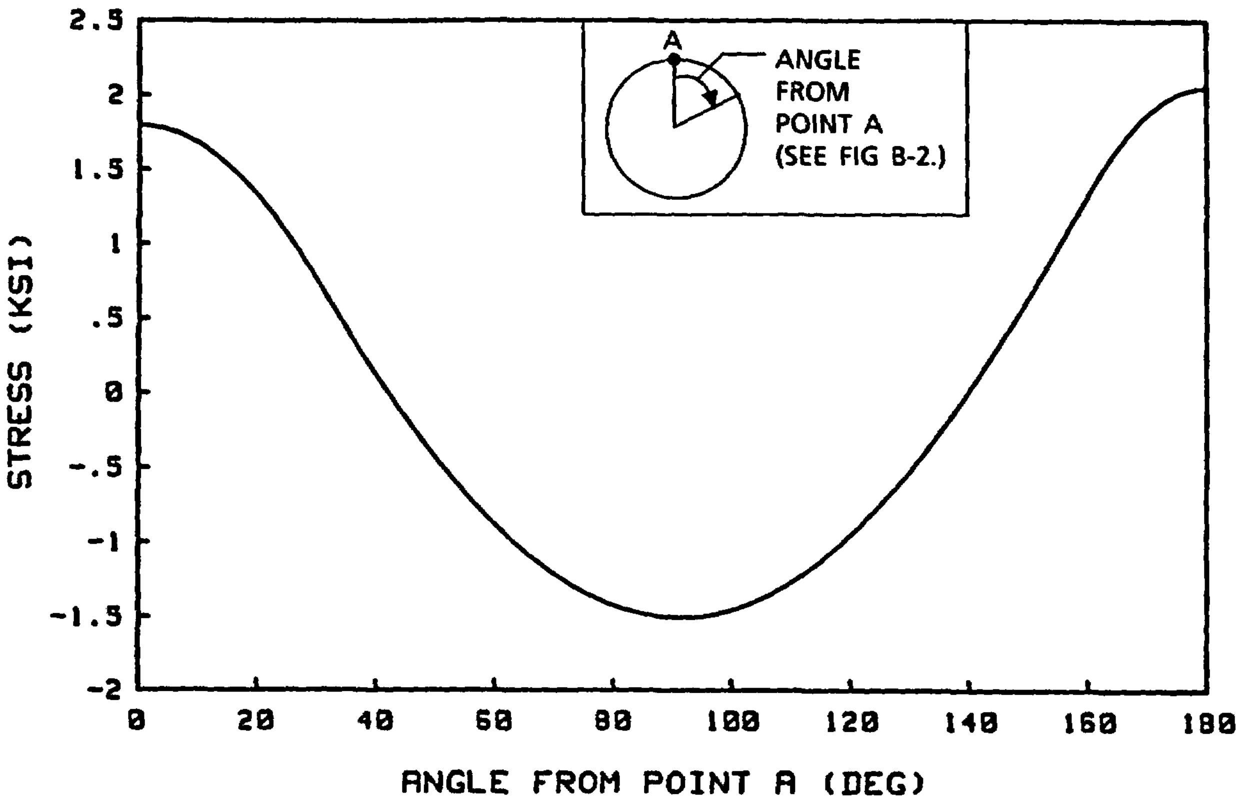
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 30 DEGREES

Figure B-9. Liner Stress - Effect of Varying Base Angle (30°)



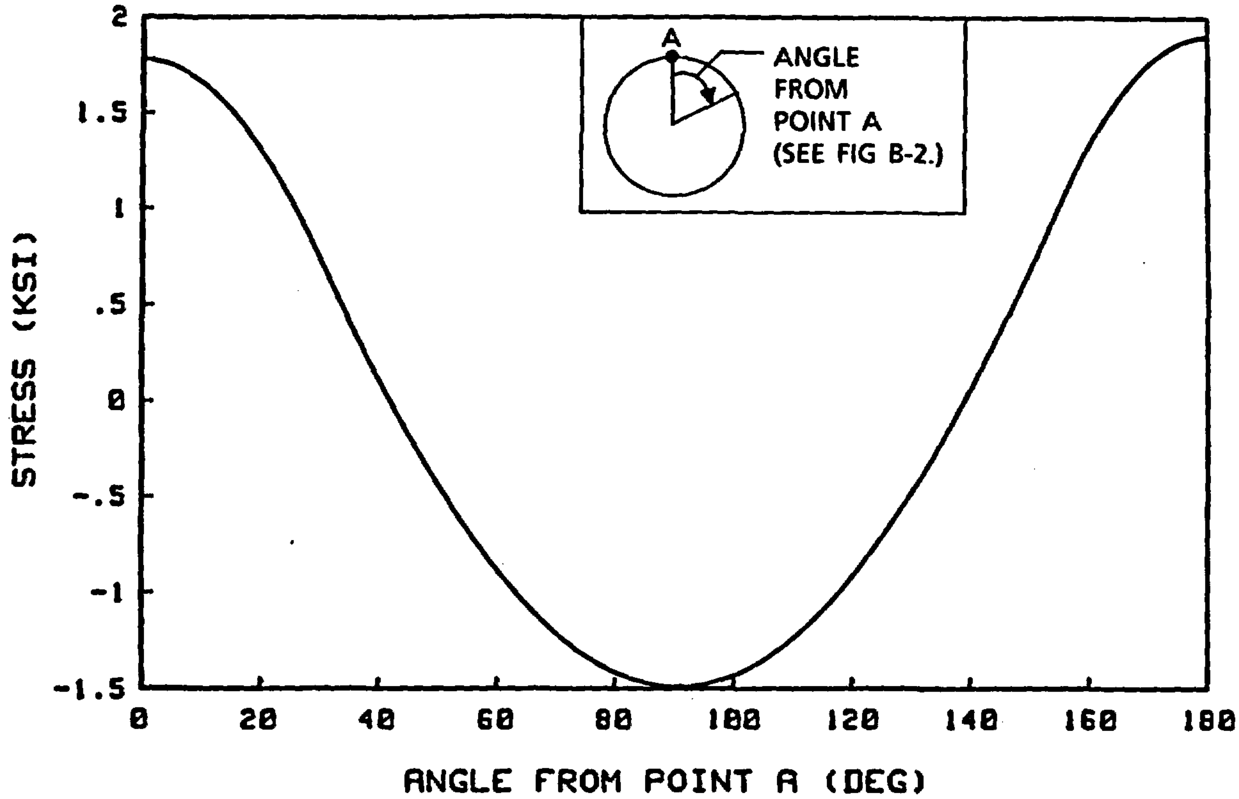
INPUT DATA

LINER RADIUS	=	18.0 INCHES
LINER THICKNESS	=	.500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING	=	20.4 LBS/IN
ROCK LOAD ANGLE	=	60 DEGREES
BASE LOAD ANGLE	=	40 DEGREES

Figure B-10. Liner Stress - Effect of Varying Base Angle (40°)



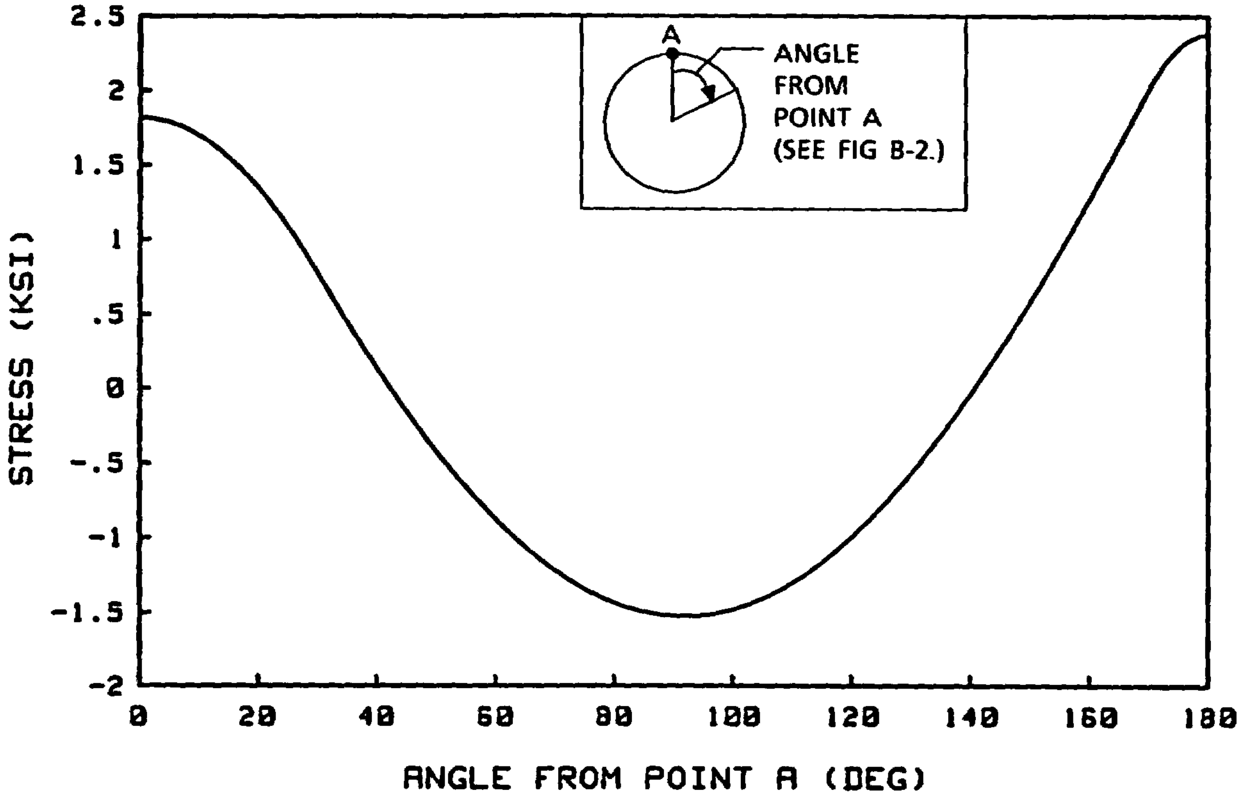
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 50 DEGREES

Figure B-11. Liner Stress - Effect of Varying Base Angle (50°)



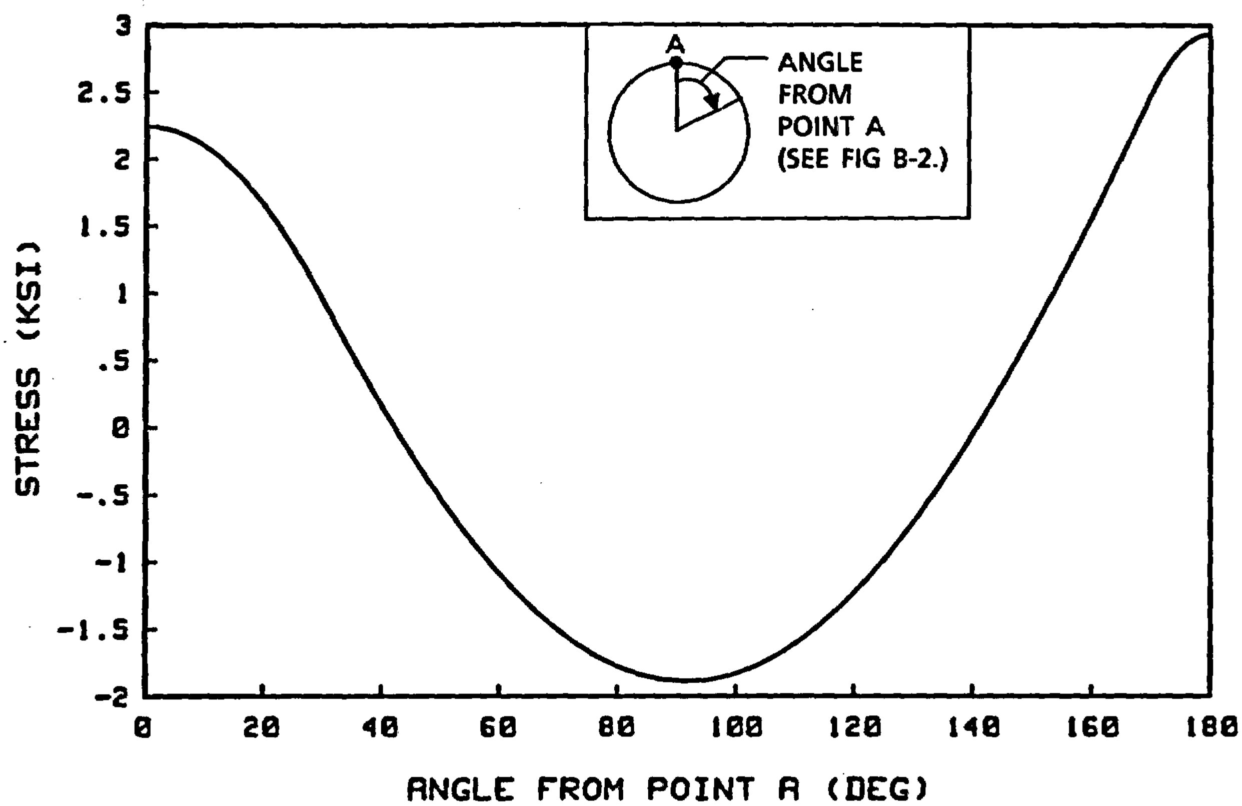
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-12. Liner Stress - Effect of Varying Liner Thickness (.500 in.)



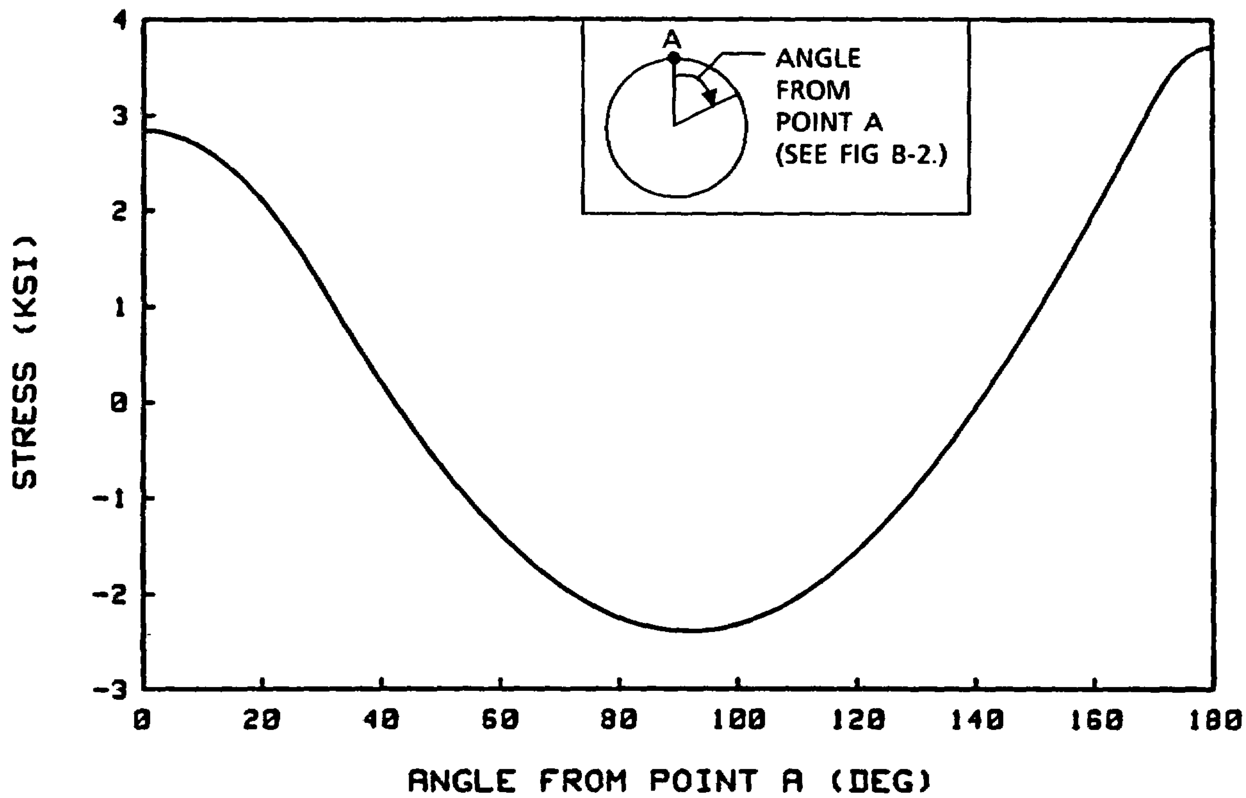
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .450 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-13. Liner Stress - Effect of Varying Liner Thickness (.450 in.)



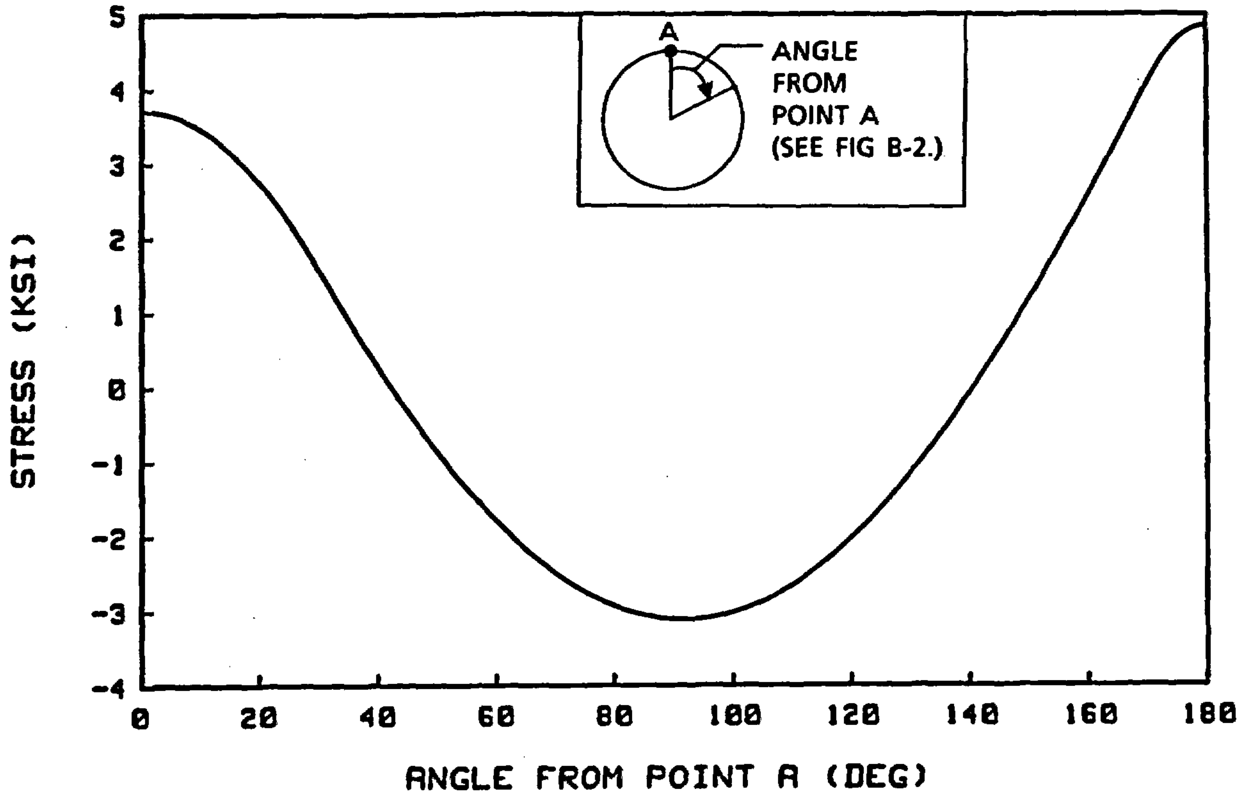
INPUT DATA

LINER RADIUS	=	18.0 INCHES
LINER THICKNESS	=	.400 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING	=	20.4 LBS/IN
ROCK LOAD ANGLE	=	60 DEGREES
BASE LOAD ANGLE	=	20 DEGREES

Figure B-14. Liner Stress - Effect of Varying Liner Thickness (.400 in.)



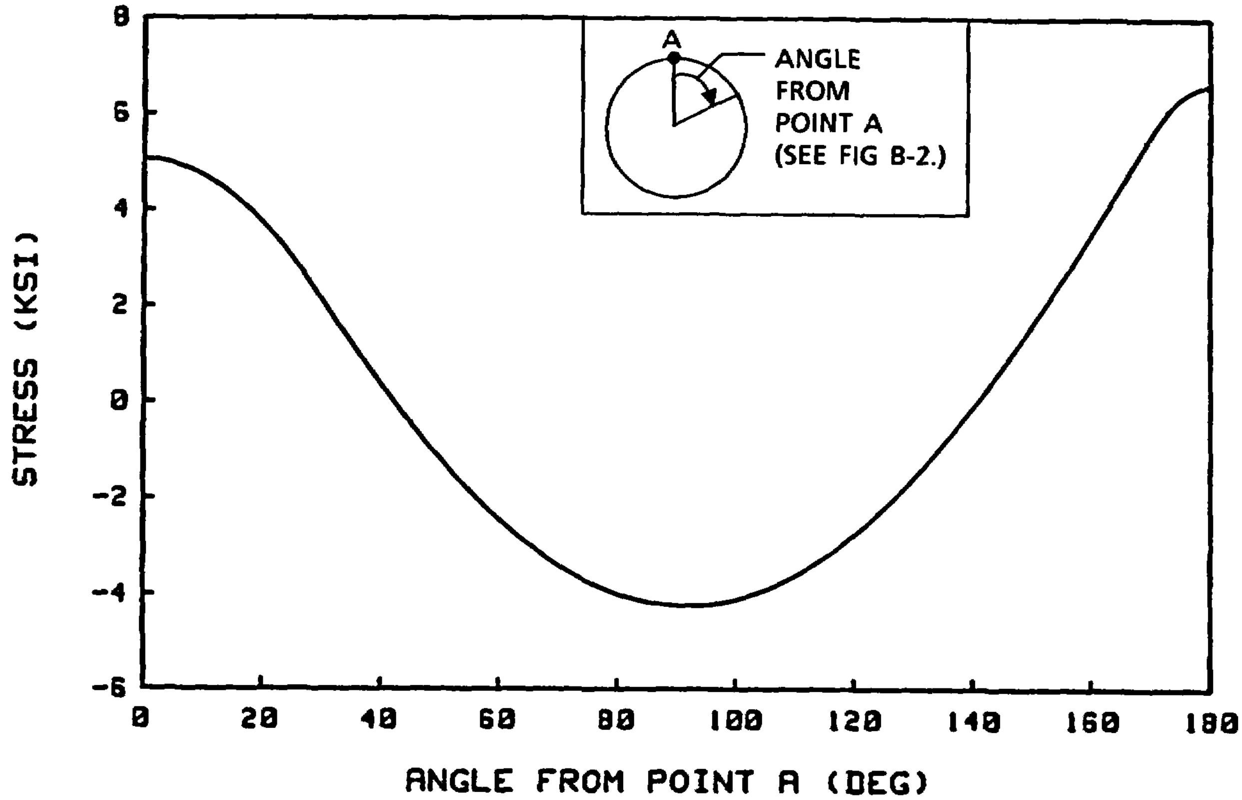
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .350 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-15. Liner Stress - Effect of Varying Liner Thickness (.350 in.)



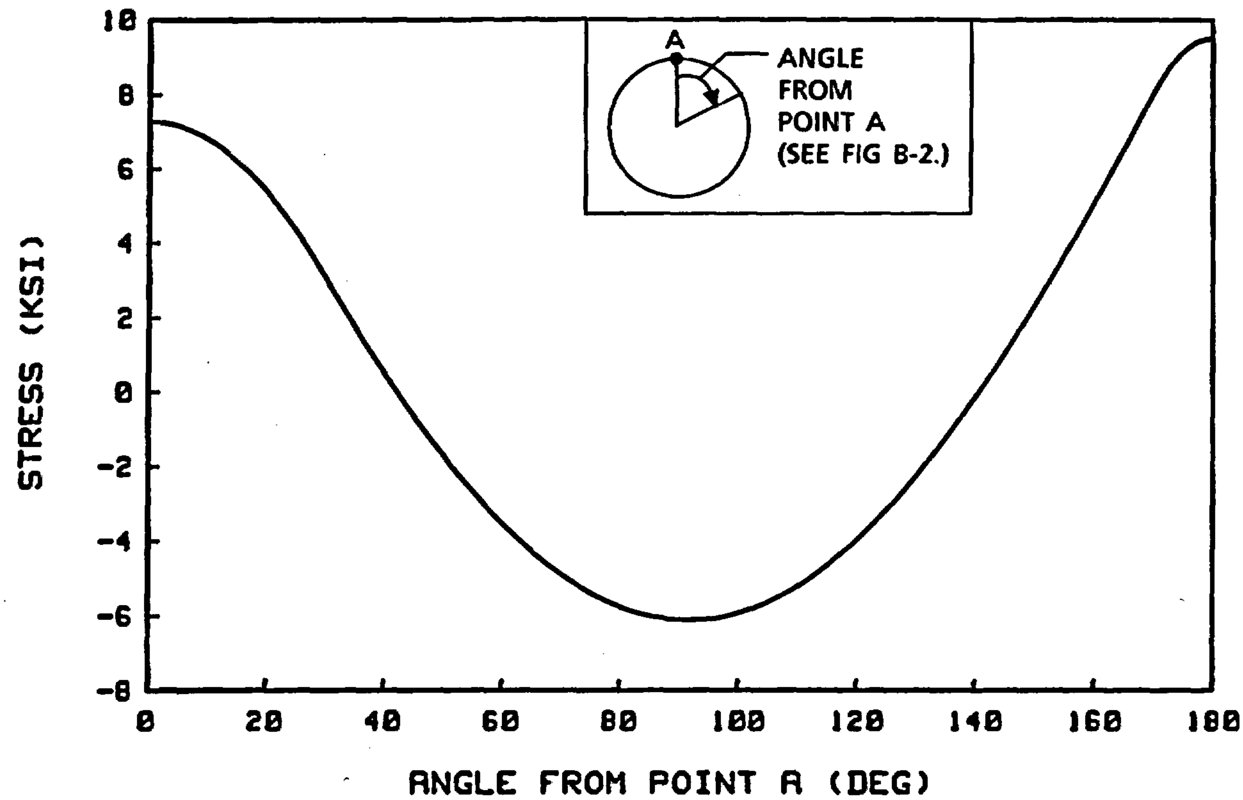
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .300 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-16. Liner Stress - Effect of Varying Liner Thickness (.300 in.)



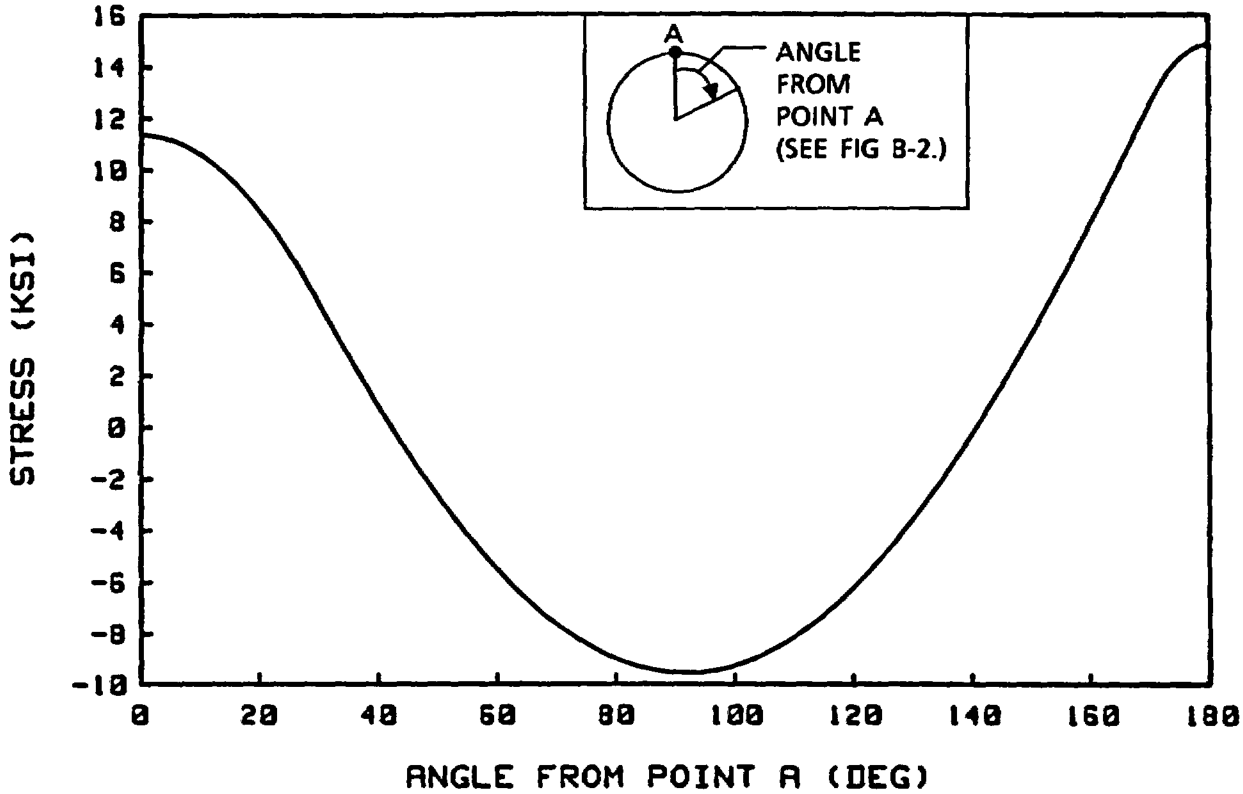
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .250 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-17. Liner Stress - Effect of Varying Liner Thickness (.250 in.)



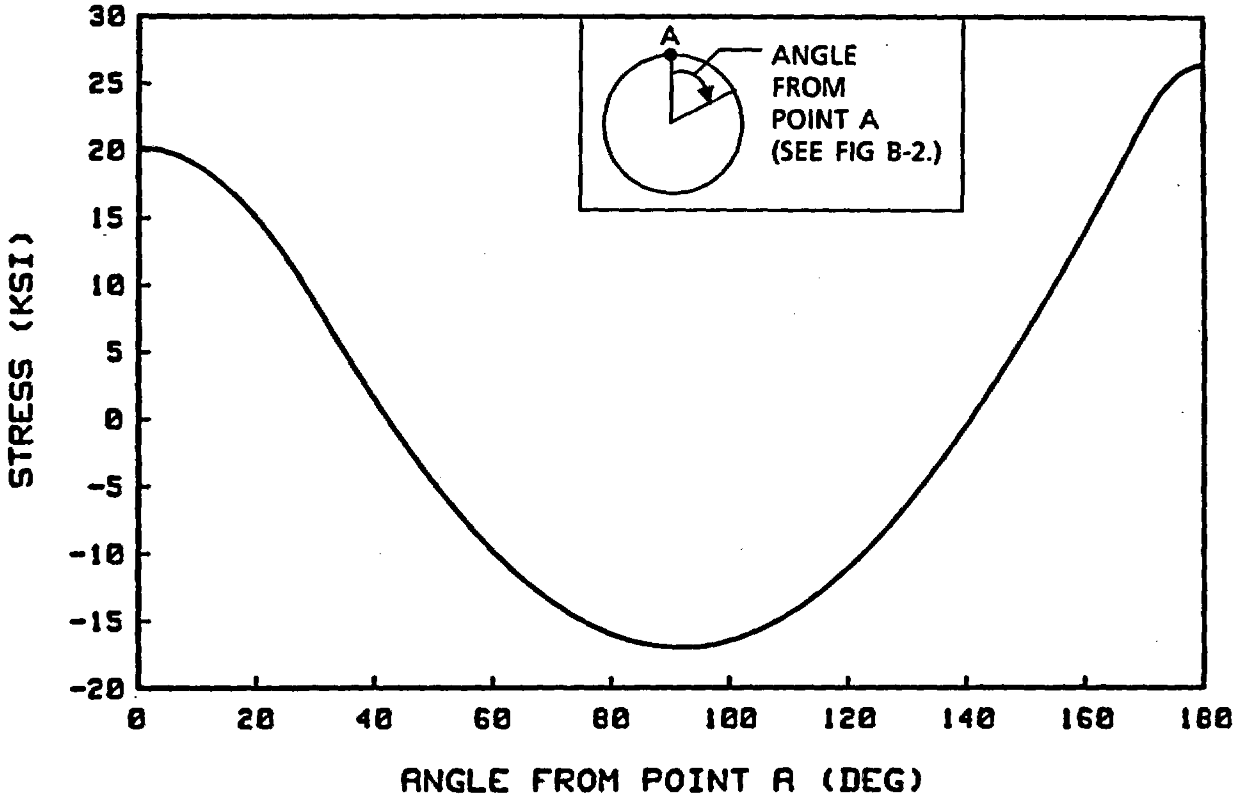
INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .200 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-18. Liner Stress - Effect of Varying Liner Thickness (.200 in.)



INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .150 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-19. Liner Stress - Effect of Varying Liner Thickness (.150 in.)

Attachment #1

COMPUTER CODE VERIFICATION

Date: 10/14/86
Code Name: PLOT_LOAD
Author: Richard Flores

Subject: This computer code calculates the bending stress as a result of rockfall loading on a liner. A diagram of the assumed loading diagram is attached.

Data Input: $R = 18.0$ in. (radius)
$t = 0.5$ in. (thickness)
$W = 20.4$ lb (rock load)
$a = 30°$ (rock load half-angle)
$b = 10°$ (reaction load half-angle)
$E = 3 \times 10^7$ psi (Young's Modulus)

Verification: The computer code is verified by performing a hand calculation at three points on the liner: the top (Pt. A), the side (Pt. B), and the bottom (Pt. C).

Results: The results from the hand calculations are as follows:

$\sigma_A = 1{,}810$ psi
$\sigma_B = 1{,}530$ psi
$\sigma_C = 2{,}380$ psi

The results from the verification computer run (Table B-1 and Figure B-20) produced the same results.

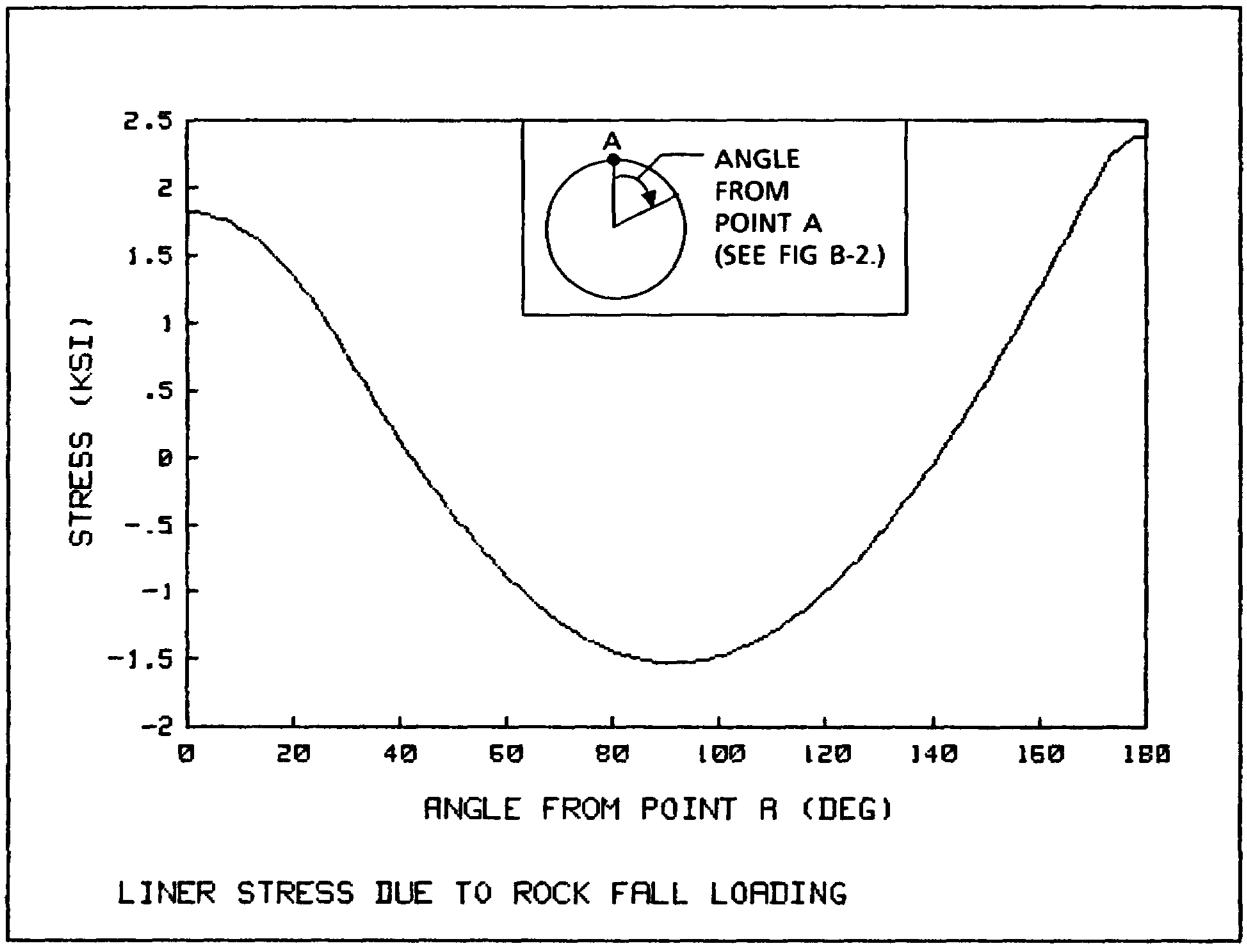
<u>Notation</u>

ω_R = distributed load from the rock
ω_B = distributed load from the base response
$\theta_R = 180° - a$ (for rock load)
$\theta_B = 180° - b$ (for base response)
$C = \text{Cos}\ \theta$
$S = \text{Sin}\ \theta$
$C_B = \text{Cos}\ \theta_B$
$C_R = \text{Cos}\ \theta_R$
$S_B = \text{Sin}\ \theta_B$
$S_R = \text{Sin}\ \theta_R$
t = liner thickness

TABLE B-1

RESULTS FROM COMPUTER CODE VERIFICATION RUN

Angle (Degrees)	Bending Moment (in-lb)	Bending Stress (Ksi)
0	75.6	1.81
5	74.4	1.78
10	70.7	1.70
15	64.6	1.55
20	56.1	1.35
25	45.3	1.09
30	32.3	0.78
35	18.6	0.45
40	5.6	0.14
45	-6.5	-0.16
50	-17.6	-0.42
55	-27.7	-0.66
60	-36.6	-0.88
65	-44.4	-1.07
70	-50.9	-1.22
75	-56.2	-1.35
80	-60.0	-1.44
85	-62.5	-1.50
90	-63.7	-1.53
95	-63.4	-1.52
100	-61.7	-1.48
105	-58.7	-1.41
110	-54.2	-1.30
115	-48.5	-1.16
120	-41.5	-1.00
125	-33.2	-0.80
130	-23.8	-0.57
135	-13.3	-0.32
140	-1.8	-0.04
145	10.7	0.26
150	23.9	0.57
155	38.0	0.91
160	52.6	1.26
165	67.7	1.63
170	83.3	2.00
175	95.1	2.28
180	99.0	2.38



INPUT DATA

LINER RADIUS = 18.0 INCHES
LINER THICKNESS = .500 INCHES

ASSUMED LOADING CONDITIONS

ROCK FALL LOADING = 20.4 LBS/IN
ROCK LOAD ANGLE = 60 DEGREES
BASE LOAD ANGLE = 20 DEGREES

Figure B-20. Liner Stress Results for Code Verification

HAND CALCULATION FOR POINT A (TOP)

From Roark and Young (1975), pages 220 and 230:

$$M_A = (M_A)_{Case\ 1} + \left[(M_C)_{Case\ 12}\right]_R + \left[(M_A)_{Case\ 12}\right]_B$$

$$M_A = \frac{WR}{\pi} - \omega_R R^2 \left[\frac{\theta_R}{\pi}(1 + C_R)\right] - \omega_B R^2 \left[\frac{1}{\pi}(\theta_B + 2S_B - \theta_B C_B) - 1 + C_B\right]$$

Since: $\omega_B = \frac{W}{2R\ S_B}$ and $\omega_R = \frac{W}{2R\ S_R}$

$$\frac{M_A}{WR} = \frac{1}{\pi} - \frac{\theta_R}{2\pi\ S_R}(1 + C_R) - \frac{1}{2S_B}\left[\frac{1}{\pi}(\theta_B + 2S_B - \theta_B\ C_B) - 1 + C_B\right]$$

*Inserting values:

$$M_A = (20.4\ \text{lb})\ (18\ \text{in})\left[\frac{1}{\pi} - 0.111 - 0.00081\right] = 75.6\ \text{in-lb}$$

$$\sigma = \frac{Mc}{I} \quad \text{and} \quad C = \frac{t}{2} \quad \text{and} \quad I = \frac{t^3}{12}(1\ \text{in}) \longrightarrow \sigma = \frac{6M}{t^2}\left(\frac{1}{1\ \text{in}}\right)$$

$$\sigma_A = \frac{6(75.6\ \text{in-lb})}{(0.5\ \text{in})^2(1\ \text{in})} = 1{,}810\ \text{psi}$$

$M_A = 75.6$ in-lb
$\sigma_A = 1{,}810$ psi

*Note: Values are based upon a 1-in. ring.

HAND CALCULATION FOR POINT B (SIDE)

From Roark and Young (1975), pages 220 and 230:

$$M_B = (M_B)_{Case\ 1} + \left[(M_B)_{Case\ 12}\right]_R + \left[(M_B)_{Case\ 12}\right]_B$$

In General: $M_B = \frac{WR}{\pi} - \frac{WR}{2}$ (Case 1)

$$M_B = \omega R^2 \quad - [\frac{1}{\pi}(\theta + 2S - \theta C) - 1 + C] + \frac{1}{\pi}(S - \theta C) + C \qquad \text{(Case 12)}$$

Combining with $\omega = \frac{W}{2R\sin\theta}$

$$\frac{M_B}{WR} = \frac{1}{\pi} - \frac{1}{2} + \frac{1}{2S_R}\left[1 - \frac{1}{\pi}(\theta_R + S_R)\right] + \frac{1}{2S_B}\left[1 - \frac{1}{\pi}(\theta_B + S_B)\right]$$

*Inserting values: $\frac{M_B}{WR} = \frac{1}{\pi} - \frac{1}{2} + 0.00751 + 0.00081$

M_B = (20.4 lb) (18 in) (-0.1734) = -63.7 in-lb

$$\sigma_B = \frac{6(-63.7 \text{ in-lb})}{(0.5 \text{ in})^2(1 \text{ in})} = -1{,}530 \text{ psi}$$

M_B = -63.7 in-lb σ_B = -1,530 psi

*Note: Values are based upon a 1-in. ring.

HAND CALCULATION FOR POINT C (BOTTOM)

From Roark and Young (1975), pages 220 and 230:

$$M_C = (M_C)_{Case\ 1} + \left[(M_C)_{Case\ 12}\right]_B + \left[(M_A)_{Case\ 12}\right]_R$$

$$M_C = \frac{WR}{\pi} - \omega_B R^2 \left[\frac{\theta_B}{\pi}(1 + C_B)\right] - \omega_R R^2 \left[\frac{1}{\pi}(\theta_R + 2\ S_R - \theta_R C_R) - 1 + C_R\right]$$

Since: $\omega_B = \frac{W}{2R\ S_B}$ and $\omega_R = \frac{W}{2R\ S_R}$

$$\frac{M_C}{WR} = \frac{1}{\pi} - \frac{\theta_B}{2S_B\pi}(1 + C_B) - \frac{1}{2S_R}\left[\frac{1}{\pi}(\theta_R + 2S_R - \theta_R C_R) - 1 + C_R\right]$$

*Inserting values: $\frac{M_C}{WR} = \frac{1}{\pi} - \frac{8.54}{\pi}(0.015) - (1)\left[\frac{1}{\pi}(5.88) - 1 + C_R\right]$

$$M_C = (20.4\ \text{lb})\ (18\ \text{in})\left[\frac{1}{\pi} - 0.04131 - \overset{0.2697}{0.00731}\right] = 99\ \text{in-lb}$$

$$\sigma_C = \frac{6(99\ \text{in-lb})}{(0.5\ \text{in})^2(1\ \text{in})} = 2{,}380\ \text{psi}$$

*Note: Values are based upon a 1-in. ring.

Attachment #2

SOURCE CODE FOR PROGRAM "PLOT-LOAD"

```
1      !
2      !                    RICHARD J. FLORES
3      !
4      !                      DIVISION 6314
5      !               SANDIA NATIONAL LABORATORIES
6      !
7      !
8      !                   PROGRAM "PLOT_LOAD"
9      !
10     !
12     !  THIS PROGRAM SIMULATES THE EFFECT OF ROCK FALL LOADING
13     !  ON THE BOREHOLE LINER.
14     !
15     !  IT INCLUDES BOTH A LINEAR AND A UNIFORM LOADING MODEL.
20     !
30     !
40     !
41     OPTION BASE 1
50     DIM Xa(200),Ma(200),Mb(200),Mc(200),X(200),Xdeg(200),Str(200)
51     DIM Rmin(2),Rmax(2),Tic(2),Y(200)
52     DIM L$[80],X1$[40],Y1$[40],Num_pts(10),Line_type(10),Out_put(10,200)
53     DIM Shear(200),Hoop(200)
60     !
61     Out_flag=0                   ! 1 FOR PRINTER
62     !                            ! 2 FOR PLOTTER
64     !
70     !      EVALUATE EVERY DEG
80     !
90     Pts=181
100    FOR I=1 TO Pts
110      Xa(I)=(I-1)*PI/180
120    NEXT I
130    !
140    Nu=.3
150    T=.5                      ! LINER THICKNESS
160    R=18                      ! LINER RADIUS  (O.D.)
161    !
162    !  ANGULAR MEASUREMENTS ASSUME A 30 DEG. APEX HALF ANGLE
163    !
170    Theta=PI/6                ! APEX HALF ANGLE
171    Beta=PI/6                 ! ROCK FALL LOADING HALF-ANGLE
172    Phi=PI-Beta               ! 180 DEG. MINUS BETA
173    Zeta=PI/18                ! 10 DEG. BASE HALF-ANGLE
175    Rho=PI-Zeta
176    !
180    W=33.0                    ! LOADING AT 30 DEG. (LB/IN)
190    !
200    CALL Uni_base(W,R,T,Nu,Phi,Xa(*),Ma(*),Pts,Shear(*),Hoop(*))
201    CALL Line_load(W,R,T,Nu,Xa(*),Mb(*),Pts,Shear(*),Hoop(*))
203    CALL Uni_base(W,R,T,Nu,Rho,Xa(*),Mc(*),Pts,Shear(*),Hoop(*))
210    !
211    Loading=3
212    !
214    FOR I=1 TO Pts
215      Xdeg(I)=Xa(I)*180/PI
216      J=Pts+1-I               !   INVERT THE LOADING FOR ROCKFALL
217      SELECT Loading
218        CASE 1                      !  LINE TOP AND BOTTOM
219          M=Mb(J)
220        CASE 2                      !  UNI TOP, LINE BOTTOM
```

```
221             M=Ma(J)+Mb(J)
222          CASE 3                    !  UNI TOP AND BOTTOM
223             M=Ma(J)+Mb(J)+Mc(I)
224       END SELECT
225       !
226       Str(I)=M*6/(1000*T^2)
227       !PRINT Xdeg(I),Str(I)
230    NEXT I
231    !PRINT
240    !PRINT Horz,Vert
250    !
251    !            PLOT THE RESULTS
252    !
253    L$="LINER STRESS DUE TO ROCK FALL LOADING"
254    X1$="ANGLE FROM POINT A (DEG)"
255    Y1$="STRESS (KSI)"
256    !
260    CALL Minmax(Xdeg(*),Str(*),Pts,Rmax(*),Rmin(*),Tic(*))
261    !
262    !         SET UP FOR MULTIPLE CURVE OPTION
263    !
264    Num_cur=1
265    Num_pts(1)=Pts
266    Line_type(1)=1
267    FOR I=1 TO Num_cur
268       FOR J=1 TO Num_pts(I)
269          Out_put(I,J)=Str(J)
270       NEXT J
271    NEXT I
272    !
274    CALL M_graph(Xdeg(*),Out_put(*),Num_cur,Num_pts(*),L$,X1$,Y1$,Rmax(*),Rmin
(*),Tic(*),Line_type(*),Out_flag)
311    !
312    Dev=701
313    !
314    IF Out_flag=1 THEN
316       CALL Outp(W,R,T,Theta,Beta,Zeta,Dev)
317    END IF
319    !
320    END
321    !
322    !*****************************************************************
323    SUB Uni_base(Tload,R,T,Nu,Phi,X(*),M(*),Pts,Shear(*),Hoop(*))
330    !
340    !  R.J. FLORES  10/4/83
350    !
360    !  THIS PROGRAM ACCOUNTS FOR THE INCREASE IN THE BASE
370    !  OF SUPPORT DUE TO THE DEFLECTION OF THE LINER.
371    !  (CASE #12 IS USED)
380    !
390    !  TLOAD IS THE TOTAL LOAD ON THE LINER.
400    !
410    OPTION BASE 1
420    E=3.E+7                ! YOUNG'S MOD
421    !
422    !         TRIG VALUES
423    !
424    St=SIN(Phi)
425    Ct=COS(Phi)
429    !
```

```
430   !        COMPUTE THE DISTRIBUTED LOAD - W
431   !
432   W=Tload/(2*R*St)        ! LINEARLY DISTRIBUTED
433   !
435   !
440   !              DEFLECTIONS
450   !
460   Con=12*W*(R^4)*(1-Nu^2)/(E*T^3)
470   !
480   Con1=(Ct*(PI-Phi)+St)/2
490   Con2=2*(PI-Phi-St)/PI
500   Alph=(T^3)/(12*(R^2)*PI*(1-Nu^2)*(2*R*T-T^2))
510   !
520   Delh=-Con*(Con1-Con2)
530   Delv=Con*(1-Ct-2*(Phi+St)/PI+St*(PI-Phi)/2-Alph*(1+Ct))
540   !
550   !
560   !            MOMENTS
570   !
580   Ma=1-Ct-(Phi+2*St-Phi*Ct)/PI
581   Ta=-Ct-(St-Phi*Ct)/PI
590   !
600   FOR I=1 TO Pts
610     IF X(I)<Phi THEN
620       Delta=0
630     ELSE
640       Delta=1
650     END IF
660     !
661     Sx=SIN(X(I))
662     Cx=COS(X(I))
663     Cd=COS(X(I)-Phi)
664     Sd=SIN(X(I)-Phi)
665     !
670     M(I)=W*R^2*(Ma-Ta*(1-Cx)-Delta*(1-Cd))
680     !
681     !
682     !                  SHEAR
683     !
684     Shear(I)=-W*R*(Ta*Sx+Sd*Delta)
685     !
686     !                  HOOP
687     !
689     Hoop(I)=W*R*(Ta*Cx-(Delta*(1-Cd)))
690     !
691     !
692   NEXT I
700   !
702   !
710   SUBEND
711   !
712   !**************************************************
713   !
720   SUB Line_load(W,R,T,Nu,X(*),M(*),Npt,Shear(*),Hoop(*))
730   !
740   !
750   !  THIS SUBROUTINE CALCULATES THE MOMENTS AND
760   !  DEFLECTIONS DUE TO THE OVERBURDEN.  IT
770   !  ASSUMES A LINE LOAD ON THE TOP AND BOTTOM.
780   !
```

```
790   !  R.J. FLORES  9/12/83
800   !
810   !
820   E=3.E+7                  ! YOUNG'S MOD
830   !
840   !              DEFLECTIONS
850   !
860   Con=12*W*R^3*(1-Nu^2)/(E*T^3)
870   Horz=Con*(2/PI-.5)
880   Vert=Con*(2/PI-PI/4)
890   !
910   !
920   FOR I=1 TO Npt
921     !
923     !              MOMENTS
924     !
930     M(I)=W*R*(1/PI-.5*SIN(X(I)))
931     !
932     !              SHEAR
933     !
934     Shear(I)=-W*COS(X(I))/2
935     !
936     !               HOOP
937     !
938     Hoop(I)=-W*SIN(X(I))/2
939     !
941   NEXT I
950   !
970   SUBEND
980   !
990   !**********************************************
1000  SUB M_graph(X(*),Y(*),Ncur,Npts(*),Label$,Xlabel$,Ylabel$,Rmax(*),Rmin(*),
Tic(*),L_ty(*),P_flag)
1010  !
1011  !     THIS VERSION WILL PLOT UP TO 10 CURVES.
1020  !
1030  !     THIS PROGRAM WILL PLOT THE VALUES X VS Y.
1040  !     THE MIN AND MAX VALUES CAN BE CALCULATED
1050  !     BY THE SUBROUTINE "MINMAX".
1060  !
1070  !     R.J.FLORES 9/10/83
1071  !     REVISED 1/23/84
1080  !
1090  !
1100  !
1110  GINIT
1120  GRAPHICS ON
1130  !
1131  IF P_flag=2 THEN
1132     PLOTTER IS 705,"HPGL"
1133  ELSE
1134     PLOTTER IS CRT,"INTERNAL"
1135  END IF
1140  !
1150  VIEWPORT 0,131,0,100
1160  FRAME
1170  VIEWPORT 19,121,23,88
1180  FRAME
1190  !
1200  !
```

```
1210  WINDOW Rmin(1),Rmax(1),Rmin(2),Rmax(2)
1220  AXES Tic(1),Tic(2),Rmin(1),Rmin(2)
1230  !
1240  !
1250  !                PLOT DATA
1260  !
1261  FOR N=1 TO Ncur
1262    LINE TYPE L_ty(N)
1270    MOVE X(1),Y(N,1)
1280    FOR I=2 TO Npts(N)
1290      DRAW X(I),Y(N,I)
1300    NEXT I
1301  NEXT N
1310  !
1320  !
1330  VIEWPORT 0,131,0,100
1340  WINDOW 0,100,0,100
1350  !
1360  !                LABEL X
1370  !
1380  CSIZE 3
1390  LORG 5                        !PEN AT CENTER OF THE LABEL
1400  Horiz=1.5
1410  MOVE Horiz,20                 ! PEN STARTING POSITION
1420  Value=Rmin(1)-Tic(1)          ! INITIAL X + 1 INCREMENT
1430  Inc=1+(Rmax(1)-Rmin(1))/Tic(1)
1440  Hchange=78/(Inc-1)
1450  Horiz=Horiz+13                ! LOCATION INCREMENT
1460  !
1470  FOR I=1 TO Inc
1480    Value=Value+Tic(1)          ! X INCREMENT
1490    MOVE Horiz,20
1500    Horiz=Horiz+Hchange         ! LOCATION INCREMENT
1510    LABEL Value
1520  NEXT I
1530  !
1540  !                  LABEL Y
1550  !
1560  Vert=16.5
1570  Value=Rmin(2)-Tic(2)
1580  LORG 8                        ! LABEL AT R.H. SIDE OF PEN
1590  Vert=Vert+6.4
1600  Inc=1+(Rmax(2)-Rmin(2))/Tic(2)
1610  Vchange=65/(Inc-1)
1620  !
1630  FOR I=1 TO Inc
1640    Value=Value+Tic(2)
1650    MOVE 15,Vert
1660    IF Value<.001 AND Value>-.001 THEN      ! CHECK FOR ZERO
1670      MOVE 13.5,Vert
1680      LABEL "0"
1690 !    LABEL Value
1700    ELSE
1710      LABEL Value
1720    END IF
1730    Vert=Vert+Vchange
1740  NEXT I
1750  !
1760  !                   LABEL X AXIS
1770  !
```

```
1780  CSIZE 3.5
1790  LORG 5
1800  MOVE 53,14
1810  LABEL Xlabel$
1820  !
1830  !                       LABEL Y AXIS
1840  !
1850  DEG
1860  LDIR 90
1870  MOVE 6,55
1880  LABEL Ylabel$
1890  !
1900  !                        LABEL PLOT
1910  !
1920  LDIR 0
1930  LORG 2
1940  MOVE 9,5
1950  LABEL Label$
1960  !
1970  SUBEND
1980  !
1990  !  ********************************************
2000  SUB Minmax(X(*),Y(*),Npts,Rmax(*),Rmin(*),Tic(*))
2010  !
2020  !  THIS SUBROUTINE WILL DETERMINE THE OPTIMAL VALUES
2030  !  FOR THE GRAPHICS PROGRAM P_GRAPH.
2040  !
2050  !  R.J. FLORES 9/10/83
2060  !
2070  DIM Ex(2),Man(2),Dif(2),Temp(4)
2080  !
2090  !          DETERMINE THE MIN AND MAX VALUES
2100  !
2110  Rmax(1)=X(1)
2120  Rmin(1)=X(1)
2130  Rmax(2)=Y(1)
2140  Rmin(2)=Y(1)
2150  !
2160  FOR I=2 TO Npts
2170    IF X(I)>Rmax(1) THEN Rmax(1)=X(I)
2180    IF X(I)<Rmin(1) THEN Rmin(1)=X(I)
2190    IF Y(I)>Rmax(2) THEN Rmax(2)=Y(I)
2200    IF Y(I)<Rmin(2) THEN Rmin(2)=Y(I)
2210  NEXT I
2220  !
2230  !      IF THE GRAPH SHOULD START AT ZERO
2240  !      REMOVE THE CORRECT REMARK.
2250  !
2260  !IF Rmin(1)>0 THEN Rmin(1)=0
2270  !IF Rmin(2)>0 THEN Rmin(2)=0
2280  !
2290  !       DETERMINE THE SIZE OF THE TICS
2300  !
2310  Dif(1)=Rmax(1)-Rmin(1)
2320  Dif(2)=Rmax(2)-Rmin(2)
2330  Ex(1)=INT(LGT(ABS(Dif(1))))
2340  Ex(2)=INT(LGT(ABS(Dif(2))))
2350  !
2360  Man(1)=INT(.5+(Dif(1)/(10^Ex(1))))
2370  Man(2)=INT(.5+(Dif(2)/(10^Ex(2))))
```

```
2380  !
2381  !PRINT Man(*)
2383  !         SET UP FOR APPROX 10 TICS
2384  !
2390  FOR I=1 TO 2
2400  !
2410  IF Man(I)<=2 THEN
2420    Tic(I)=2*(10^(Ex(I)-1))                 ! 5 FOR 5 TICS
2430  ELSE
2440    IF Man(I)<=5 THEN
2450      Tic(I)=5*(10^(Ex(I)-1))               ! 10 FOR 5 TICS
2460    ELSE
2470      Tic(I)=10^(Ex(I))                     ! 2* FOR 5 TICS
2480    END IF
2490  END IF
2500  !
2510  NEXT I
2520  !
2530  !             MAX AND MIN FOR THE SCALES
2540  !
2550  !
2560  !  NOTE: IF THE MIN OR MIN IS ALMOST AN EXACT MULTIPLE OF THE
2570  !        TIC SPACING, IT IS INEFFICIENT TO ADD ANOTHER TIC.
2580  !        THE VARIABLES A AND B SET THE WINDOW.
2590  !
2600  A=.999
2610  B=1.001
2620  !
2630  FOR I=1 TO 2
2640    Temp(I)=Rmax(I)        ! COMPARISON SET UP
2650    Temp(I+2)=Rmin(I)
2660    T1=Temp(I)+Tic(I)
2670    T2=Temp(I+2)-Tic(I)
2680    !
2690    IF Rmin(I)>=0 THEN
2700      Rmin(I)=Tic(I)*(INT(ABS(Rmin(I))/Tic(I)))           ! BOTH +
2710      IF A*Rmin(I)<T2 AND B*Rmin(I)>T2 THEN Rmin(I)=Rmin(I)+Tic(I)
2720      Rmax(I)=Tic(I)*(1+INT(Rmax(I)/Tic(I)))
2730      IF A*Rmax(I)<T1 AND B*Rmax(I)>T1 THEN Rmax(I)=Rmax(I)-Tic(I)
2740    ELSE
2750      Rmin(I)=-Tic(I)*(1+INT(ABS(Rmin(I))/Tic(I)))        ! MIN -
2760      IF A*Rmin(I)>T2 AND B*Rmin(I)<T2 THEN Rmin(I)=Rmin(I)+Tic(I)
2770      IF Rmax(I)>=0 THEN
2780        Rmax(I)=Tic(I)*(1+INT(Rmax(I)/Tic(I)))            ! MAX +
2790        T1=Temp(I)+Tic(I)
2800        IF A*Rmax(I)<T1 AND B*Rmax(I)>T1 THEN Rmax(I)=Rmax(I)-Tic(I)
2810      ELSE
2820        Rmax(I)=-Tic(I)*(INT(ABS(Rmax(I))/Tic(I)))        ! MAX -
2830        IF A*Rmax(I)>T1 AND B*Rmax(I)<T1 THEN Rmax(I)=Rmax(I)-Tic(I)
2840      END IF
2850    END IF
2860  !
2870  !
2880  !
2890  NEXT I
2900  !
2910  SUBEND
2920  !
2930  !  *********************************************************************
2940  !
```

```
2950  SUB Outp(W,R,T,Theta,Beta,Zeta,Dev)
2960  !
2961  !
2962  !             DUMP GRAPHICS
2963  !
2965  PRINTER IS Dev              ! PRINT OUTPUT TO 701
2966  FOR Pri=1 TO 7
2967     PRINT
2968  NEXT Pri
2973  !
2974  IF Dev=701 THEN
2976     DUMP DEVICE IS Dev         ! SET PRINTER HPIB TO 701
2977     DUMP GRAPHICS
2978  END IF
2980  !
2981  !                OUTPUT DATA
2982  !
2983  PRINT
2984  PRINT
2985  PRINT
2986  PRINT TAB(22);"INPUT DATA"
2987  PRINT
2990  PRINT USING 2991;R
2991  IMAGE 10X,"LINER RADIUS      = ",3D.D," INCHES"
2992  PRINT USING 2993;T
2993  IMAGE 10X,"LINER THICKNESS   = ",D.3D," INCHES"
2994  !
2995  !              OUTPUT ASSUMED LOADING
2996  PRINT
2997  PRINT
2998  PRINT TAB(14);"ASSUMED LOADING CONDITIONS"
2999  PRINT
3000  IMAGE 10X,"ROCK FALL LOADING = ",3D.D," LBS/IN"
3001  PRINT USING 3000;W
3002  !
3007  PRINT USING 3008;2*Beta*180/PI
3008  IMAGE 10X,"ROCK LOAD ANGLE   = ",3D," DEGREES"
3009  PRINT USING 3010;2*Zeta*180/PI
3010  IMAGE 10X,"BASE LOAD ANGLE   = ",3D," DEGREES"
3011  !
3012  !
3013  IF Dev=701 THEN OUTPUT Dev;CHR$(12)
3015  !
3016  PRINTER IS 1
3017  !
3018  SUBEND
```

Attachment #3

HOOP AND SHEAR LOAD CALCULATIONS

Hoop Load Calculation

At the side (Pt. B):

$$T_B = \left(T_B\right)_1 + \left[\left(T_B\right)_{12}\right]_B + \left[\left(T_B\right)_{12}\right]_R$$

$$T_B = -\frac{W}{2} + 0 + 0 = -\frac{20.416}{2} = -10.2 \text{ lb}$$

$$\sigma_B = \frac{T_B}{t(1 \text{ in})} = \frac{-10.2 \text{ lb}}{(0.5 \text{ in})\ (1 \text{ in})} = -20.4 \text{ psi}$$

$$\boxed{\sigma_B = -20.4 \text{ psi}}$$

Shear Load Calculation

At the side (Pt. B):

$$V_B = -T_A = \omega R \left[\frac{1}{\pi}(S - \theta_C) + C\right]\Big|_{B,R} \qquad \omega = \frac{W}{2R \sin\theta}$$

$$\frac{V_B}{W} = \frac{1}{2S_R}\left[\frac{1}{\pi}(S_R - \theta_R C_R) + C_R\right] + \frac{1}{2S_B}\left[\frac{1}{\pi}(S_B - \theta_B C_B) + C_B\right]$$

@ $\theta_R = 150°$ and $\theta_B = 170°$

$$V_B = (20.4 \text{ lb})\ [0.0148 + 0.00162] = 0.335 \text{ lb}$$

$$\sigma_B = \frac{V_B}{t(1 \text{ in})} = \frac{0.335 \text{ lb}}{(0.5 \text{ in})(1 \text{ in})} = 0.67 \text{ psi}$$

$$\boxed{\sigma_B = 0.67 \text{ psi}}$$

REFERENCES

NACE (National Association of Corrosion Engineers), "Corrosion Data Survey," 5th edition, March 1974.

NRC (U.S. Nuclear Regulatory Commission), "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Code of Federal Regulations, Energy, Title 10, Part 60, Washington, D.C., January 1986.

Roark, R. J., and W. C. Young, Formulas for Stress and Strain, 5th Edition, McGraw Hill, New York, NY, 1975.

Yow, J. L., "Field Investigation of Keyblock Stability," UCRL-53632, Lawrence Livermore National Laboratory, Livermore, CA, April, 1985.

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APPENDIX C

VENTILATION AND COOLING ANALYSES

prepared by

Keith Wallace and Daniel Brunner
Mine Ventilation Services, Inc.

for

Parsons Brinckerhoff Quade & Douglas

This appendix presents part of the calculations done to develop the design of the underground ventilation system for the repository; it is included as a sample of the methods used to develop the ventilation design. The appendix, due to the iteration of the design, in some cases presents results based on designs that preceded the design presented in the Site Characterization Plan-Conceptual Design Report (SCP-CDR). This discrepancy in the design analyzed versus the design presented in the CDR does not significantly alter the conclusions presented in the CDR.

Data from the Reference Information Base (RIB) used to develop the conceptual design (Appendix Q) that were used in these analyses include meteorological information and virgin rock temperatures. Results of these analyses to be incorporated into the NNWSI RIB include air flow quantities for underground development and waste emplacement systems.

TABLE OF CONTENTS

C-1 Vertical Emplacement Ventilation Analysis

C-2 Vertical Emplacement Cooling Analysis

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VENTILATION AND COOLING ANALYSIS EXAMPLE

This is an example of ventilation and thermal analyses for the vertical emplacement system approximately 10 yr after emplacement. The calculation illustrates the methods and procedures used for the various other ventilation and thermal analyses performed for horizontal emplacement and other time phases of vertical emplacement. These analyses were carried out using the ventilation network analysis program VNETPC (Version 1.1) and the climatic simulation program CLIMSIM (Version 1.0).

The climatic simulation is based on the airflows and fan duties determined from the ventilation analysis.

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Objective

The objective of the ventilation analysis is to determine an optimal airflow distribution for each prospective underground layout. The results obtained are to support the site characterization plan (SCP) for the NNWSI.

Procedure

The procedure employed to establish an airflow distribution for each emplacement layout consists of using conceptual underground plans of the NNWSI repository. From these plans a ventilation schematic is drawn. A ventilation schematic is a line diagram of the underground plan that is used to establish the ventilation computer model. Each line, or branch, on the schematic represents an airflow route and is identified by a series of junctions, or nodes, and may represent a set of parallel airways. For each branch a resistance to airflow value is determined.

Required airflow quantities, calculated from dust, gas and environmental conditions, are determined for strategic underground locations. The ventilation modeling exercise consists of varying the main fan duties (volume and pressure), airway sizes, airflow direction, ventilation controls (bulkheads, regulators, etc.) or mining or emplacement schemes until the airflow requirements are achieved at a minimal capital and ventilation operating cost while not exeeding the design constraints such as air velocity (McPherson, 1982) | 1

The computer code used for this analysis is the VNETPC (ventilation network) computer program. Verification of this program is to be available.

The model selected for this analysis are described in the design basis section under "Ventilation System Modelled".

Assumptions and Design Basis

The ventilation analysis is constrained by a set of assumptions and design philosophies. The following sections are excerpted from the functional design guidelines and are offered here for completness of this document.

Two separate, continuously operating ventilation systems shall be maintained during the operational phase of the repository (10CFR60.133(g) (3)). One system shall provide air to the development operations the other to waste emplacement operations. Separate returns and exhausts shall be provided for each system. A common intake is feasible but not practical. Connections between the two systems shall be sealed with bulkheads and doors. At these connections, access shall be limited to authorized equipment and personnel. Emergency escape between the two systems shall be possible through either the main doors or through alarmed escape doors located in strategic bulkheads.

A pressure differential shall be maintained between the development operations and the waste emplacement operations such that leakage will move from the development ventilation system to the waste emplacement ventilation system. To ensure leakage in this direction the waste emplacement ventilation system shall be maintained at a negative pressure by an exhausting main fan on the surface return, and the development ventilation system shall be operated at a positive pressure by a main forcing fan on the surface intake.

If the pressure differential between the two ventilation systems exceeds a practical limit (to be determined) across the bulkheads, a push-pull (two fan) ventilation system may be required for the waste emplacement area.

All main fans shall be on surface and shall not be reversible.

Air Volume and Velocity Criteria

Volume reqirements shall be sufficient to comply with all applicable 10CFR60 and 30CFR57 (non-gassy underground metal and non-metal mine) requirements. Specific criteria for gas and dust control will be based on the Threshold Limit Values (TLVs) adopted by the American Conference of Governmental Industrial Hygienist (ACGIH).

The following minimum airflow requirements are given for conceptual design.

a) diesel equipment:
125 cfm per brake horsepower over the machine *

b) personnel:
210 cfm per underground employee

c) Tunnel Boring Machine (TBM): 42,000 CFM PER TBM

d) Waste Transporter (360 bhp) *
45,000 cfm over each waste transporter

The air velocity in all ventilation airways shall be established by economic and dust control consideration but are not to be greater than those shown on the following table.

The minimum air velocity in all active working areas shall be 60 ft/min. Underground shop air requirements shall be determined from ASHRAE considerations. Air which passes through a shop, decontamination facility or testing facility shall be returned directly to exhaust.

Unless otherwise noted in the development or waste emplacement ventilation sections, the underground climate in all working areas shall meet the following environmental criteria:

Air Cooling Power (ACP)** >=500 W/m^2
Dry Bulb Temperature (td) <= 40 C (104 F)

Should cooling of the air be required, spray chambers or coiled heat exchangers may be employed. Chilled water for underground cooling shall be provided from a surface refrigeration plant.

All meteorological design parameters necessary to determine the underground climate are estimated from Sandia report SAND840440/2, "Meteorological Design Parameters for the Canidate Site of a Radioactive-Waste Repository at Yucca Mountain, Nevada", December, 1984.

* Subject to change.
** Mitchell and Whiller, 1972.

VELOCITY CRITERIA*

Area	Maximum Velocities (ft/min)
Intake shafts (unobstructed)	4,000 (a)
Return shafts (unobstructed)	4,000 (a)
Waste transport ramp	1,500
Tuff ramp or shaft	1,500
Men and materials shaft	2,300
Perimeter airway	2,000
Main entry drifts	1,500
Main return drifts	1,500
Haulage airways (no conveyor)	1,200
Haulage airways (conveyor - homotropal)	1,000
Haulage airways (conveyor - antitropal)	800
Emplacement drifts	1,500
Development areas (drilling, etc.)	600

(a) Maximum shaft velocities assume the shafts are dry and unobstructed.

* National Advisory Board, 1980.

Parsons Brinckerhoff

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Engineers • Architects • Planners

COMPUTATION SHEET

Job No. 3696A161
Made by CR ROGERS
Date 4/28/86
Checked by D. Brunner
Date 5/8/86

Subject VERTICAL EMPLACEMENT

SHAFT/AIRWAY AIRFLOW LIMITS

	VELOCITY LIMITS (FT/MIN)	AREA (FT^2)	AIR FLOW (KCFM)
WASTE RAMP	1500 ✓	281.0 ✓	422 ✓
WASTE MAIN	1500 ✓	425.0 ✓	638 ✓
TUFF RAMP	1500 ✓	400.0 ✓	600 ✓
TUFF MAIN (W/O BELT)	1500 ✓	398.0 ✓	597 ✓
TUFF MAIN (W/BELT)	1000 ✓	380.0 ✓	380 ✓
SERVICE MAIN	1500 ✓	303.0 ✓	455 ✓
PERIMETER	2000 ✓	372.0 ✓	744 ✓
EXHAUST (MID-PANEL)	1500 ✓	185.0 ✓	278 ✓
PANEL ACCESS (W/BELT)	1000 ✓	217.0 ✓	217 ✓
PANEL ACCESS (W/O BELT)	1200 ✓	237.0 ✓	284 ✓
EMPLACEMENT DRIFT	1500 ✓	305.0 ✓	458 ✓
M&M SHAFT	2000 ✓	292.0 ✓	672 ✓
EXHAUST SHAFT	4000 ✓	314.16 ✓	1257 ✓
ES I	4000 ✓	113.1 ✓	452 ✓
ES II	4000 ✓	28.27 ✓	113 ✓

NOTE: REFER TO PAGES 27-65 FOR THE AREAS NOTED ABOVE.

<u>Development Ventilation System</u>

The development ventilation system shall be capable of supplying air to support the construction of perimeter drifts, central mains advanced ahead of other construction, emplacement drifts and boring and lining operations for both vertical and horizontal emplacement modes. The system must be flexible to accomodate changed layouts and schedules.

<u>Waste Emplacement Ventilation System</u>

The waste emplacement ventilation system capacity must be sufficient to ensure safe transport, emplacement and retrieval operations. The system shall be designed to minimize routine activities downstream of emplaced waste. The training and performance confirmation areas shall be ventilated at all times to allow for continuous access.

All waste emplacement air shall be exhausted through a surface structure with the capability to pass the air through a series of HEPA filters. Fan capacity shall be sufficient to pull an airflow through the filters adequate to implement recovery procedures resulting from detection of excessive radiation in the airstream. During operation of the HEPA filters the airflow volume in the waste emplacement ventilation system shall be reduced by one-half. This constraint is subject to change.

Ventilation requirements applicable to both the vertical and horizontal emplacement configurations shall be to allow simultaneous spent fuel emplacement operations in two emplacement drifts and DHLW and WVW emplacement in ~~one~~ two emplacement driftS, ~~each.~~

<u>Inspection and Maintenance</u>

After the boreholes in a spent fuel drift have been filled to capacity, the drift may be isolated from the main stream airflow. Initially each emplacement drift shall be inspected on an annual basis. After repository performance experience is gained, the inspection schedule may be modified. Prior to inspection, the emplacement drift in both emplacement configurations shall be ventilated with a minimum velocity of 60 ft/min for at least 24 hours. (To clear any natural gasses which may be encountered underground.) (INSPECTION CRITERIA = TWB < 45°C, ACP > 30 w/m²)

Prior to any major drift repair or maintenance, the emplacement drift shall be ventilated sufficiently to cool the drift to allow safe crew activity for an undetermined length of time. The environmental criteria shall be an ACP) ~~=~~ 500 w/m² AND a dry bulb temperature ~~<~~ 40°C. Prior to entry the emplacement drift shall be monitored for radioactivity. The ventilation and cooling capacity shall be sufficient to cool two drifts simultaneously for maintenance and repair.

Upon further study, the criteria given in this section is subject to change.

Waste Retrieval

The waste emplacement ventilation system shall be flexible enough to accomodate two categories of waste retrieval. Should the retrieval of a single, predetermined canister be required to support performance assessment, a single emplacement drift shall be cooled sufficiently to allow safe entry. This type of retrieval shall be proceeded by a two month's advance notice (subject to change).

Should the removal of all the emplaced waste be required, all ventilation (including development air) could be dedicated to support waste retrieval. The retrieval rate shall not exceed ten canisters per day (subject to change).

Ventilation Systems Modelled

In order to support the SCP/CDR the airflows expected for both the vertical and horizontal emplacement methods, as well as, estimates of the size of vertical drifts is required. To this end it was decided that the initial ventilation modelling of each emplacement mode would be performed at / two moments in time when both development and waste emplacement ventilation systems are operational.

From these models the maximum airflows and fan duties could be estimated over the projected life of the repository.

The ventilation systems modelled are extensions of earlier work involving a two-phase repository plan. Since this work, however, added parameters, such as DHLW, WVHLW, dedicated performance and training areas make incorporating the early work [redacted] impossible. Therefore, new ventilation estimates are needed to determine airflow direction and quantity.

The ventilation systems selected for modelling were chosen in order to give a substantial area where waste is emplaced and yet development work is in progress, as well as, emplacement operations. ~~The waste emplacement operations are in the panel noted (typical panel) in the thermal analysis work by [illegible].~~ The models are intended to show the maximum ventilation requirements for the development and waste emplacement systems for both configurations

For this analysis it is assumed that mining of the panels is from the main airways to the perimeter airway and that waste emplacement is exactly the inverse of this.

Branch Resistance Calculations - Defined

As mentioned in the introduction, once a schematic is drawn for a given repository plan a resistance to airflow is calculated for each branch on the schematic. To calculate airflow resistance the following equation is employed:

$$R = \frac{k(L+L_{EQ})\,per\,\rho}{52A^{3}\rho_{s}} \qquad \text{(P.U.-Practical Unit)} \qquad (.1.)*$$

where R = resistance (P.U.)

ρ = air density (lb/ft^{3})

k = friction factor ($lbf\ min^{2}/ft^{4}\ x10^{10}$)

L = length of branch (ft)

L_{EQ} = equivalent length of airflow shock loss (ft)

per = perimeter of airway (ft)

A = cross-sectional area of airway (ft^{2})

ρ_{s} = standard air density ($0.075\ lb/ft^{3}$)

For this analysis the resistance calculated for each branch is determined in a sequence of steps. First it is assumed that the air density is standard density, hence, the ρ's cancel each other in equation (.1.). Second, the resistance per linear foot is calculated from:

$$R = \frac{k\,(1)\,per}{52A^{3}} \qquad \text{(P.U./ft)} \qquad (.2.)$$

The friction factor for each branch is estimated from empirical tables while the perimeter and cross-sectional area are determined from typical cross-sections of each airway. Typical friction factors are given on the next page.

To determine the equivalent length (L_{EQ}) for each branch the following equation is employed:

$$L_{EQ} = K \cdot HMD \qquad \text{(ft)} \qquad (.3.)**$$

* Atkinsons Equation: Hartman, 1982
** McElroy, 1935

Typical Friction Factors *

	(lbf min^2/ft^4x10^10)	(kg/m^3)
Rectangular Airways		
Smooth Concrete	20	0.0037
Girders on Brick or Concrete Walls	50	0.0093
Unlined Airways with Uniform Sides	65	0.0121
Unlined Airways with Irregular Conditions	85	0.0158
Girders on Timber Props	100	0.0186
Steel Concrete Lined		
Smooth Concrete Lined	20	0.0037
Bricked Between Arches All Round	30	0.0056
Concrete Slabs or Timber Laggin	40	0.0074
Lagged Behind Arches in Good Condition	60	0.0111
Rough Conditions with Irregular Rood, Sides and Floor	85	0.0158
Shafts		
Smooth Lined Unobstructedc Shaft	16	0.0030
Brick Lined Unobstructed Shaft	20	0.0037
Brick Lined Shaft with Rope Guides and Water or Air Ranges	40	0.0074
Tubbing Lined Shaft with No Guides or Cages	75	0.0139
Brick Lined Shaft with Two Sets of Side Buntons	95	0.0176
Timber Lined Shaft with a Middle Line of Buntons	120	0.0223

*McPherson, M.J., "The Metrication and Rationalization of Mine Ventilation Calculations"; The Mining Engineer, August 1971.

where x = number of HMDs (dimensionless)
HMD = hydraulic mean diameter (ft)

The HMD is calulated from:

HMD = 4A/per* (ft) (.4.)

The number of HMDs (x) is a design parameter that is used to account for airflow direction changes and obstructions. That is at any lcoation where additional air turbulence may be encountered. The values for x employed in this analysis were determined from the following empirical table. (next page)

Therefore, once the resistance per linear foot (P.U/ft) and equivalent length (ft) for each branch is determined the resitance for each branch can easily be calculated by measuring the actual airway length and multiplying the total length by the resistance per linear foot.

It is noted that for this analysis the practical unit (P.U.) is employed as the resistance unit. The practical unit is simply:

1 P.U. - 1 milli-inch water gauge/(one thousand cfm)^2

This allows the square law ($p=RQ^2$) to be applied without additional constraints.

<u>Parallel Branch Resitance Calculations - Defined</u>

If a branch represents a set of parallel airways the following equation is employed:

*McElroy, G.E., 1935

Type		No. of HMDs (Dimensionless)
Acute Round Bend		10.0
Acute Sharp Bend		30.0
Right Angle Bend, Sharp		20.0
Right Angle Bend, Round		3.8
Obtuse Sharp Bend		15.0
Obtuse Round Bend		2.0
Discharge		14.0
Inlet		4.6
Abrupt Contraction	(Ao/Ai)####	
	0.75	1.2
	0.50	2.8
	0.25	4.3
Abrupt Expansion	(Ao/Ai)####	
	0.75	1.2
	0.50	2.8
	0.25	4.3
Obstruction	(Aob/A)####	
	0.20	20.5
	0.40	41.0

* The number of hydraulic mean diameters is calulated from the following, assuming standard density of air to be 0.75 lb/ft^3, the general equation is:

$$\frac{Le}{D_H} = \frac{X\ 3235}{k \cdot 4}\ (ft)^{**}$$

where X = shock loss factor (dimension)

k = frict. factor $\frac{lf\ bmin^2}{ft^4} \times 10^{10}$

For a sharp bend x = 1.4###

assuming $k = 60\ \frac{lb\ min^2}{ft^4} \times 10^{10}$ $\quad \frac{Le}{DH} = \frac{1.4}{60}(809) = 18.9 \approx 20$

$$Le = x = 20\ HMDs$$

** Hartman, 1982

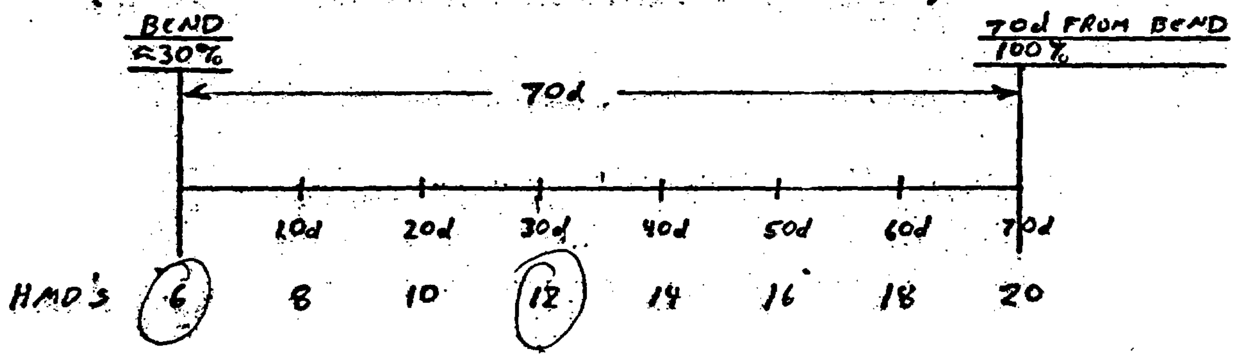
\#\#\# McElroy, 1935

\#\#\#\# Ao=Outer Area, Ai= Inner Area, Aob=Obstruction Area, A=Airway Area

The values represented in the previous table are estimated for isolated airways more than 70 HMDs between obstructions or bends. If obstructions or bends are closer than 40 HMDs then the number of

Loss Distribution for Sharp 90° Bend HMD = 20

(A 90° SHARP RIGHT ANGLE BEND ≈ 20 HMD's)



NOTE: FOR A 90° SHARP RIGHT ANGLE BEND ONLY ABOUT 30% OF THE SHOCK LOSS IS INCURRED AT THE BEND. THE REMAINING 70% OF THE LOSS IS INCURRED IN THE FOLLOWING ENTRY FOR AN APPROXIMATE LENGTH OF 70 DIAMETERS DUE TO TURBULENCE.

REFERENCE ~~SE~~ McPHERSON ~~4/22/85~~ and Brunner, 1983 — DNA

Resistance Due To Shock Losses

$$P_{shock} = \rho X \frac{u^2}{2} \qquad \frac{m^2}{s^2} \cdot \frac{kg}{m^3} = \frac{N}{m^2} = Pa \qquad -1.$$

where:
u = velocity m/s
ρ = density kg/m³
X = empirically determined shock loss factor (Hartman)
P_{shock} = pressure drop due to shock loss

$$P_{shock} = R_{shock} \cdot Q^2 \qquad -2.$$

Q = volume flow rate m³/s
R_{shock} = resistance due to shock loss

hydraulic mean diameters is less than the sum of the two x's. This is due to interference of the turbulent wake downstream from the first obstruction or bend. Engineering judgement is used to determine shock loss factors in this situation.

Ref. to page 11 Table

PARALLEL BRANCH CALCULATION (CONTINUED)

$$\frac{1}{R_T^{1/2}} = \frac{1}{R_1^{1/2}} + \frac{1}{R_2^{1/2}} + \ldots + \frac{1}{R_N^{1/2}} \quad \text{(P.U.)} \qquad (.5.)*$$

Where R_T = Total equivalent resistance of parallel branches (P.U.)

R_1 = Resistance of first airway (P.U.)

R_2 = Resistance of second airway (P.U.)

R_N = Resistance of third airway (P.U.)

If each parallel branch resistance is the same, equation (.5.) may be simplified to:

$$R_T = \frac{R}{n^2} \quad \text{(P.U.)} \qquad (.6.)$$

Where R = Resistance of each parallel airway (P.U.)

n = number of drifts in parallel

For example, doors in emplacement drifts have an estimated resistance of 25 (P.U.). Therefore, equation (.6.) would be rewritten as:

$$R_T = \frac{25}{n^2} \quad \text{(P.U.)}$$

The branch resistance calculation sheets (attached as an appendix) show parallel resistance calculations by listing in the comment column the following:

n in ll R = R_1

Where n = number of drifts in parallel
ll = parallel symbol
Rl = resistance of each branch in parallel (P.U.)

Equation (.6.) is employed for this format.

Ventilation Control Resistance Values*

For this analysis the following resistances were assumed for various ventilation controls:

Control	Resistance (P.U.) *
Single Door	25.
Double Door	200. (airlock)
Single Bulkhead **	200. (stoppings)
Double Bulkhead **	400. (stoppings)
Brattice Line	5.
Temporary Seal	25.

** Bulkhead is defined as a masonary wall built into a crown and wall of the airway.

* Wallace, ~~1982~~ and McPherson, 1982

1 △

```
10 REM VNET EQUIVALENT LENGTH AND RESISTANCE CALCULATION PROGRAM VERTICAL
20 CLEAR:SCREEN 0:COLOR 0,7,14:CLS
30 DIM A1(11),B1(11)
40 KEY OFF
50 FOR I=1 TO 11
60 READ A1(I)
70 NEXT I
80 DATA 1.62,1.12,1.55,1.86,1.57,3.32,1.54,9.79,6.06,11.00,3.21
90 FOR I=1 TO 11
100 READ B1(I)
110 NEXT I
120 DATA 18.03,22.91,18.60,17.18,21.66,17.68,21.64,11.68,15.83,14.30,18.02
130 LOCATE 4,10:PRINT "VERTICAL EMPLACEMENT VENTILATION CALCULATION PROGRAM"
135 LOCATE 8,10:PRINT "Enter reference letter ";
140 A$=INKEY$:IF A$="" THEN 140 ELSE PRINT A$
150 IF A$="a" OR A$="A" THEN J=1:P$="Waste Ramp":GOTO 270
160 IF A$="b" OR A$="B" THEN J=2:P$="Waste Main":GOTO 270
170 IF A$="c" OR A$="C" THEN J=3:P$="Tuff Ramp":GOTO 270
180 IF A$="d" OR A$="D" THEN J=4:P$="Tuff Main With Belt":GOTO 270
190 IF A$="e" OR A$="E" THEN J=5:P$="Tuff Main Without Belt":GOTO 270
200 IF A$="f" OR A$="F" THEN J=6:P$="Service Main":GOTO 270
210 IF A$="g" OR A$="G" THEN J=7:P$="Perimeter Drift":GOTO 270
220 IF A$="h" OR A$="H" THEN J=8:P$="Panel Access Drift With Belt":GOTO 270
230 IF A$="i" OR A$="I" THEN J=9:P$="Panel Access Drift Without Belt":GOTO 270
240 IF A$="j" OR A$="J" THEN J=10:P$="Exhaust or Midpanel Drift":GOTO 270
250 IF A$="k" OR A$="K" THEN J=11:P$="Emplacement Drift":GOTO 270
260 CLS:GOTO 130
270 COLOR 0,7,J
280 LOCATE 10,10:PRINT "Enter length of ";P$;" (ft) ";:INPUT "",L
290 IF L=0 THEN LOCATE 10,34:PRINT "     ":GOTO 270
300 LOCATE 12,10:INPUT "Enter number of hydraulic mean diameters ",X
310 EQL=B1(J)*X
320 LOCATE 14,10:PRINT "Equivalent length = ";:PRINT USING "#####.##";EQL;
330 PRINT " ft."
340 TL=B1(J)*X+L
350 LOCATE 16,10:PRINT "Total length = ";:PRINT USING "#####.##";TL;
360 PRINT " ft."
370 R=A1(J)*.000001*(TL)
380 LOCATE 18,10:PRINT "Airway resistance = ";:PRINT USING "##.#####";R;
390 PRINT " P.U."
400 LOCATE 20,10:PRINT "Press any key to continue..OR 'Q' TO QUIT"
410 C$=INKEY$:IF C$="" THEN 410 ELSE CLS
420 IF C$="Q" OR C$="q" THEN END ELSE 130
```

- TWO TRIALS WERE MADE FOR EACH OF THE 11 AIRWAY SIZES; MANUALLY AND WITH THE CALCULATION ROUTINE

  1) THE FIRST SERIES OF TRIALS ASSUMED ONLY A TOTAL LENGHT OF 100' WITH NO USE OF THE HYDRAULIC MEAN DIAMETERS INPUT

  2) THE SECOND SERIES OF TRIALS ASSUMED A LENGTH OF 100' WITH 10 HYDRAULIC MEAN DIAMETERS

- THE FOLLOWING TWO PAGES SHOW VERIFICATION CHECKS FOR THE 11 AIRWAY SIZES

Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 18 OF 137

FINAL FILING PAGE NO.

RESISTANCE CALCULATION

ROUTINE VERIFICATION

VERTICAL EMPLACEMENT

DESIGNED BY GR ROGERS DATE 5/19/86

CHECKED BY D. Brunner DATE 5/8/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE PER FOOT (P.U./FT x10^{-6})	RESISTANCE CALC. ROUTINE (P.U.)	RESISTANCE MANUAL (P.U.)
–	–	–	A	100	10	180.3	280.3	1.62	.00045	.000454 4.54×10^{-4}
–	–	–	B	100	10	229.1	329.1	1.12	.00037	.000369 3.69×10^{-4}
–	–	–	C	100	10	186.0	286.0	1.55	.00044	.000443 4.43×10^{-4}
–	–	–	D	100	10	171.8	271.8	1.86	.00051	.000506 5.06×10^{-4}
–	–	–	E	100	10	216.6	316.6	1.57	.00050	.000497 4.97×10^{-4}
–	–	–	F	100	10	176.8	276.8	3.32	.00092	.000919 9.19×10^{-4}
–	–	–	G	100	10	216.4	316.4	1.54	.00049	.000487 4.87×10^{-4}
–	–	–	H	100	10	116.8	216.8	9.79	.00212	0.0021
–	–	–	I	100	10	158.3	258.3	6.06	.00157	0.0404
–	–	–	J	100	10	143.0	243.0	11.00	.00267	0.00267
–	–	–	K	100	10	180.2	280.2	3.21	.00090	.000899 8.99×10^{-4}

DO NOT WRITE OUTSIDE BORDER

Mine Ventilation Services, Inc.

RESISTANCE CALCULATION

ROUTINE VERIFICATION

VERTICAL EMPLACEMENT

JOB NO. 3696A161

SHEET 19 OF 137

FINAL FILING PAGE NO.

DESIGNED BY GR ROGERS DATE 5/19/86

CHECKED BY D Brunner DATE 5/8/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE PER FOOT (PU/FT $\times 10^{-6}$)	RESISTANCE CALC ROUTINE (P.U)	RESISTANCE MANUAL (P.U.)
—	—	—	A	100	—	—	100	1.62	.00016	.000162 1.62×10^{-4}
—	—	—	B	100	—	—	100	1.12	.00011	1.12×10^{-4}
—	—	—	C	100	—	—	100	1.55	.00016	1.55×10^{-4}
—	—	—	D	100	—	—	100	1.86	.00019	1.86×10^{-4}
—	—	—	E	100	—	—	100	1.57	.00016	1.57×10^{-4}
—	—	—	F	100	—	—	100	3.32	.00033	3.32×10^{-4}
—	—	—	G	100	—	—	100	1.54	.00015	1.54×10^{-4}
—	—	—	H	100	—	—	100	9.79	.00098	9.79×10^{-4}
—	—	—	I	100	—	—	100	6.06	.00061	6.06×10^{-4}
—	—	—	J	100	—	—	100	11.00	.0011	11.00×10^{-4}
—	—	—	K	100	—	—	100	3.21	.00032	3.21×10^{-4}

DO NOT WRITE OUTSIDE BORDER

<u>Ventilation Airflow Calculations - Vertical Emplacement</u>

Using the criteria given in the assumptions section, airflow requirements are determined for strategic areas within the facility. The following pages show the airflow requirements based on a governing ventilation criteria for the vertical emplacement mode.

Development Ventilation System

Area	Equipment	Personnel in Area	Governing Criteria	Cross-Sectional Area	Required Airflows	Minimum Required Airflows/Area (cfm)
Spent Fuel Waste Emplacement:						
Development Six Drifts	2 LHD's (277 bhp)	26	125cfm/bhp		69,250 ✓	
	2 Jumbos (electric)		60 ft/min	~~300~~ 305ft2	36,000 ✓	
	2 Bolters (electric)		60 ft/min	305ft2		
						100,000 * ✓
Waste Main Perimeter Drift	TBM	5	42,000 CFM/TBM		42,000	42,000 ✓
Access Drifts Development and Tuff Mains	1 LHD (~~227~~ 277 bhp)	13	125cfm/bhp		34,625 ✓	
	1 Jumbo or Bolter (electric		60ft/min	305ft2	18,000 ✓	
						50,000 ✓
Shop	See Attachment					85,000 ✓
Drilling/lining**	Drill (electric)	4	60ft/min	305ft2	18,000 ✓	20,000
	Liner (electric)	4	60ft/min	306ft2	18,000 ✓	20,000

* Series ventilation

** Airflows assume dust control at Drilling equipment.

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Engineers • Architects • Planners

COMPUTATION SHEET

Job No. 3696 A16'
Made by K. WALLACE
Date 3/13/86
Checked by D. Brunner
Date 5/8/86

Subject VERTICAL EMPLACEMENT

Waste Emplacement Ventilation System

Area	Equipment	Personnel	Governing Criteria	Minimum Airflow Requirements (cfm)
Ramp	Waste Emplacement Transporter (360 bhp)	2	125 cfm/bhp	45,000 ✓
Main	Waste Emplacement Transporter (360 bhp)	2	125 cfm/bhp	45,000 ✓
Access Drift	Waste Emplacement Transporter (360 bhp)	2	125 cfm/bhp	45,000 ✓
Emplacement Drift	Waste Emplacement Transporter (360 bhp)	2	125 cfm/bhp	45,000 ✓
Shop	See Attachment			30,000 ✓
Decontamination Facility	See Attachment			25,000 ✓
Dedicated Performance Area	unknown	unknown	unknown	25,000 ✓
Training Area	Waste Emplacement Transporter (360 bhp)	5	125 cfm/bhp	45,000 ✓
Panel	none	none	Cooling	30,000** ✓

~~*initial estimate of airflow entering the panel through each twin access drifts.~~

** Rapid cooling of drift for inspection/maintenance.

Main Shop Airflow Requirements (ASHREA)*

Area	Length (ft)	Width (ft)	Equipment	Criteria	Requirements	Total System
Shop						
Access	365	25		2.5 cfm/ft2		O.K.
			1 x 190hp LHD	125 cfm/bhp	23,750	
Access (To						
Airlock	80	24		2.5 cfm/ft2	5,000	O.K.
Shop Bays	(40	20) x 6		3.0 cfm/ft2	27,900	
Shop Entry	(180	25)				51,650
			1 x 190hp LHD	125 cfm/bhp	23,750	
Refueling Bay	40	20		2.5 cfm/ft2	2,000	O.K.
Tires	40	20		2.5 cfm/ft2	2,000	O.K.
Machine Shop	40	20		2.5 cfm/ft2	2,000	O.K.
Hydraulic Shop	40	20		2.5 cfm/ft2	2,000	O.K.
Drill Shop	40	20		2.5 cfm/ft2	2,000	O.K.
Lube	40	20		2.5 cfm/ft2	2,000	O.K.
Wash Bays	(40	20) x 2		2.5 cfm/ft2	4,000	O.K.
			1 x 190hp LHD	125 cfm/bhp	23,750	23,750
Electrical	40 x 20 x 15			10 AC/hr	2,000	O.K.
Battery	40 x 20 x 15			10 AC/hr	2,000	O.K.
Electrical Sub	40 x 20 x 15			10 AC/hr	2,000	O.K.
Skimmer and						
Entry	170 x 20			2.5 cfm/ft2	8,500	O.K.
Welding	40 x 20			3 cfm/ft2	2,400	O.K.
Training/Gear	40 x 20					O.K.
Maint. Office	40 x 20					O.K.
				1.2 cfm/ft2	2,880	
Warehouse						
Parts, etc.	210	20		2.5 cfm/ft2	10,500	O.K.
	(40	20) x 5		2.5 cfm/ft2	10,000	10,000
	170	20		2.5 cfm/ft2	8,500	O.K.
Office	40	20		1.2 cfm/ft2	960	O.K.
						85,400
					Allow	85,000

*Shop layouts taken from PBQ&D plans.
O.K.-in series-no additional ventilation required.

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COMPUTATION SHEET

Job No. 3696A161
Made by K. Wallace
Date 3/18/86
Checked by D. Brown
Date 5/8/86

Subject Vertical Emplacement

Waste Emplacement Decontamination Facility Airflow Requirements (ASHREA)

Area	Length (ft)	Width (ft)	Equipment *	Criteria	Requirements	Total System
Decontamination Facility						
Access/Openings	150	20		2.5cfm/ft2	7,500	O.K.
Emergency Equipment	130	20		2.5cfm/ft2	6,500	6,500
	130	20		2.5cfm/ft2	6,500	O.K.
			(150hp) Tank Truck	125 cfm/bhp	18,750	18,750
Water Storage	10	25		1.2cfm/ft2	300	O.K.
Decon. Equipment	15	20		1.2cfm/ft2	360	O.K.
Decon. Room	110	20		1.2cfm/ft2	2,640	2,640
First Aid	15	10		1.2cfm/ft2	180	O.K.
Office	15	10		1.2cfm/ft2	180	O.K.
Red Check	15	10		1.2cfm/ft2	180	O.K.
Shower	15	5		1.2cfm/ft2	90	O.K.
Monitoring	10	10		1.2cfm/ft2	120	O.K.
Hot/Change Room	15	5		1.2cfm/ft2	90	O.K.
Change Room	15	10		1.2cfm/ft2		O.K.
	5	15				
Waste Main-Security						
Security-Sign-in	20	25		1.2cfm/ft2	600	O.K.
Rad Check Room						
						27,890
					Allow	25,000

* see next page

Waste Emplacement Shop Airflow Requirements (ASHREA)

Area	Length (ft)	Width (ft)	Equipment*	Criteria	Requirements	Total System
Access	200	20		2.5cfm/ft2	10,000	O.K.
			1 LHD (190hp)	125cfm/ft2	23,750	23,750
Refueling	40	20		2.5cfm/ft2	2,000	O.K.
Wash Bay	40	20		2.5cfm/ft2	2,000	O.K.
Bay 1	40	20		2.5cfm/ft2	2,000	O.K.
Bay 2	40	20		2.5cfm/ft2	2,000	O.K.
PM/Lube	40	20		2.5cfm/ft2	2,000	O.K.
Skimmer	25	20		2.5cfm/ft2	1,250	O.K.
Hydraulic	40	20		2.5cfm/ft2	2,000	O.K.
Welding	40	10		3.0cfm/ft2	1,200	O.K.
Office	20	10		1.2cfm/ft2	240	O.K.
Warehouse						
Access	60	20		2.5cfm/ft2	3,000	O.K.
Pipe Shop	40	20		2.5cfm/ft2	2,000	O.K.
General Warehouse	160	20		2.5cfm/ft2	8,000	8,000
Office	20	10		1.2cfm/ft2	240	O.K.
						31,750
					Allow	30,000

* Should the waste transporter be required to enter either the decontamination facility or the shop area, the regulator between the exhaust drift and these facilities can be opened to allow the required airflow. The airflow requirements are based on layouts from PBQ&D Plans.

SUMMARY

DEVELOPMENT VENTILATION AREA	MINIMUM AIRFLOW REQUIREMENT (CFM)
SHOP	85,000
SPENT FUEL MINING AREA (6 HEADINGS)	100,000
MINING AREA - PANEL ACCESS DRIFTS	50,000
TBM (PERIMETER DRIFT)	40,000
BOREHOLE DRILLING IN EMPLACEMENT DRIFT	20,000
ADVANCING TWO PANEL ACCESS DRIFTS	50,000

WASTE EMPLACEMENT VENTILATION SYSTEM AREA	MINIMUM AIRFLOW REQUIREMENT (CFM)
RAMPS	45,000
MAINS	45,000
EMPLACEMENT DRIFTS	45,000
SHOP/DECONTAMINATION FACILITY	55,000
TRAINING AREA	45,000
DEDICATED PERFORMANCE CONFIRMATION AREA	25,000
PANEL ACCESS DRIFT	50,000

BRANCH RESISTANCE CALCULATIONS

The following page shows the resistance per linear foot and hydraulic mean diameters of each major airway in the vertical emplacement ventilation network. The resistance for each shaft is calculated toward the end of this section.

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Job No. 3696 A161
Made by K. Wallace
Date 3/31/86
Checked by D. Brunner
Date 5/9/86

COMPUTATION SHEET

Subject VERTICAL EMPLACEMENT RESISTANCE/FT. AND HYDRAULIC MEAN DIAM.

AREA	REFERENCE LETTER	FRICTION FACTOR (a) ($lb \cdot min^2/ft^4 \times 10^{10}$)	PERIMETER (b) (FT)	AREA (b) (FT^2)	RESISTANCE PER FOOT ($PU/ft \times 10^{-6}$)	HYDRAULIC MEAN DIAMETER (d) (FT)
WASTE RAMP	A	30	62.35	281	1.62	18.03
WASTE MAIN	B	60	74.20	425	1.12	22.91
TUFF RAMP	C	60	86.00	400	1.55	18.60
TUFF MAIN (W/ BELT)	D	60	88.50	380	1.86	17.18
TUFF MAIN (W/O BELT)	E	70	73.50	398	1.57	21.66
SERVICE MAIN	F	70	68.55	303	3.32	17.68
PERIMETER DRIFT	G	60	68.75	372	1.54	21.64
PANEL ACCESS (W/ BELT)	H	70	74.30	217	9.79	11.68
PANEL ACCESS (W/O BELT)	I	70	59.90	237	6.06	15.83
EXHAUST DRIFT MID-PANEL	J	70	51.73	185	11.00	14.30
EMPLACEMENT DRIFT	K	70	67.70	305	3.21	18.02

(a) Estimated from Table on page 9.

(b) From cross-sections, pages ,

(c) Calculated from:

$$R = \frac{k (per) 1}{5.2 (A)^3} \quad (P.U. / ft)$$

(d) Calculated from:

$$HMD = 4A/per \quad (ft)$$

Example Calculation of Resistance/ft and HMD

Waste Ramp (Reference Letter Ⓐ)

$$R = \frac{K \, per \, L}{5.2 A^3} = \frac{30(62.35)(1)}{5.2(281)^3} = \underline{1.62 \times 10^{-6} \text{ P.U./ft}}$$

$$\left[(lb \cdot min^2/ft^4 \times 10^{10})(ft) / (5.2)(ft^2)^3 \right]$$

$$HMD = 4A/per = 4(281)/62.35 = \underline{18.03 \text{ ft}}$$

$$\left[(ft^2)/(ft) \right]$$

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Job No. 3696 A161

Made by K. WALLACE

Date 3/31/86

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Date 5/9/86

Subject Vertical Emplacement - Cross-Sections

The cross-sections used in this analysis are identical to the cross-sections used in calculation 3236 A103 (except for the panel access drift, which is shown separately). For completeness a copy of the cross-sections is shown on the next few pages.

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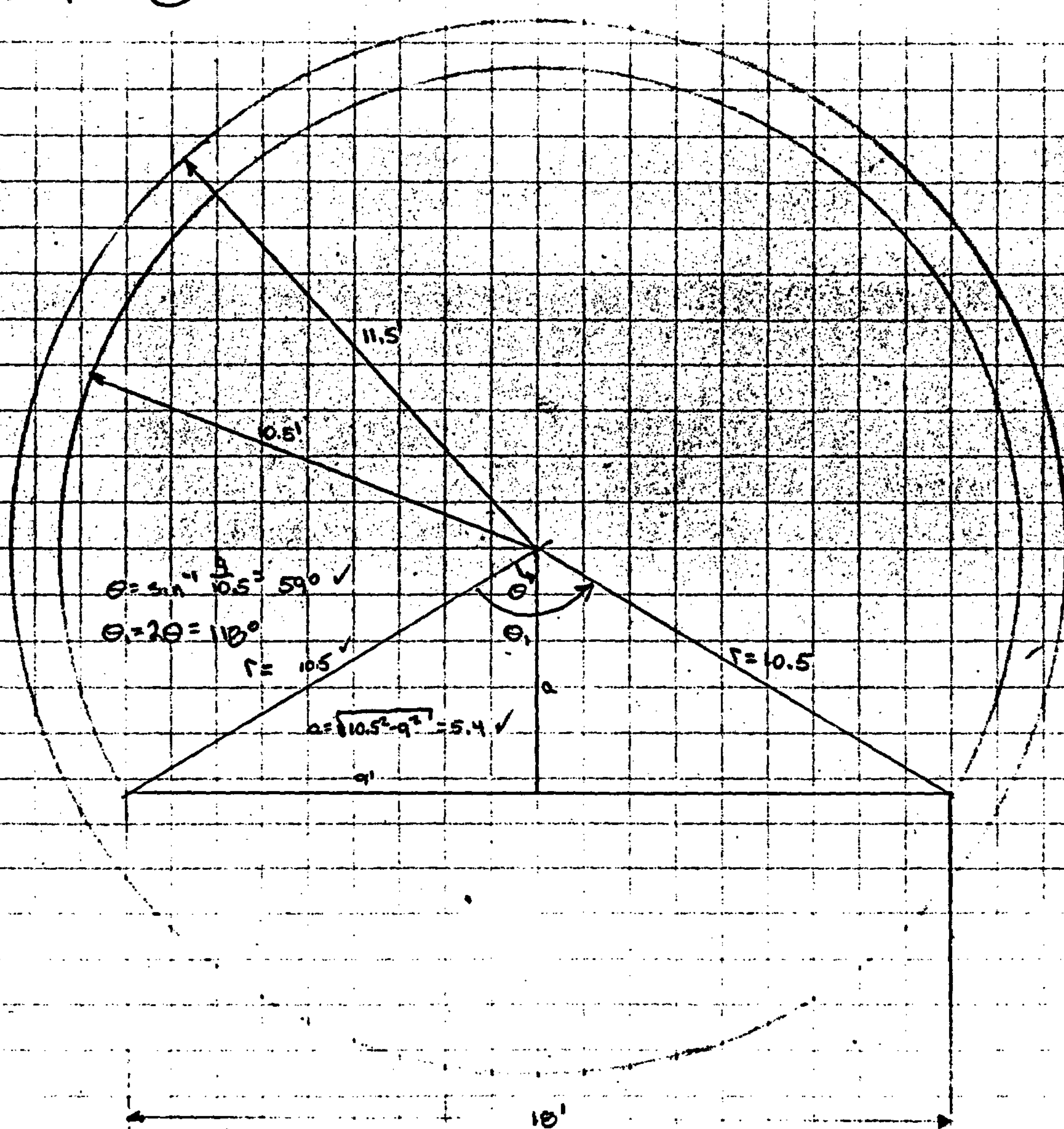
COMPUTATION SHEET

Job No. ~~3336A103~~
Made by K. WALLACE
Date 4/18/85
Checked by D.B.
Date 4/26/85

Subject Vertical Emplacement - Waste Ramp

Reference Letter (A)



Inside Dimensions:

$$Area = \pi r^2 - \theta_1/360 * \pi r^2 + (1/2)18 * a = \pi(10.5)^2 - 118/360 * \pi(10.5)^2 + 9 * 5.4$$

Area = 281.4 ft² use <u>281 ft²</u> ✓

$$perimeter = 2\pi r - (\theta_1/360 * 2\pi r) + 18 = 2\pi(10.5) - (118/360 * 2\pi(10.5)) + 18$$

Perimeter = <u>62.35 ft.</u> ✓

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COMPUTATION SHEET

Job No. ~~3836A103~~
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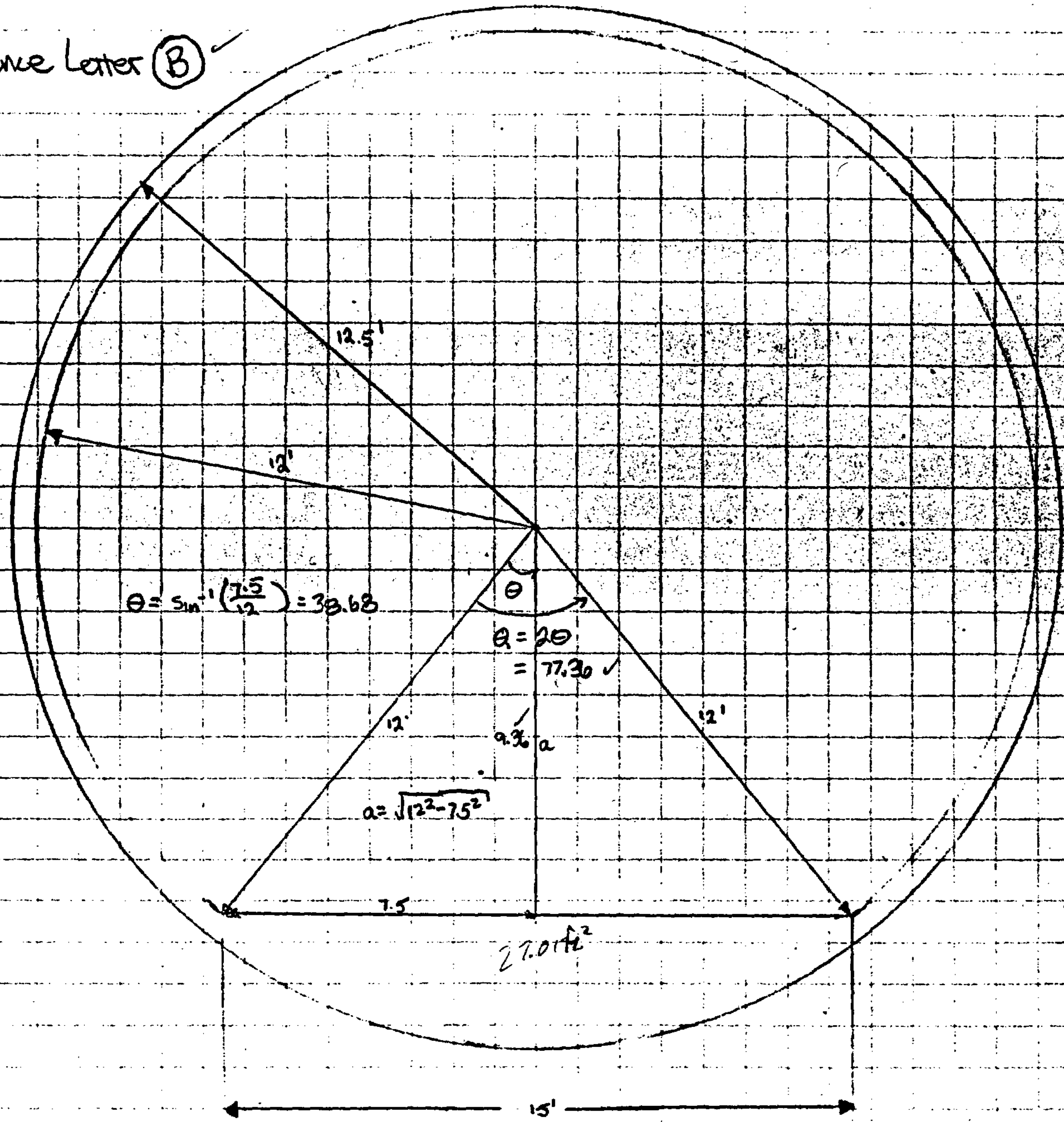
Date 4/18/85
Checked by D. Brunner
Date 4/26/85

Subject Vertical Emplacement - Waste Main

Reference Letter (B) ✓



Inside dimensions:

$$\text{Area} = \pi r^2 - \theta/360 * \pi r^2 + 1/2 * 15 * a = \pi(12)^2 - 77.36/360 * \pi(12)^2 + 7.5(9.36)$$

Area = 425.4 ft^2 use <u>425 ft^2</u> ✓

$$\text{Perimeter} = 2\pi r - (\theta/360 * 2\pi r) + 15 = 2\pi(12) - (77.36/360 * 2\pi(12)) + 15$$

Perimeter = <u>74.2 ft</u> ✓

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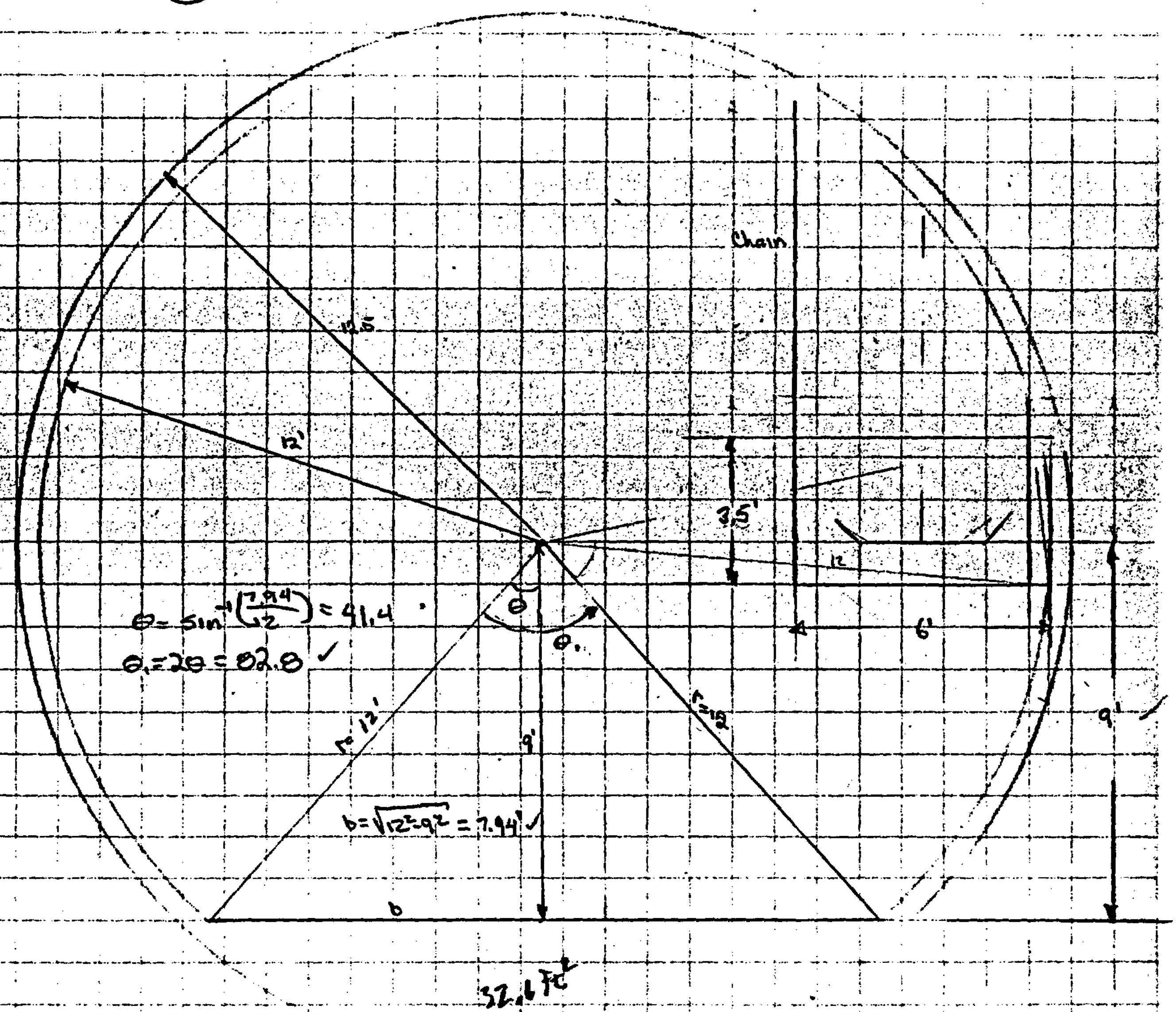
COMPUTATION SHEET

Page ~~26~~ of ~~156~~
Job No. ~~3836-A105~~
Made by K. WALLACE
Date 4/18/85
Checked by D. B[illegible]
Date 4/26/85

Subject Vertical Emplacement - Tuff Ramp

Reference Letter (C) ✓



$\theta = \sin^{-1}\left(\frac{7.94}{12}\right) = 41.4$

$\theta_1 = 2\theta = 82.8$ ✓

$b = \sqrt{12^2 - 9^2} = 7.94'$ ✓

32.6 ft²

Inside Ventilation Dimensions:

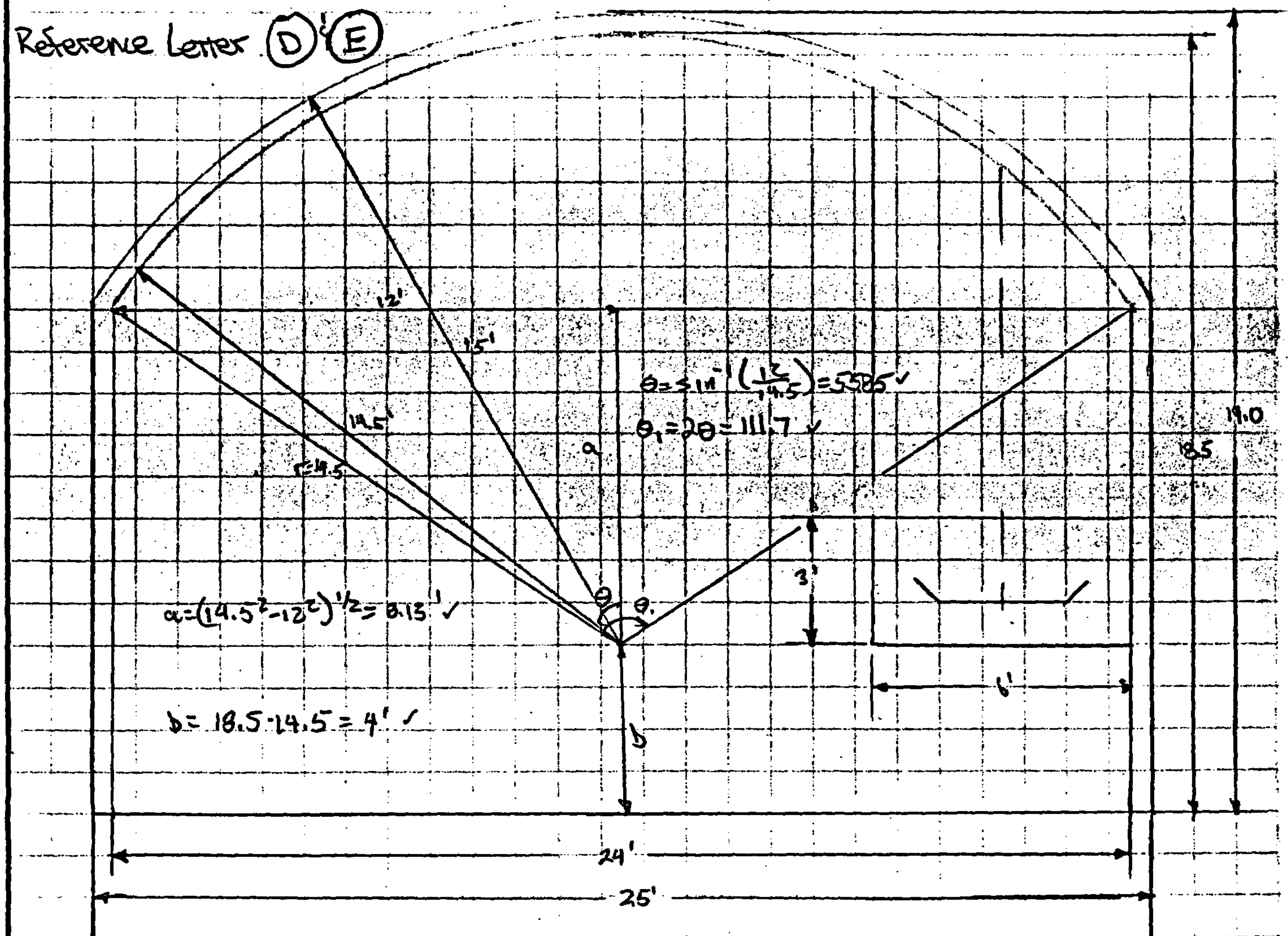
Area $= \pi r^2 - \theta_1/360 * \pi r^2 + b*9$ − Belt Area   Belt Area $= 3.5' * 6 = 21\ ft^2$ (approx.)

Area $= \pi(12)^2 - 82.8/360(\pi)(12)^2 + (7.94*9) - 21 = 399$ ✓ use 400 ft² ✓

perimeter $= 2\pi r - \theta_1/360 * 2\pi r + 2b + (3.5 + 12 + 3.5)$ ( ) perimeter around belt

perimeter $= 2\pi(12) - 82.8/360 * 2\pi(12) + 2(7.94) + 12 =$ 86.0 ft ✓

Reference Letter (D) & (E)



Inside Dimensions:

(D) Area = $w(h_c - 0.079\,W)$ - Belt Area   Belt Area = $3' * 6' = 18\ ft^2$

Area = $24(18.5 - 0.079(24)) - 18 = 380.4\ ft^2$ use $\underline{380\ ft^2}$ ✓

perimeter = $\theta_1/360 * 2\pi r + 2(b+a) + 24 + (3+6+6+3)$ (belt perimeter)

perimeter = $111.7/360 * 2(\pi)(14.5) + 2(8.13+4) + 24 + 12 = \underline{88.5\ ft}$ ✓

(E) without belt Area = $380 + 18 = \underline{398\ ft^2}$

Perimeter = $88.5 - 15 = \underline{73.5\ ft}$.

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COMPUTATION SHEET

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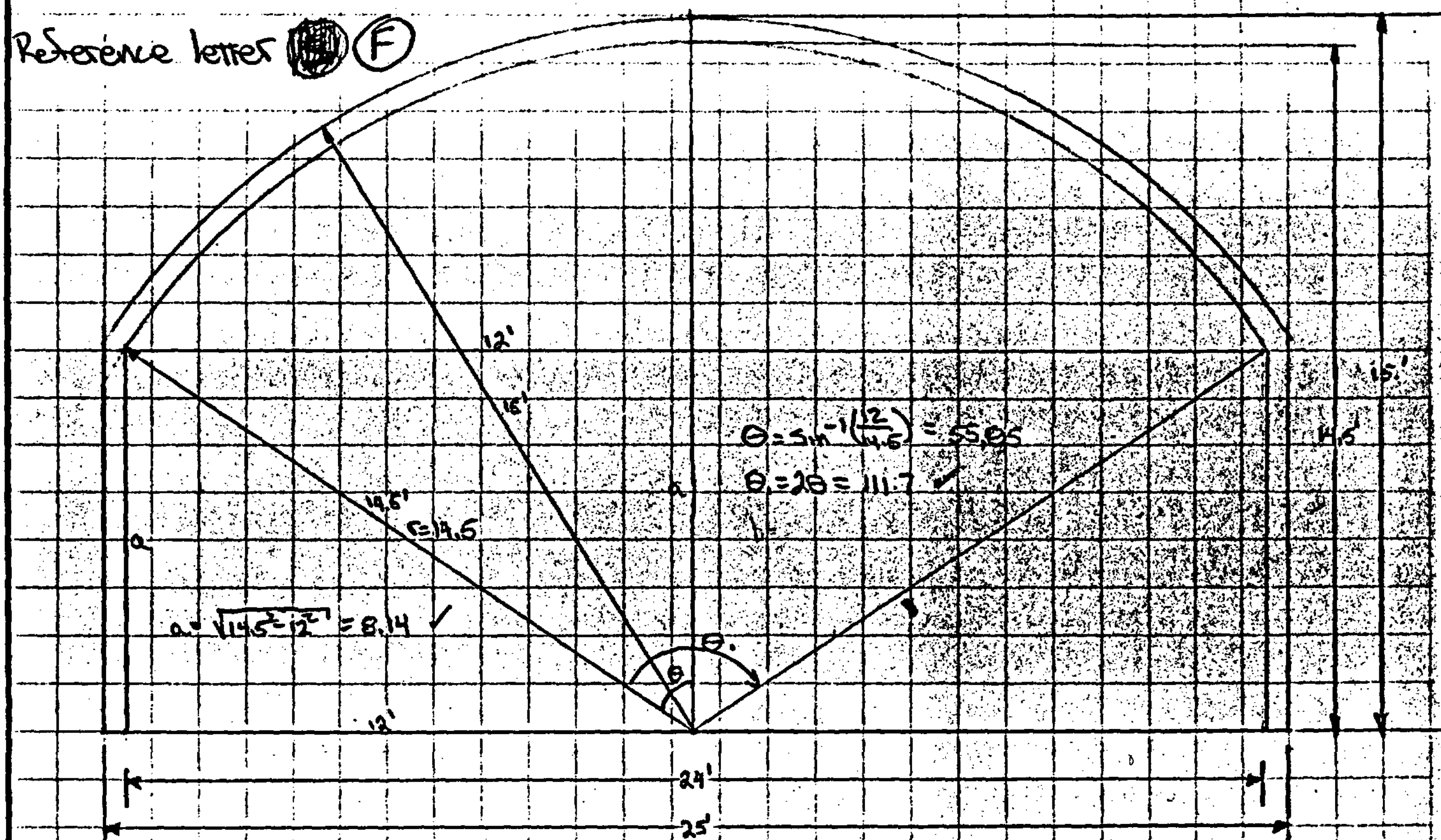
Job No. ~~3836 A103~~
Made by K. WALLACE
Date 4/18/85
Checked by D. Bruner
Date 4/26/85

Subject: Vertical Emplacement – Service Main

Reference letter (F)



Inside Dimensions:

$$\text{Area} = \theta_1/360 * \pi(r)^2 - \tfrac{1}{2}24*a + a*24 = 111.7/360 * \pi(14.5)^2 - \tfrac{1}{2}(24)8.14 + 8.14*24$$

Area = 302.6 ft² use **303 ft²** ✓

$$\text{perimeter} = \theta_1/360 * 2\pi r + 2a + 24 = 111.7/360 * 2\pi(14.5) + 2(8.14) + 24$$

perimeter = **68.55 ft** ✓

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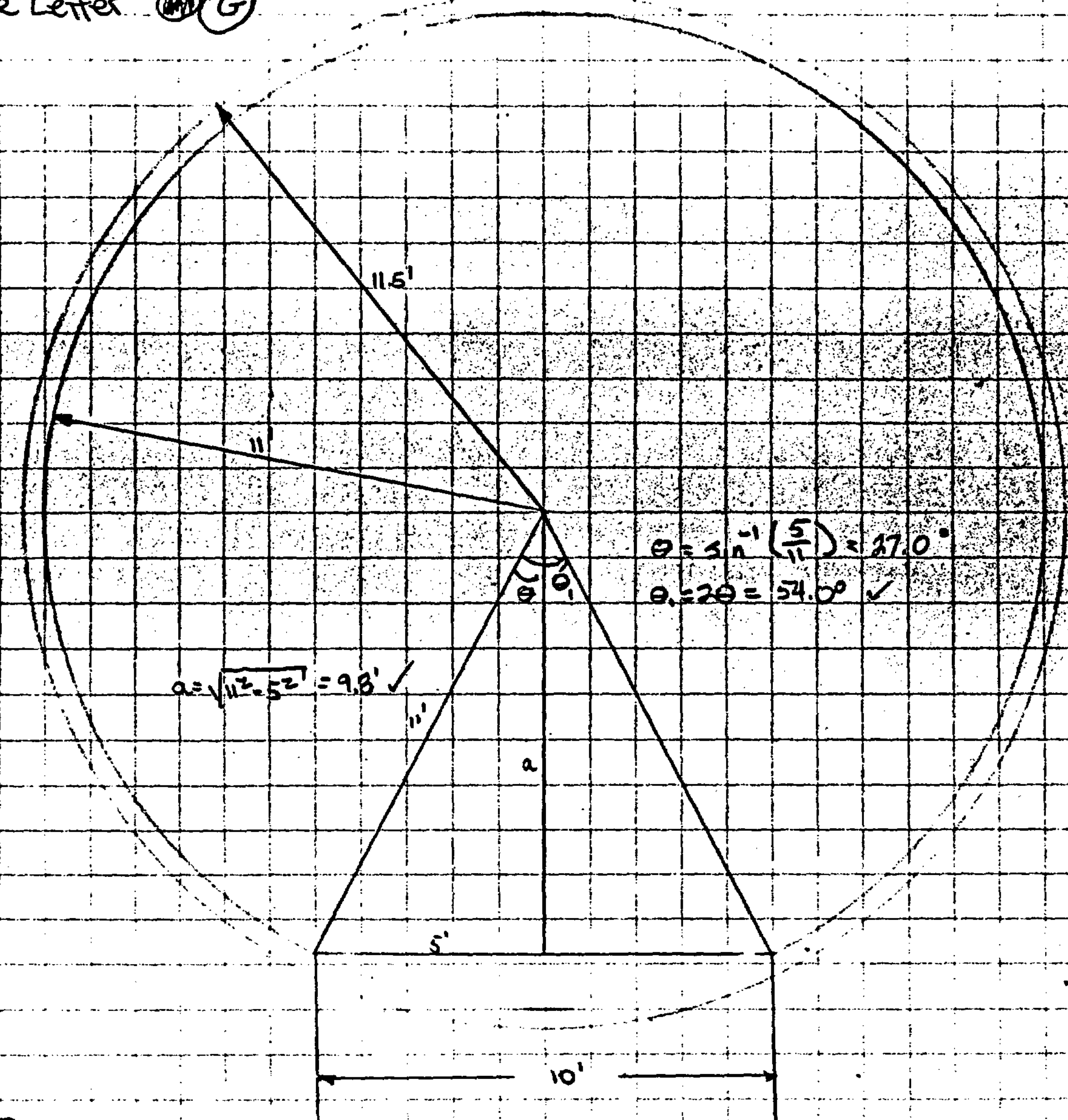
Made by K. WALLACE
Date 4/18/85
Checked by D. Brown
Date 4/26/85

Subject Vertical Emplacement Perimeter Drift

Reference Letter (G)



Inside Dimensions:

$$\text{Area} = \pi r^2 - \theta_1/360 \cdot \pi r^2 + \tfrac{1}{2} \cdot 10 \cdot a = \pi(11)^2 - \frac{54}{360} \cdot \pi(11)^2 + 5 \cdot 9.8$$

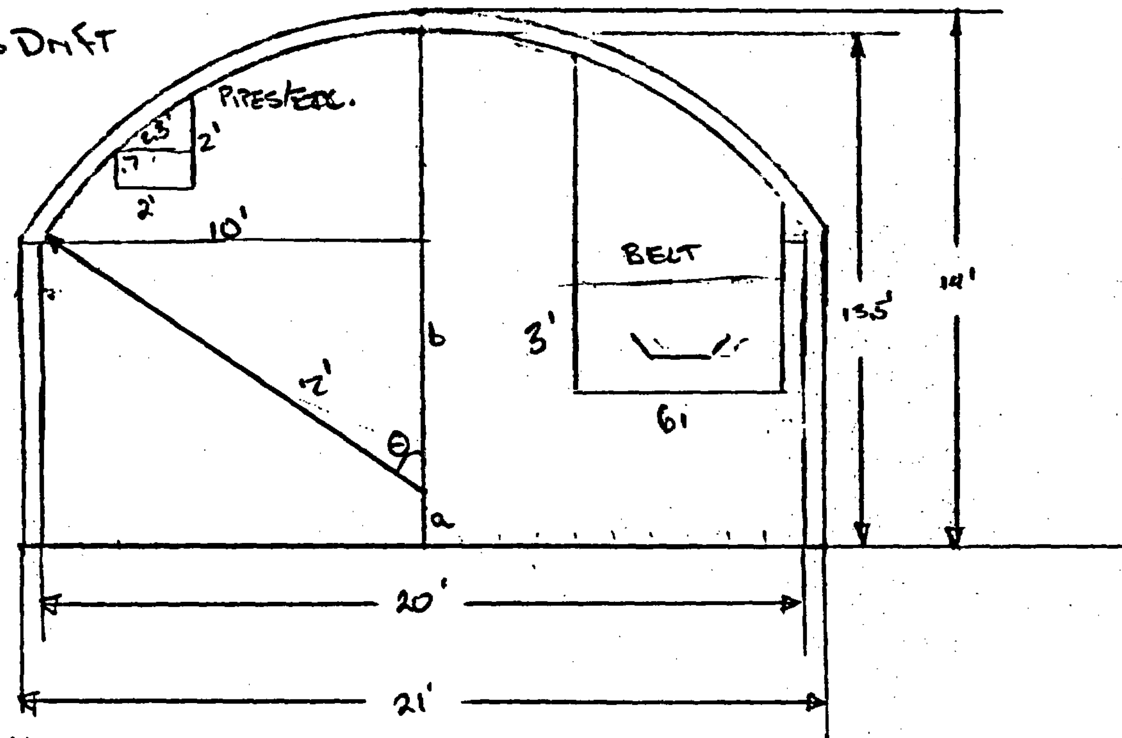
Area = 372.1 ft^2 use <u>372 ft^2</u> ✓

$$\text{Perimeter} = 2\pi r - \theta_1/360 \cdot 2\pi r + 10 = 2\pi(11) - 54/360 \cdot 2\pi(11) + 10$$

Perimeter = <u>68.75 ft</u> ✓

Panel Access Drift

(H) & (I)



$b = (12^2 - 10^2)^{1/2} = 6.63$ ft ✓

$a = 1.5$ ft ✓

$\theta = \sin^{-1}\left(\frac{10}{12}\right) = 56.44^\circ$ ✓

$2\theta = 112.88^\circ$ ✓

PANEL ACCESS WITH BELT: (H)

$$\text{Area} = (2\theta/360)\pi r^2 - (1/2(20)b) + (a+b)*20 - (3*6) - (1.4) - 1/2\,2(1.3)$$

$$= (112.88/360)\pi(12)^2 - 1/2(20)(6.63) + (1.5+6.63)*20 - (3*6) - 1.4 - 1.3 = \underline{217 ft^2}$$

$$\text{perimeter} = 2*(a+b) + 20 + (2\theta/360)2\pi r + 6 + 6 + 3 - 3 + 4.7 - 2.3$$

$$= 2*(8.13) + 20 + (112.88/360)2\pi(12) + 14.4 = \underline{74.3 \text{ ft.}}$$

PANEL ACCESS WITHOUT BELT & FIXTURES (I)

$$\text{Area} = \text{Previous Area} + (3*6) + 1.4 + 1/2(2)(1.3) = 217 + 18 + 1.4 + 1.3 = \underline{237 ft^2}$$

$$\text{Perimeter} = \text{Previous Perimeter} - 6 - 6 - 3 + 3 - 4.7 + 2.3 = 74.3 - 14.4 = \underline{59.9 \text{ ft}}$$

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Job No. ~~3836-A103~~

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Date 4/18/85

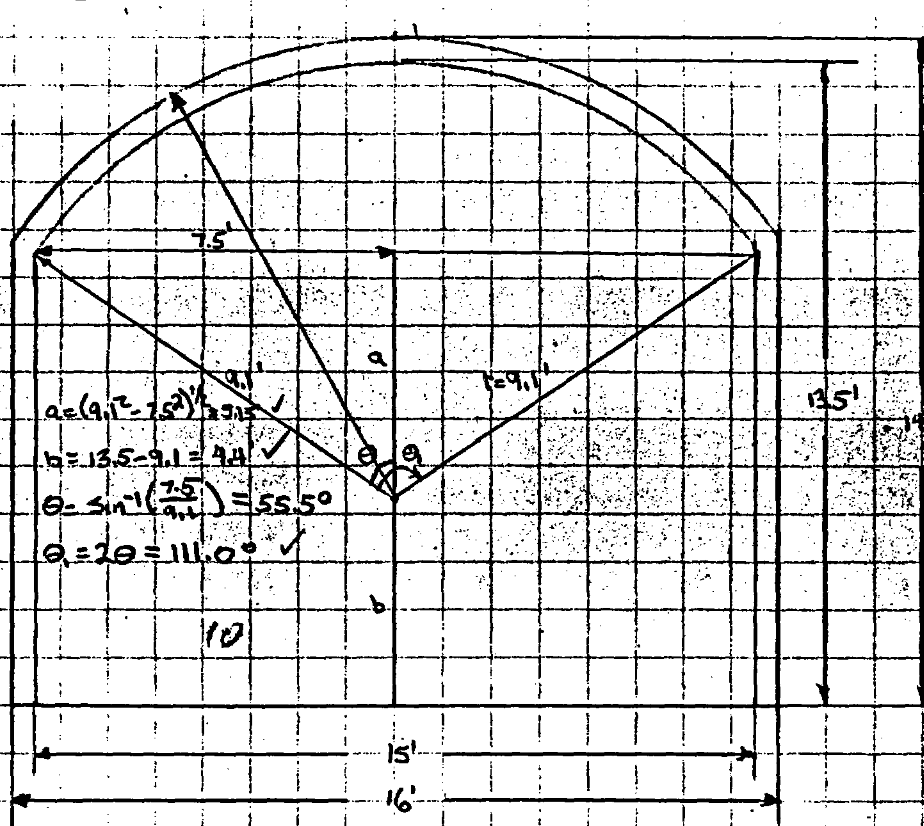
COMPUTATION SHEET
- Mid-panel drift
- ~~[illegible]~~ Exhaust Drift

Checked by D.B.

Subject Vertical Emplacement - ~~[illegible]~~

Date 4/26/85

Reference Letter (J)



$a = (9.1^2 - 7.5^2)^{1/2} = 5.15$ ✓

$b = 13.5 - 9.1 = 4.4$ ✓

$\theta = \sin^{-1}\left(\frac{7.5}{9.1}\right) = 55.5°$

$\theta_1 = 2\theta = 111.0°$ ✓

Inside Dimensions:

$\text{Area} = \theta_1/360\,(\pi r^2) - \tfrac{1}{2}(15 * a) + (a+b) * 15 = \frac{111}{360}(\pi)(9.1)^2 - (7.5)(5.15) + (5.15+4.4) * 15$

Area = 184.8 use <u>185 ft²</u> ✓

$\text{perimeter} = \theta_1/360\,(2\pi r) + 2(a+b) + 15 = \frac{111}{360}(2\pi)(9.1) + 2(5.15+4.4) + 15$

perimeter = <u>51.73 ft</u> ✓

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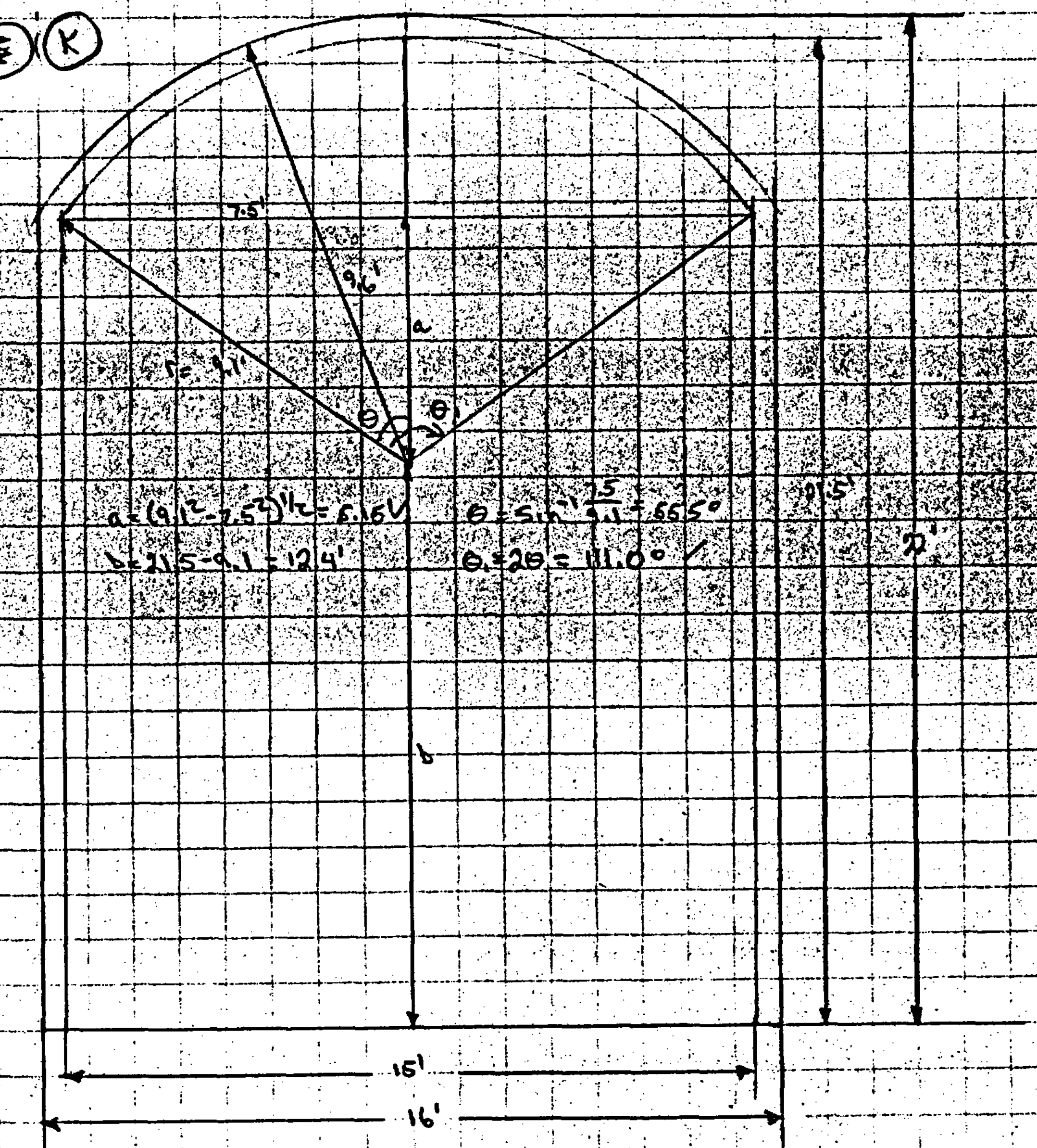
Date 4/12/85
Checked by D. B.
Date 4/27/85

COMPUTATION SHEET
Spent Fuel

Subject: Vertical Emplacement - Emplacement Drift

Reference Letter (K)



Inside Dimensions:

Area = $15*(a+b) + \theta_1/360*\pi r^2 - 7.5*a = 15*(5.15+12.4) + \frac{111.0}{360}*\pi(9.1)^2 - 7.5*5.15$

Area = 304.8 ft² use <u>305 ft²</u> ✓

Perimeter = $\theta_1/360 * 2\pi r + 2(a+b) + 15 = \frac{111.0}{360} * 2\pi(9.1) + 2(5.15+12.4) + 15$

Perimeter = <u>67.7 ft</u> ✓

Subject Shaft Resistance

Shaft Resistance Calculations

The shaft resistance calculations were determined from well known equations. Since the shaft sizes and depths are unchanged from the previous (3836A103) calculations a re-analysis was unnecessary. A copy of those calculations is enclosed for completeness.

SHAFT RESISTANCE SUMMARY

SHAFT	RESISTANCE (p.u.)
1. MEN & MATERIALS SHAFT	0.00895 ✓
2. WASTE EXHAUST SHAFT	0.006947 ✓
3. TWELVE FOOT WASTE INTAKE SHAFT	0.01172 ✓
4. SIX FOOT WASTE INTAKE SHAFT	0.3047 ✓

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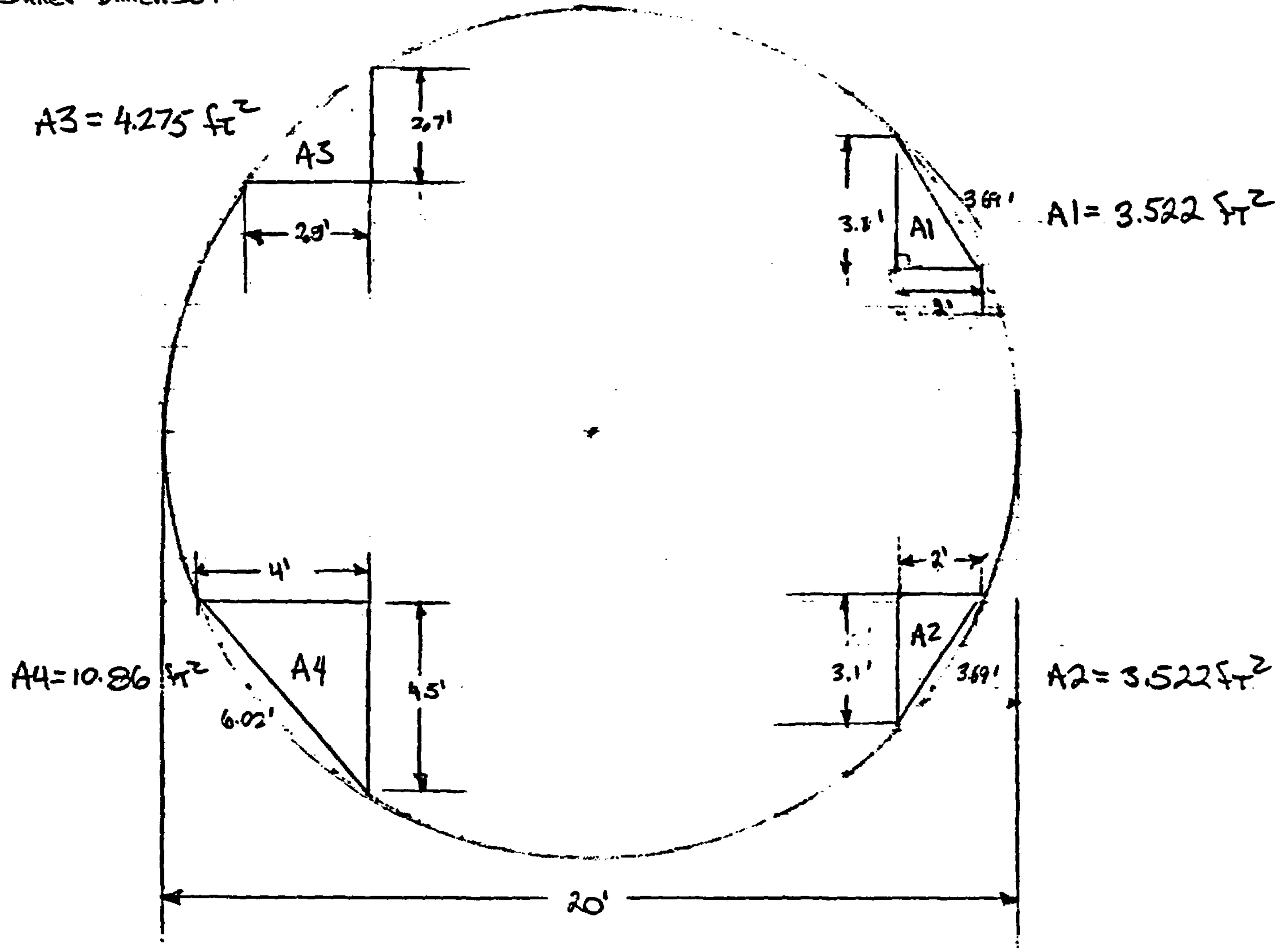
COMPUTATION SHEET

Page ~~35~~ of ~~146~~
Job No. ~~5836-A103~~
Made by K. Wallace
Date 4/28/85
Checked by D. Brunner
Subject Vertical Employment - Men and Materials Shaft Res
Date 5/28/85

Inner Dimensions



Procedure:

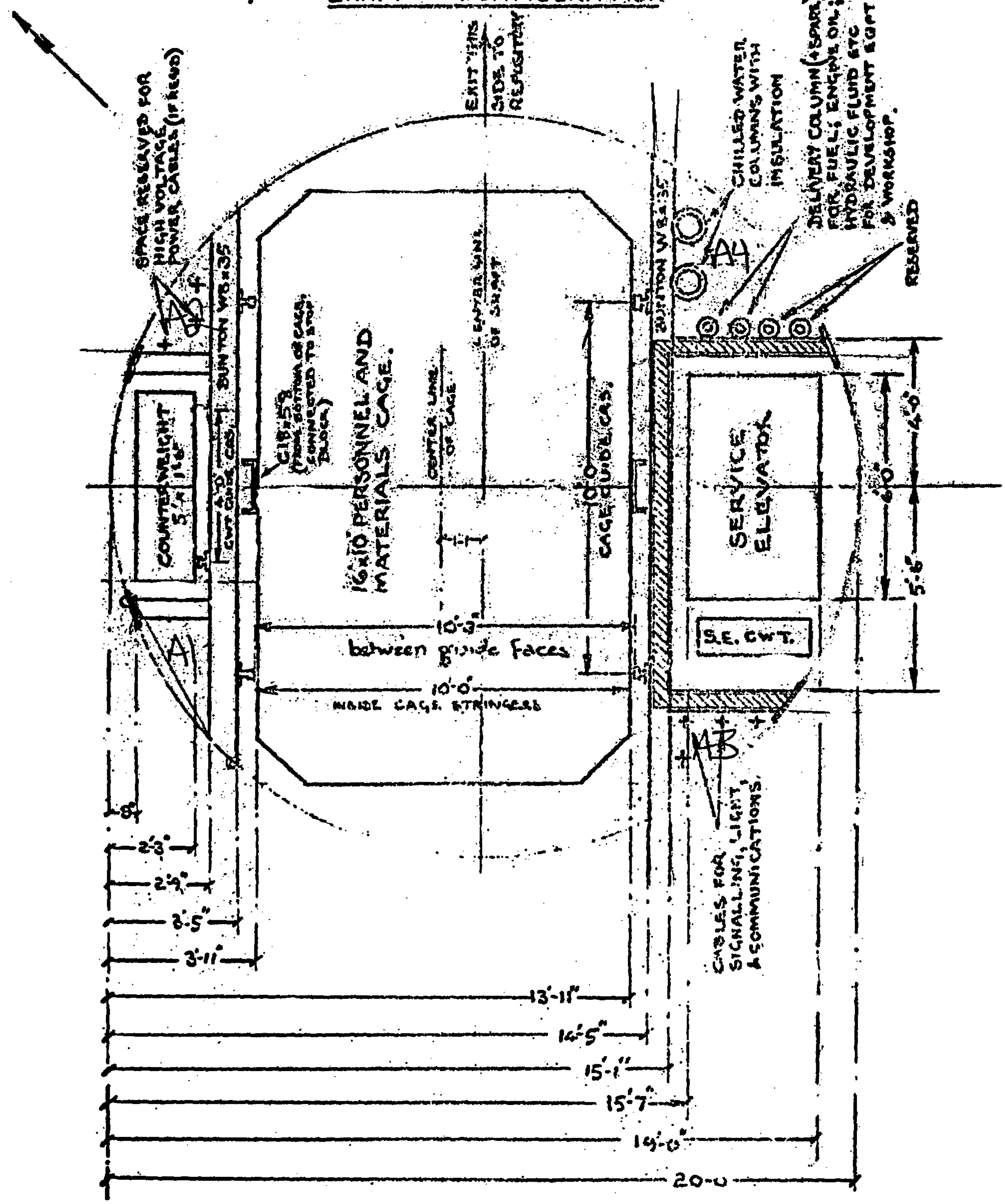
Shaft cross-section was taken from next page. The resistance was calculated in the following manners

1) Account for the resistance of the buntons by employing a friction factor which was empirically determined for a shaft with buntons (refer to page 9.).

2) Remove areas within the shaft which have permanent structures running the length of the shaft. Calculate a new ventilation area and perimeter.

3) Account for the cage and moving components of the shaft by a "shock loss resistance".

2) SHAFT CONFIGURATION



4) Account for air entry shock losses by calculating a resistance for a bend.

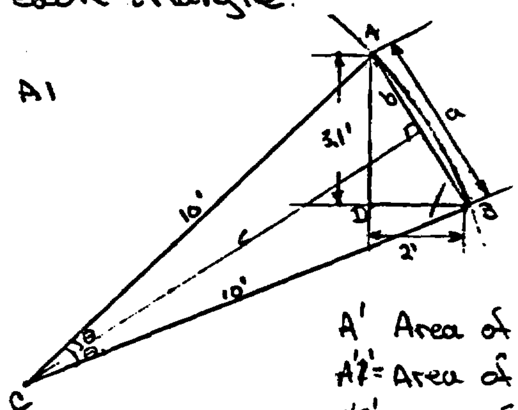
5) Sum the resistances and apply to the computer simulation.

Calculation:

Area Calculation:

If the shaft were unobstructed the area would be πr^2 or $\pi(100) = 314.16 \text{ ft}^2$. However, the triangles shown on the previous page need to be subtracted from this area. The following is the calculation of area and perimeter for each triangle.

Area A1



$a = (3.1^2 + 2^2)^{1/2} = 3.69'$ ✓

$b = \frac{1}{2}a = 1.845'$ ✓

$\theta = \sin^{-1}\left(\frac{1.845}{10}\right) = 10.63°$ ✓

$\theta_1 = 2\theta = 21.26°$

A' Area of Arch segment $= \frac{21.26}{360} \times \pi(10)^2 = 18.55 \text{ ft}^2$ ✓

A1' = Area of triangle ABC $= \frac{1}{2}ac = \frac{1}{2}(3.69)(10^2 - 1.845^2)^{1/2} = 18.13$

A2' Area of arch $= A' - A1' = 18.55 - 18.13 = 0.42 \text{ ft}^2$ ✓

Area of ADB = Triangle ADB + A2'

Triangle ADB $= \frac{1}{2}(3.1)(2) = 3.1 \text{ ft}^2$

$A1 = 3.1 \text{ ft}^2 + 0.42 \text{ ft}^2 = 3.52 \text{ ft}^2$ ✓

Arch perimeter $= \frac{21.26}{360} \times 2\pi(10) = 3.711 \text{ ft}$ ✓

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COMPUTATION SHEET

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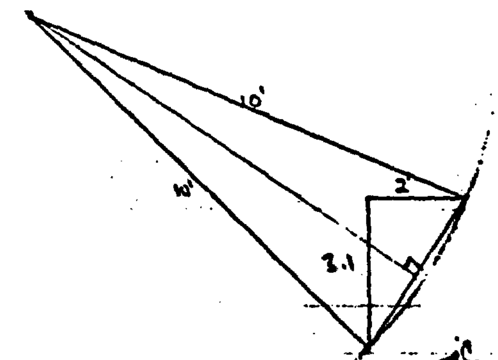
Job No. ~~3036-A103~~
Made by K. WALLACE
Date 4/28/85
Checked by [signature]

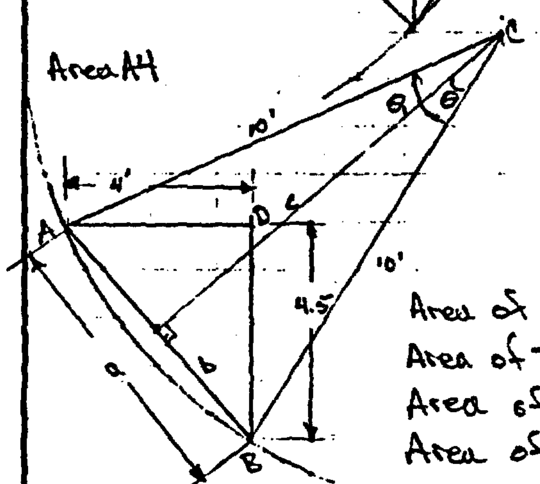
Subject Vertical Emplacement - Men and Materials Shaft Date 5/30/85

Area A2 = A1 = $\underline{3.522\ ft^2}$



Same as A1 area ✓

Area A4



$a = (4^2 + 4.5^2)^{1/2} = 6.02$ ft ✓

$b = 1/2 a = 3.01$ ft ✓

$c = (10^2 - b^2)^{1/2} = 9.54$ ft ✓

$\theta = \sin^{-1}(\frac{b}{10}) = 17.52°$ ✓

$\theta_1 = 2\theta = 35.04°$ ✓

Area of Arch Segment $= A' = \frac{35.04}{360} * \pi(10)^2 = 30.58$ ✓

Area of Triangle ABC $= A1' = 1/2\, ac = 1/2(6.02)(9.54) = 28.72$ ✓

Area of Arch $= A' - A1' = A2' = 1.86\ ft^2$ ✓

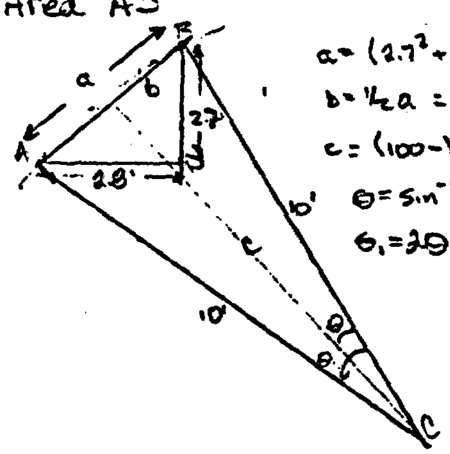
Area of ADB = ΔADB + A2' = A4

ΔADB = 1/2(4)(4.5) = 9 ✓

A4 = 9 + 1.86 10.86 ft^2 ✓

Perimeter of arch $= \frac{35.04}{360} * 2\pi(10) = 6.116$ ft ✓

Area A3



$a = (2.7^2 + 2.8^2)^{1/2} = 3.89$ ft ✓ Area of Arch

$b = 1/2 a = 1.94$ ft. ✓

$c = (100 - b^2)^{1/2} = 9.809$ ft ✓

$\theta = \sin^{-1}(\frac{b}{10}) = 11.21°$ — 11.18°

$\theta_1 = 2\theta = 22.43°$ — 22.37°

Area of Arch Segment $= A' = \frac{22.43}{360} * \pi(10)^2 = 19.57\ ft^2$ ✓ (19.52)

Area of Triangle ABC $= A1' = 1/2\, ac = 1/2(3.89 * 9.809) = 19.08\ ft^2$

Area of Arch $= A' - A1' = A2' = 0.49\ ft^2$ — .44

Area of ADB = ΔADB + A2' = A3 ΔABD = 1/2(2.8)(2.7) = 3.78

A3 = 3.78 + 0.49 = 4.27 ft^2 — 4.22

Perimeter of arch $= \frac{22.43}{360} * 2\pi(10) = 3.91$ ft

3.90 —

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COMPUTATION SHEET

Subject Vertical Emplacement/Waste Materials Shaft

Effective Ventilation Area of Shaft =

$A_{eff} = A_{shaft} - A1 - A2 - A3 - A4 = 314.16 - 3.52 - 3.52 - 10.86 - 4.22 = 291.97\ ft^2$

Area = use 292 ft^2 ✓

Perimeter of Shaft = $per_{shaft} - Per_{A1} - Per_{A2} - Per_{A3} - per_{A4} + 3.1 + 2 + 3.1 + 2 + 4 + 4.5 + 2.7 + 2.8$

$= 62.83 - 3.711 - 3.711 - 6.116 - 3.90 + 24.2 =$ 69.58 ft ✓

Resistance of Shaft:

From diagram on next page, the length of the shaft from the collar to the spent fuel repository level is (4140' - 3110') = 1,030 ft. The length of the shaft from the spent fuel level to the DHLW level is (3110 - 3000) = 110 ft.

The friction factor is estimated at 95 lbs $\cdot min^2/ft^4 \times 10^{10}$ (Table on pg 9) unrestricted

Resistance from collar to spent fuel level: △

From equation (.1.) (page 8):

$$R = \frac{k(l + l_{eq})per}{52\,A^3} \quad (P.U.)$$

Plugging in the appropriate values given above gives (l_{eq} is taken as 0 since any additional resistance is calculated directly)

$$R = \frac{95\,(1040)(69.58)}{52\,(292)^3} = \underline{0.00531} \quad (P.U.)$$

Entry Losses:

The air enters the shaft via an 18 ft diameter

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COMPUTATION SHEET

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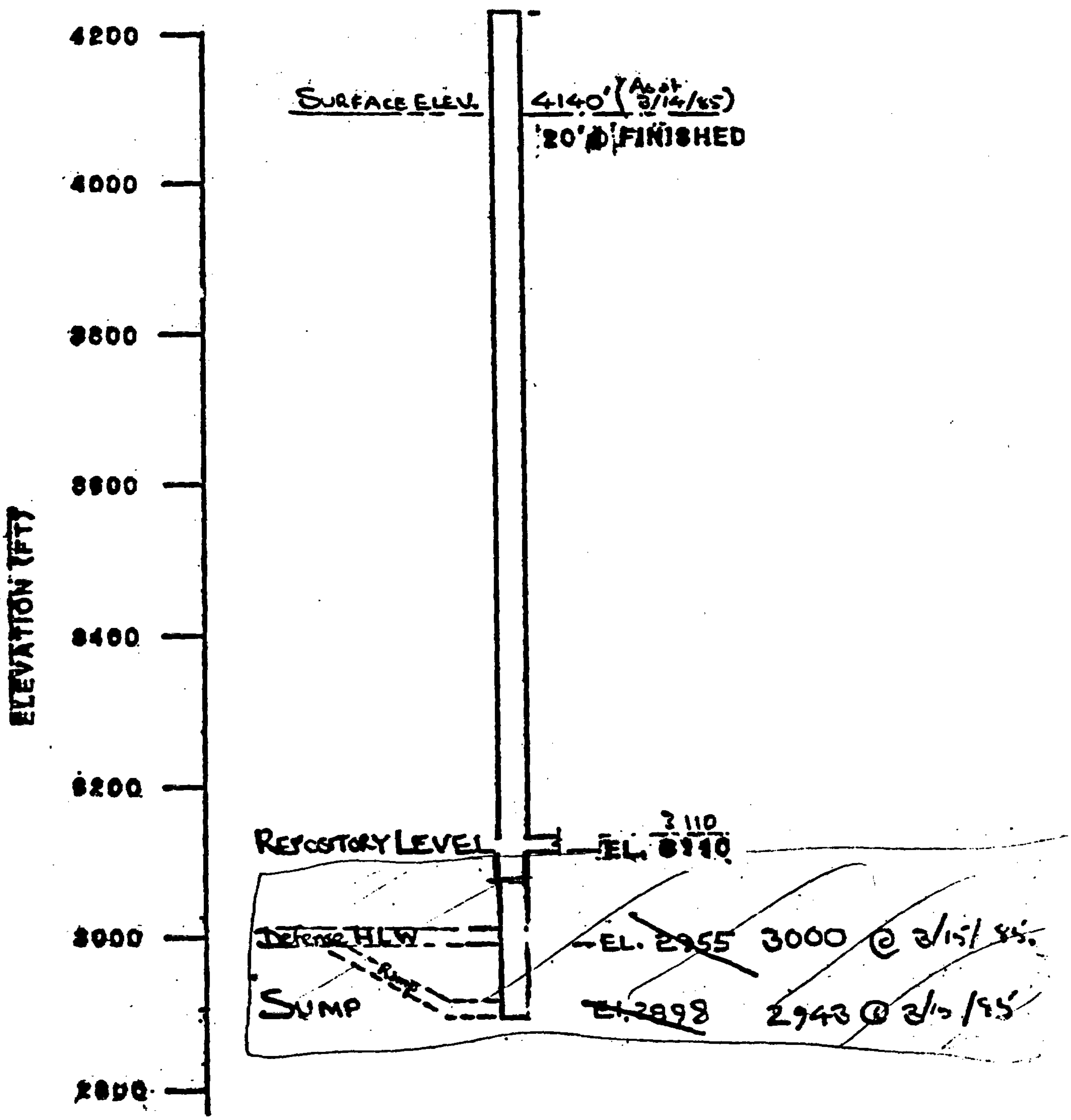
NWRT
Subsurface Facility Design Contract No. 47-7368

From

Page ~~30~~ 23 of ~~188~~ 46
Job No. ~~15836~~
Made by M Sirveo
Date 2/28/85 rev 3/14/85
Checked by CDM rev 3/15/85
Date 2 Apr 85

Subject Men & Materials shaft.
Ref. Dwgs.

PRINCIPAL ELEVATIONS - MEN & MATERIALS SHAFT.



concrete pipe. Since the air negotiates an approximate 76° turn at entry to the shaft, an additional resistance is necessary. This is computed from the following equation:

The shock loss factor is computed from:

$$X^{*} = \frac{0.60}{m\, a^{0.5}}\left(\frac{\theta}{90}\right)^2 \quad ✓ \qquad (.7)$$

where m = radius ratio = r/b where r = b/2 and b = airway width ∴ m = 1/2
a = aspect ratio = d/b where d = airway height = 1

Therefore,

$$X = \frac{0.6}{\frac{1}{2} \cdot 1}\left(\frac{76}{90}\right)^2 = 0.856 \quad ✓$$

using:

$$R_{sh} = \frac{62.21}{A^2} X^{**} \ (P.U.) \quad ✓ \qquad (.8)$$

then $R_{sh} = \frac{62.21}{(292)^2} 0.856 = \underline{0.000625}$ ✓ (P.U.)

$R_{pipe} = \frac{k\, l\, per}{52 A^3}$ where k = 30, l = 60 ft, per = 56.55' and A = 254.47 (for 18'

$R_{pipe} = \frac{(30)(60)(56.55)}{52(254.47)^3} = \underline{0.000119\ (P.U.)}$ ✓, $R_{entry} = R_{sh} + R_{pipe} = \underline{0.000744}$ P.

A_m = Cross-section of cage = 10'×16' = 160 ft² ratio of $\frac{A_m}{A} = \frac{160}{292} = 0.54$
From Table in Hartman, 1982 X is estimated to be 4. ✓ Therefore,

$$R_{cage} = \frac{62.21}{A^2} X = \frac{62.21}{(292)^2} \cdot 4 = \underline{0.0029}\ P.U. \quad ✓$$

* McElroy, 1935
** McPherson, ~~1985~~ and Brunner, 1983

Hence the total resistance of the shaft from the collar to the spent fuel level is

$$R_{shaft} = R + R_{entry} + R_{cage} \quad \text{(P.U.)}$$

$$R_{shaft} = 0.00531 + 0.000744 + 0.0029 = \underline{0.00895 \text{ P.U.}}$$

Losses at the station are accounted for in the branch leaving the shaft

Resistance from spent fuel level to DHLW level

Using the equations from the above section:

$$R = \frac{K\,l\,per}{52\,A^3} = \frac{95(110)(69.58)}{52(292)^3} = \underline{0.00056} \text{ P.U.}$$

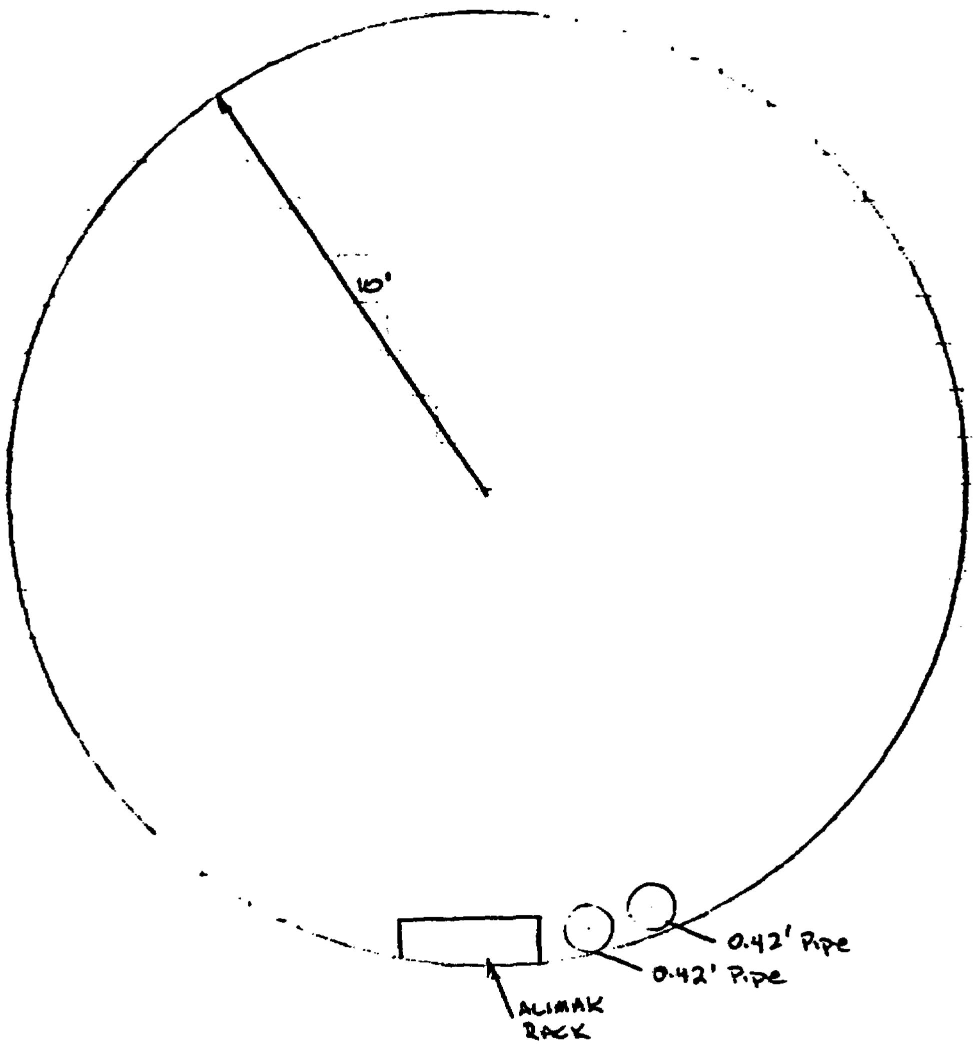
$R_{cage} = \underline{0.0029 \text{ P.U.}}$ (same as in the above section)

$$R_{shaft} = R + R_{cage} = 0.00056 + 0.0029 = \underline{0.00346 \text{ P.U.}}$$

(no entry losses for this case)

Losses at the station are accounted for in the branch leaving the shaft

Inner Dimensions



Procedure:

1) Calculate the shaft resistance using a friction factor to account for alimak rack and pipes. ✓

2) Calculate entry losses to the shaft. ✓

3) Calculate exit losses at collar. ✓

Δ

$$R_{shaft} = \frac{k\, l + l_{eq}\, per}{5.2 A^3}$$ Equation (1.) page 8

where $k = 40\ lbf \cdot min^2/ft^4 \times 10^{10}$ (from Table on page 9) ✓
$l = 1050\ ft$ (see next page) ✓
$per = 2\pi r = 2\pi(10) = 62.83\ ft.$ ✓
$A = \pi r^2 = 314.16\ ft^2$ ✓
$l_{eq} = 0$ (resistance for entry and exit losses accounted for individually)

$$\therefore R_{shaft} = \frac{40(1050)(62.83)}{5.2(314.16)^3} = \underline{0.001637\ P.U.}$$ ✓

Entry losses:

Air entering the shaft will negotiate both a right angle bend and an obstruction at the conveyance landing.

Using equation (7.) on page 41 the shock loss factor for a right angle bend is

$$X = \frac{0.60}{0.5 \times 1} \left(\frac{\theta}{90}\right)^2$$

where $\theta = 90$

Hence, $X = 1.2$ ✓

A_m = The obstruction area is taken as $(8' \times 3') = 24\ ft^2$ (see next page)
A = The area around the obstruction is 19 ft circular (see next page) or $\pi(8.5)^2 = 226.98\ ft^2$

The ratio $\frac{A_m}{A} = 0.106$ or from Table in Hartman, 1982 $X \simeq 1.0$ ✓

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COMPUTATION SHEET

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NWRT

Subsurface Facility Design Contract No. 47-7368

Page ~~4~~ ~~6~~ of ~~15~~ ~~25~~

Job No. ~~35345~~

FROM: Made by M Graves

Date 3/25/85

Checked by CBM

Date 2 Apr 85

Subject EMPLACEMENT EXHAUST SHAFT

Ref. Dwgs.

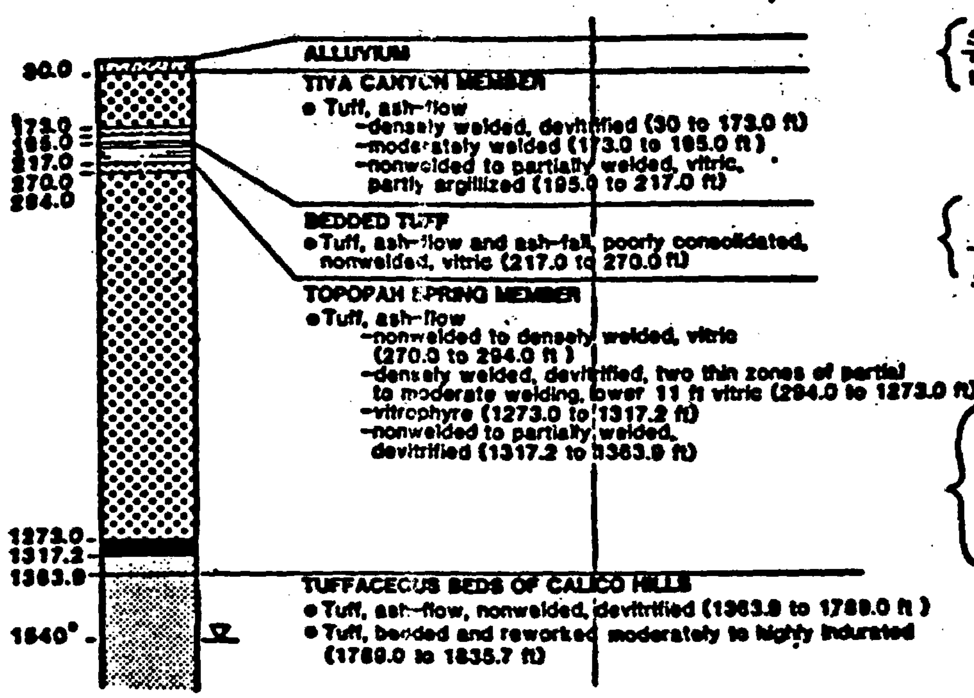
EXAMINATION OF AVAILABLE DATA AND DRAWINGS.

BOREHOLES UE-25a #1 / UE25b #1 ARE LOCATED IN CLOSE PROXIMITY TO THE EMPLACEMENT EXHAUST SHAFT AND PROVIDE AN ACCEPTABLE GUIDE FOR CONCEPTUAL DESIGN.

UE-25a#1/UE-25b#1 GENERAL STRATIGRAPHIC LOG

(Spengler, et al, 1979, OFR 79-1244 and Bish,et al, 1983,LA-9321-MS)

		N	E
SURFACE EL. a#1	3932.8	764900	566350
b#1	3938.2	765264	566417



REMARKS

SHAFT COLLAR TO BE EXTENDED THRU ALLUVIUM TO PENETRATE INTO DENSELY WELDED TUFF

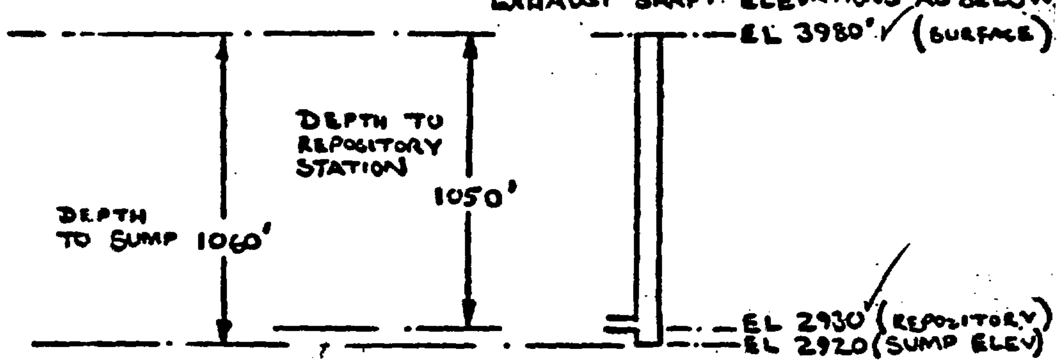
POORLY CONSOLIDATED! MAY NEED SPECIAL ATTENTION TO TEMPORARY SUPPORT DURING SINKING PHASE.

CAUTION

NOTE HIGHLY FRAGMENTED NATURE OF THE CORE. SEE PHOTOGRAPHS, 1097' & 1340' IN A81

▽ WATER TABLE @ EL 239
a#1 = 1540 ft depth
b#1 = 1546

SNL DWG N° R06881 ISSUE DATE 1/22/85 AS AMENDED BY PHONE CALL TO SANDIA 3/25/85 GIVES EMPLACEMENT EXHAUST SHAFT ELEVATIONS AS BELOW.



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COMPUTATION SHEET

Page ~~11~~ of ~~25~~

Job No.

Parsons Brinckerhoff Quade & Douglas, Inc.

FROM Made by M Grieves

NWRT
Subsurface Facility Design Contract No. 47-7368

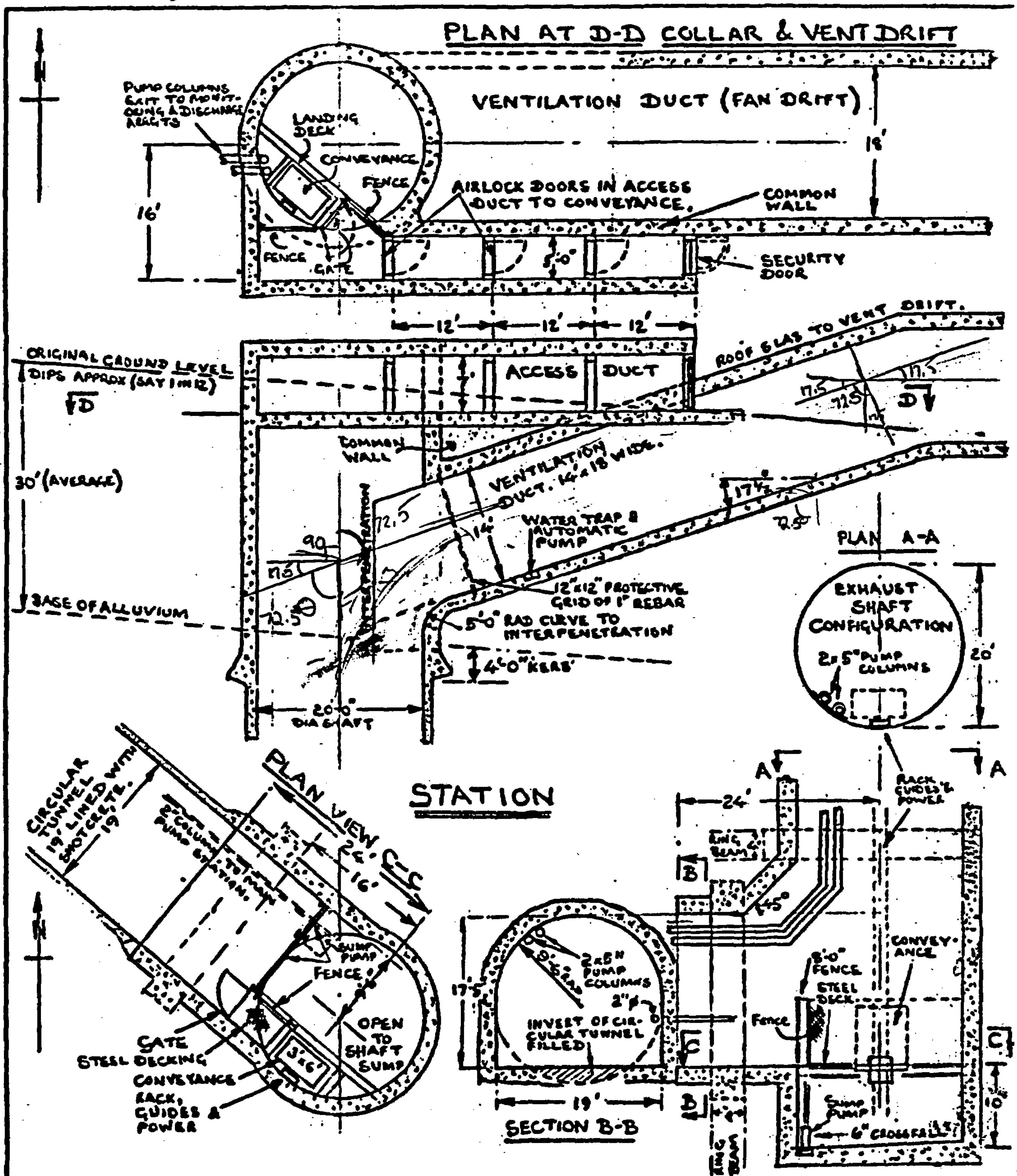
Date 2/26/85

Subject EMPLACEMENT EXHAUST SHAFT

Checked by

Ref. Dwgs.

Date 2 Apr 85



Combining the shock loss factors gives 2.2.
Employing equation (8.)(page 41) the resistance is:

$$R_{inlet} = \frac{62.21}{A^2} X = \frac{62.21}{(226.98)^2} * 2.2 = 0.00266 \text{ P.U.} \checkmark$$

Exit losses

Bend at surface, $\theta = 72.5^\circ$, radius of bend = 5'0"
using the following equation (Hartman, 1982)

$$X = \frac{0.25}{m^2 a^{0.5}} \left(\frac{\theta}{90}\right)^2 \quad 41$$

.67 .78

where $m = r/b$
$a = d/b$
b = airway width = 18 ft
d = airway height = 14 ft

hence

$m = 5/18 = 0.2778$
$a = 14/18 = 0.7778$
$\theta = 72.5^\circ$

14 x 18'

Therefore

$$X = \frac{0.25}{(0.2778)^2 (0.7778)^{1/2}} \left(\frac{72.5}{90}\right)^2 = 2.38 \checkmark$$

Added to this is the shock loss factor for the 1x1 ft rebar (1" thick or an area of 37.8 ft²) area ratio is $\frac{252-37.8}{252} = 0.85$ from table on next page $X = 0.2$
Total $X = 2.58$

$$R_{exit} = \frac{62.21}{(18 \times 14)^2} * 2.58 = 0.00253 \text{ (P.U.)}$$

Resistance of airway from shaft to fan:

$$R = \frac{K\, l\, per}{52 A^3} = \frac{30(50)(64)}{52(252)^3} = 0.00012 \checkmark \text{ (P.U.)}$$

$R_{exit} = R_{exit}' + R_1 = 0.00253 + 0.00012 = 0.00265$ (P.U.)

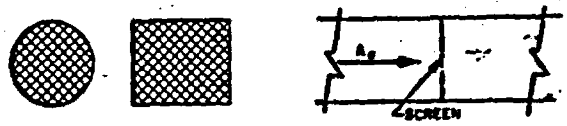
$R_T = R_{inlet} + R + R_{out} = 0.00266 + 0.001637 + 0.00265$ ✓

$R_T = 0.006947$ P.U. ✓

~~(Initial simulations used 0.006767 - error in calculation - this is a 3% error from value which should have been used - not considered to have a major impact on this level of design)~~

Resistance to Screens: (HVAC 1981 Fundamentals Handbook)

7-8 Obstruction, Screen in Duct, Round, and Rectangular



$n = A_{or}/A_o$

where

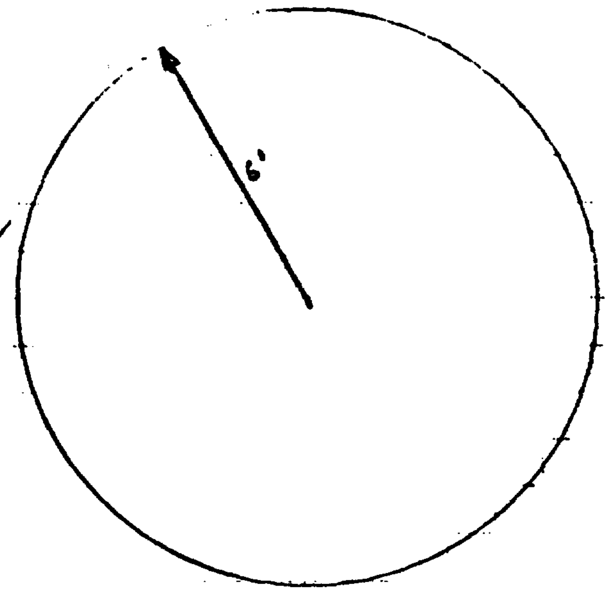
n = free area ratio of screen, dimensionless.
A_{or} = total flow area of screen, mm² (in.²).
A_o = area of duct, mm² (in.²).

n	0.30	0.40	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.0
X = C_o	6.2	3.0	1.7	1.3	0.97	0.75	0.58	0.44	0.32	0.14	0

Inner Dimensions

Area $= \pi r^2 = 113.1\ ft^2$

perimeter $= 2\pi r = 37.7\ ft$ ✓



PROCEDURE:

1) Calculate the resistance of the shaft using normal parameters.

2) Calculate the added resistance at the surface inlet.

Resistance of Shaft

From conversations with J. Grenia and R. Hang (conversation Memorandum 4/18/85) it is assumed that the Alimak conveyance system shown on the next couple of pages is no longer in the design. Therefore, the following parameters are assumed for the 12 ft shaft:

$k = 16\ lbf \cdot min^2/ft^4 \times 10^{10}$ (from Table on page 9) ✓

$l_{eq} = 0$

$A = 113.1\ ft^2$ } see above calculation

$per = 37.7\ ft$ }

$l = 1020\ ft$ (on page 51) ✓

Therefore $R_{shaft} = \dfrac{k(l+l_{eq})per}{52\ A^3} = \dfrac{16(1020)(37.7)}{52(113.1)^3} = \underline{\underline{0.008178\ P.U.}}$ ✓ (1)

COMPUTATION SHEET

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acility Design Contract No. 47-7368

ject EXPLORATORY SHAFT CONVERSION

f. Dwgs.

Page ~~50~~ 188 of ~~19~~

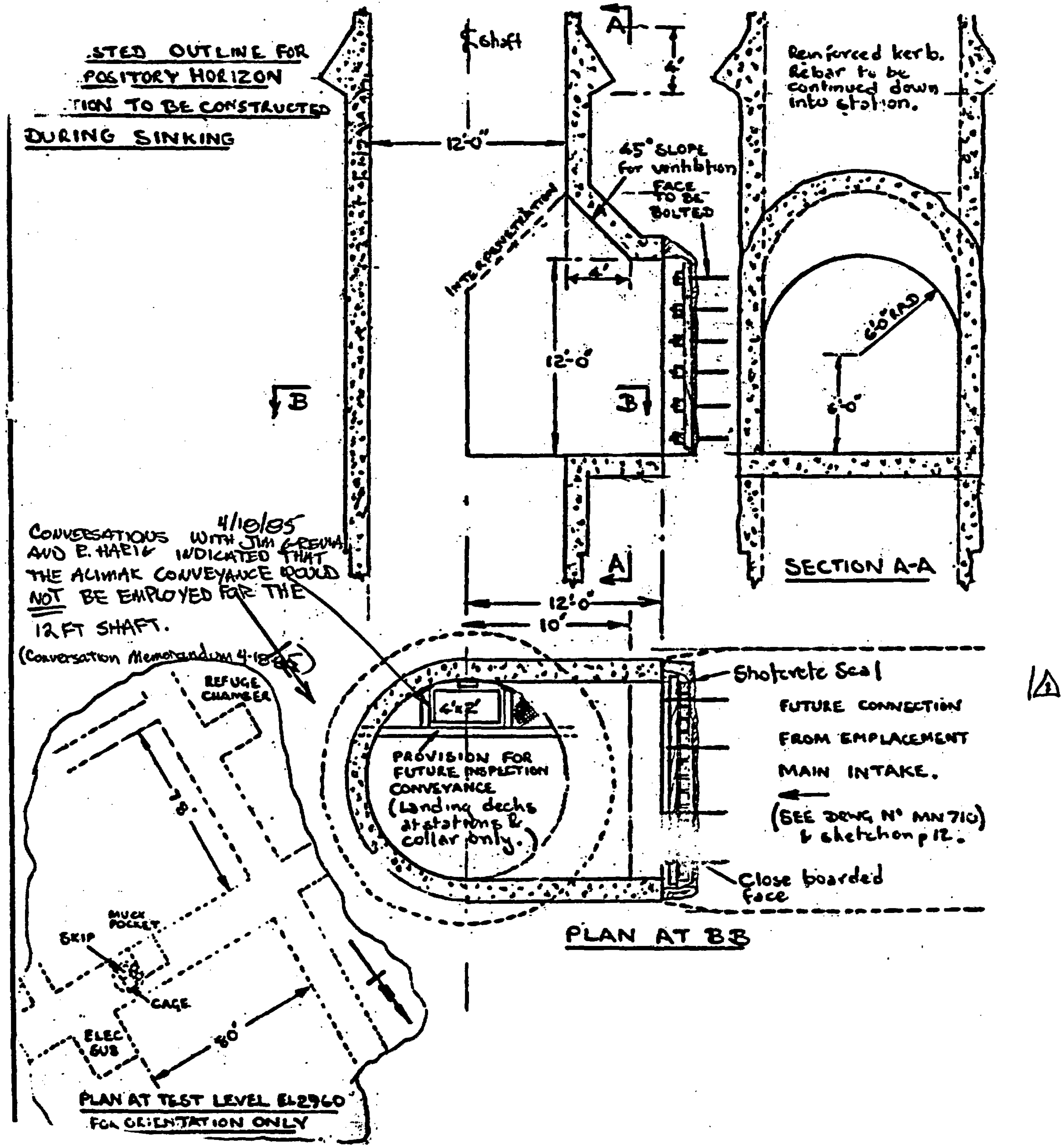
Job No. ~~3526~~

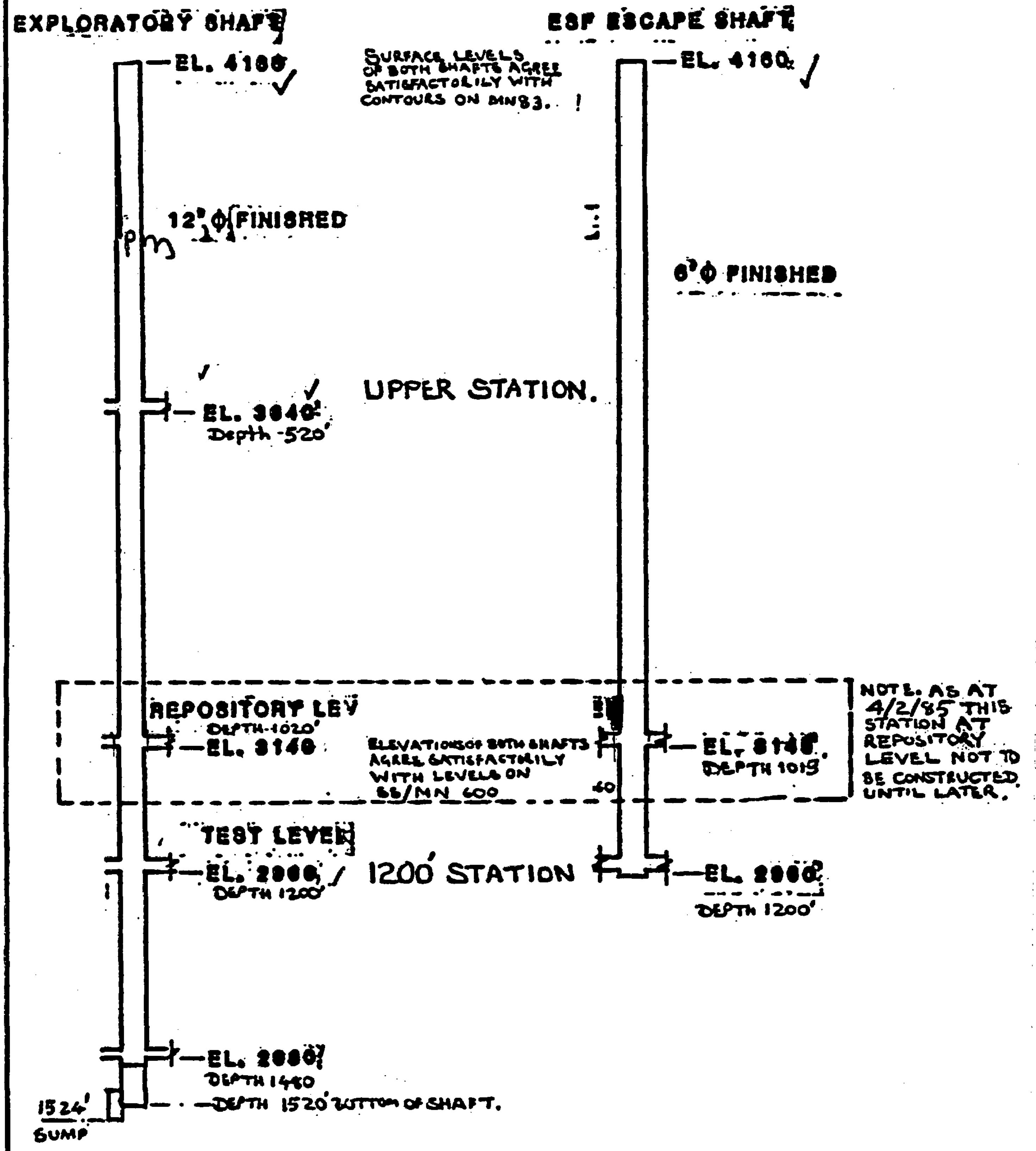
From Made by M. Grieves

Date 4/4/85

Checked by [illegible]

Date 5 Apr 85





EXPLORATORY SHAFT
ESF ESCAPE SHAFT
EL. 4186
SURFACE LEVELS OF BOTH SHAFTS AGREE SATISFACTORILY WITH CONTOURS ON MN83.
EL. 4160
12' Φ FINISHED
6' Φ FINISHED
UPPER STATION.
EL. 3640'
Depth -520'
REPOSITORY LEV
DEPTH 1020'
EL. 3140
ELEVATIONS OF BOTH SHAFTS AGREE SATISFACTORILY WITH LEVELS ON SS/MN 600
EL. 3145.
DEPTH 1015
NOTE. AS AT 4/2/85 THIS STATION AT REPOSITORY LEVEL NOT TO BE CONSTRUCTED UNTIL LATER.
TEST LEVEL
EL. 2960
DEPTH 1200'
1200' STATION
EL. 2960
DEPTH 1200'
EL. 2680
DEPTH 1480
1524' SUMP
DEPTH 1520' BOTTOM OF SHAFT.

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COMPUTATION SHEET

Entry Losses

From the design given on the next page entry losses for the 12 ft ES shaft is three fold:

a) Air entry losses
b) losses due to protective screens
c) right angle bend losses

a) Air entry losses: Using the following Table and assuming a square edged entry X_a is 0.34.

Table A-3c Coefficient of Inlet

Edge	z	C_i	X
Formed	1.05	0.975	0.0006
Round	1.50	0.785	0.05
Square	2.50	0.630	0.34

Source: McElroy, 1935.

b) Losses due to protective screens: From the Table on page 48 and the figure on the next page, the following calculation is performed.

Area of screen window 5 ft × 14 ft = 70 × 3 (3 windows) = 210 ft²

Area of metal on window (2" × 2" screen assumed to be 1/8" thick)
Therefore, per window there is
$[14 \times 12/2 \times 5 \div 1/8 \times 1/12] + [5 \times 12/2 \times 14 \times 1/8 \times 1/12] - [83 \times 29 \times (1/8 \times 1/12)^2] = 8.289\ ft^2$

or 24.87 ft² for all 3 windows

From Table

$$n = \frac{A_{or}}{A_o} = \frac{(210 - 24.87)}{210} = 0.882 \text{ and } X_b \simeq 0.16$$

$X_{Total} = X_a + X_b = 0.34 + 0.16 \quad 0.50$

Hence, the added resistance for (a) and (b) is (From equation (8.) page 41)

$$R_{WET} = \frac{62.21}{(210)^2} \times 0.50 = \underline{0.00071 \text{ (P.U.)}}$$

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COMPUTATION SHEET

Page ~~53~~ 158 ~~15~~ of ~~19~~

Job No. ~~3836~~

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NWRT

Subsurface Facility Design Contract No. 47-7368

FROM Made by M. Grieves

Date 4/4/85

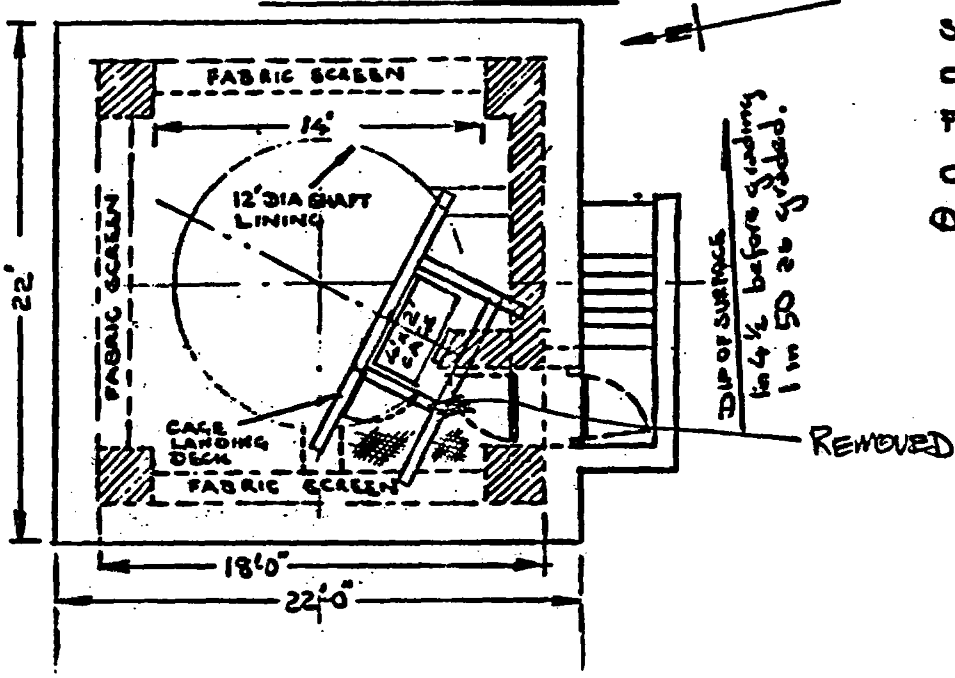
Checked by CGM

Date 5 Apr 85

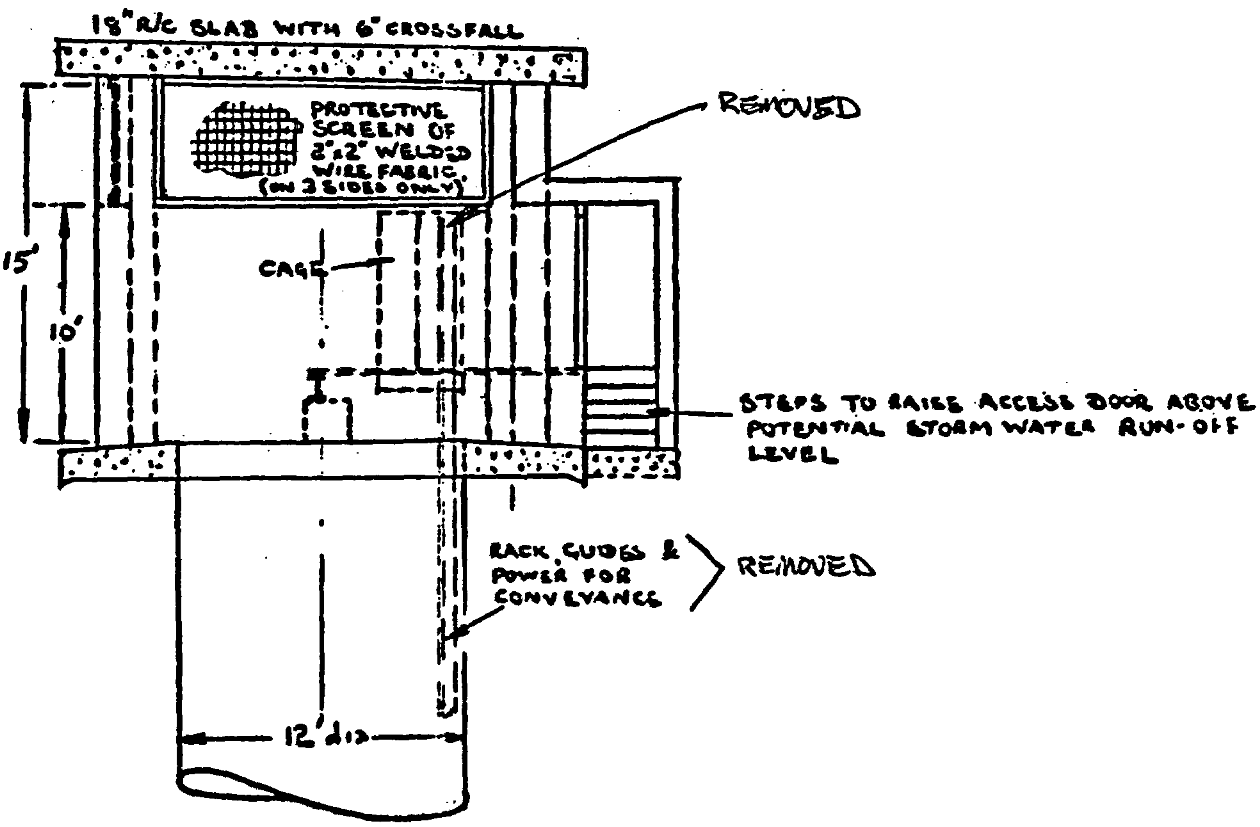
Subject EXPLORATORY SHAFT CONVERSION.

Ref. Dwgs.

PLAN AT COLLAR EL.



SKETCHES SHOWING COLLAR ARRANGEMENTS FOR 12'-0" SHAFT AT CONVERSION TO INTAKE DUTIES



SECTION

c) right angle bend loss (Equation (.7.) page 41)

$$X = \frac{0.60}{m\,a^{1/2}}\left(\frac{\theta}{90}\right)^2$$ where: $m = r/b$, $r = b/2$, b = airway width
$a = d/b$, d = airway height

Assuming the area of the window X is calculated to be:

$$X = \frac{0.60}{1/2\,(5/14)^{1/2}}\left(\frac{90}{90}\right)^2 = 2.01$$ ✓

Resistance for bend at one window (equation (8.) page 41)

$$R = \frac{62.21}{(70)^2} \cdot 2.01 = 0.02551$$ ✓

3 windows in parallel gives (eq'n (6.) page 13)

$$R_{angle} = \frac{0.0255}{n^2} \quad \frac{0.0255}{9} = \underline{0.00283 \text{ P.U.}}$$ ✓

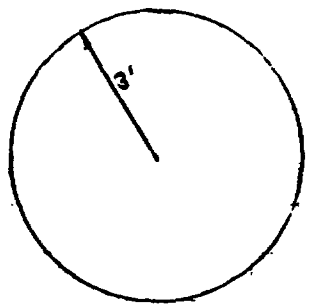
Total Shaft Resistance:

$$R = R_{sh} + R_{inlet} + R_{angle}$$

$$R = 0.008178 + 0.00071 + 0.00283 = \underline{0.01172 \text{ P.U.}}$$ ✓

Outlet losses at the repository level are accounted for in the outlet branch.

(Initial simulations used 0.01153 - error in calculation - This is a 1.6% error from value which should have been used - not considered relevant for this level of design)



Area = πr^2 = 28.27 ft^2 ✓
perimeter = $2\pi r$ = 18.85 ft ✓

Procedure:
Same as 12 ft shaft (page 49)

Resistance of Shaft

The following parameters are assumed for the six foot shaft

k = 16 lbf·min^2/ft^4 × 10^{10} (from Table on page 9) -
l_{eq} = 0 -
A = 28.27 ft^2 } see above calculation -
per = 18.85 ft } -
l = 1020 (from page –) -

Hence, using equation (.1.) the resistance is calculated to be.

$$R_{sh} = \frac{k(l+l_{eq})\,per}{52\,A^3} = \frac{16(1020)(18.85)}{52\,(28.27)^3} = 0.2618 \checkmark \text{P.U.}$$

Entry losses
The type of entry losses for the six foot diameter shaft are identical to the losses of the twelve foot diameter shaft. Hence following the same procedures gives:

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COMPUTATION SHEET

a) air entry losses (From Table on page 52) $X_a = 0.34$

b) losses due to protective screens: (see next page)

Area of screen window $= (2.5' \times 4.5') = 11.25\ ft^2 \times 4$ (4 windows)
$= 45\ ft^2$

Area of metal on window (assumed 2"x2" & 1/8" thick)

$= [(2.5 \times 6 - 1) + (4.5 \times 6 - 1) \times 2] \times 1/8 \times \frac{1}{12} - (4 \times 26 \times [\frac{.125}{12}]^2) = 1.294\ ft^2$

or $= 5.18\ ft^2$ for all 4 windows

Therefore, from table on page 48,

$$n = \frac{A_{or}}{A_o} = \frac{(45 - 5.18)}{45} = 0.885 \text{ and } X_b = 0.16$$

$$X_{TOTAL} = X_a + X_b = 0.34 + 0.16 = 0.50$$

$$R_{inlet} = \frac{62.21}{(45)^2} 0.50 = \underline{0.01536\ P.U.}$$ (from equation 8, page 41)

c) angle losses. (Equation (7.) page 41):

$$X = \frac{0.60}{m\, a'^{1/2}} \left(\frac{\theta}{90}\right)^2$$

Assuming the area of the windows X is calculated to be

$$X = \frac{0.60}{1/2 (4.5/2.5)^{1/2}} \left(\frac{90}{90}\right)^2 = 0.894$$

Resistance for a single bend is (from equation (8.) page 41).

$$R = \frac{62.21}{(11.25)^2} * 0.894 = 0.4394\ P.U.$$

Four windows in parallel gives

$$R_{angle} = \frac{0.4394}{n^2} = \frac{0.4394}{16} = \underline{0.0275\ P.U.}$$

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COMPUTATION SHEET

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Job No. ~~3836~~

Made by M Grieves

Date 4/4/85

Checked by CDm

Date 5 Apr 85

Parsons Brinckerhoff Quade & Douglas, Inc.

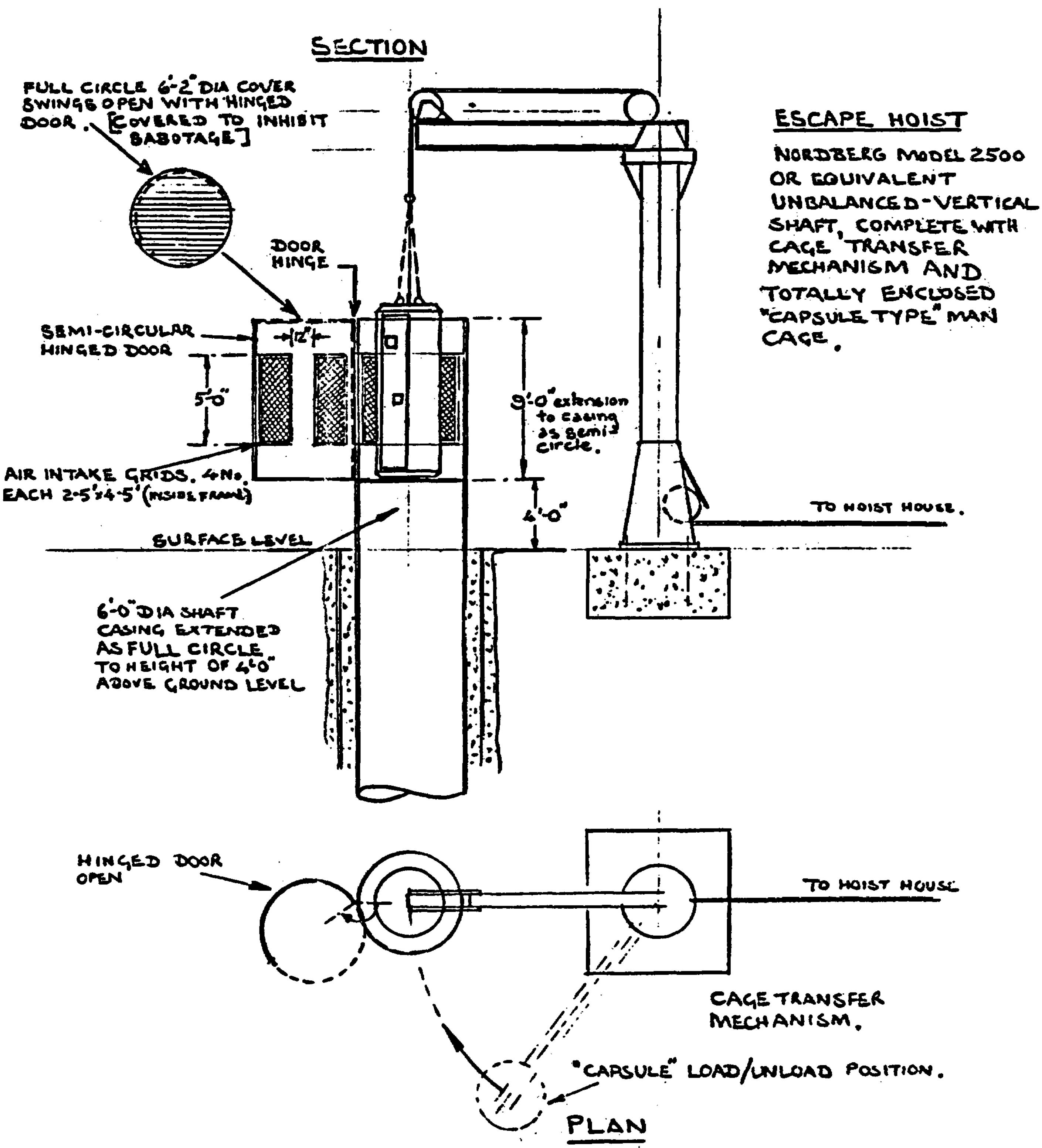
From

NWRT
Subsurface Facility Design Contract No. 47-7388

Subject EXPLORATORY SHAFT CONVERSION

Ref. Dwgs.

CONVERSION OF 6'-0" DIA E.S. TO EMPLACEMENT INTAKE DUTY



Total 6' shaft Resistance:

$$R = R_{sh} + R_{inter} + R_{angle}$$

$$= 0.2618 + 0.01536 + 0.0275 = \underline{0.3047}\ \underline{P.U.}$$

~~Initially simulations used 0.2944 error in calculation. This is a 3.40% error from the value which should have been used. Not considered relevant for this level of design.~~

Mine Ventilation Services, Inc.

JOB NO. 3696A161
SHEET 68 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
COMMINGLING DHLW – VENTILATION ANALYSIS
SHAFTS, RAMPS, & SURFACE CONNECTIONS

DESIGNED BY GK ROGERS DATE 4/1/86
CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HWD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
1	1	102	ES I	—	—	—	—	.00586	✓
2	102	106	ES I	—	—	—	—	.00586	✓
3	2	107	ES II	—	—	—	—	0.3047	✓
4	2	1	ES II SURFACE CONNECT.	—	—	—	—	0	✓
5	78	79	M&M SHAFT	—	—	—	—	.00895	✓
6	78	1	M&M SHAFT SURFACE CONNECTION	—	—	—	—	0	✓
7	60	59	TUFF RAMP	4797	12	164.64	4961.64	.02709	
8	59	1	TUFF RAMP SURFACE CONNECTION	—	—	—	—	0	
9	27	28	WASTE RAMP	6362	9	142.02	6504.02	.01971	
10	27	1	WASTE RAMP SURFACE CONNECTION	—	—	—	—	0	
11	4	3	WASTE EXHAUST shaft	—	—	—	—	.006947	✓
12	3	1	WASTE EXHAUST SURFACE CONNECT.	—	—	—	—	0	✓

DO NOT WRITE OUTSIDE BORDER

NOTE: THE VALUES FOR RESISTANCE-PER-FOOT AND HYDRAULIC MEAN DIAMETER FOR THE TUFF RAMP AND WASTE RAMP WERE INCORRECTLY TAKEN FROM THE HORIZONTAL EMPLACEMENT CALCULATION PACKAGE. THE CORRECT INPUT GIVES THE FOLLOWING RESULTS:

TUFF RAMP RESISTANCE (P.U.) = 0.00769 (INSTEAD OF 0.02709)
WASTE RAMP RESISTANCE (P.U.) = 0.01054 (INSTEAD OF 0.01971)

THE INCORRECT VALUES ARE THUS CONSERVATIVE, AND THEIR USE AT THIS STAGE IS CONSIDERED INSIGNIFICANT WITH RESULTS WITHIN THE ACCURACY LIMITS FOR THE STUDY.

Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 68 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT

COMMINGLING DHLW - VENT. ANALYSIS

DESIGNED BY GR ROGERS DATE 4/1/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
13	4	183	G	340	9	194.8	535	.00082	
14	4	5	G	640	9	194.8	835	.00129	
15	5	6	G	100	—	—	—	.00015	
16	6	7	G	685	—	—	—	.00105	
17	7	8	G	685	—	—	—	.00105	
18	8	9	G	85	—	—	—	.00013	
19	9	10	G	660	6	130	790	.00122	
20	10	11	G	660	—	—	—	.00102	
21	11	12	G	85	—	—	—	.00013	
22	12	13	G	700	—	—	—	.00108	
23	13	14	G	700	—	—	—	.00108	
24	14	15	G	90	—	—	—	200.000N	STOPPING
25	15	16	G	720	—	—	—	.00111	
26	16	17	G	720	—	—	—	5	BRATTICE
27	17	18	G	100	—	—	—	.0015	

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 69 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
COMMINGLING DHLW - VENT. ANALYSIS

DESIGNED BY GR ROGERS DATE 4/1/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
28	18	19	G	705	—	—	—	.00109 ✓	
29	19	20	G	705	—	—	—	.00109	
30	20	21	G	85	—	—	—	.00013 ✓	
31	21	22	G	670	—	—	—	.00103 ✓	
32	22	23	G	670	—	—	—	.00103 ✓	
33	23	24	G	90	—	—	—	.00014 ✓	
34	24	25	G	1130	2	43 ✓	1173	.00181 ✓	
35	25	26	G	750	—	—	—	.00115 ✓	
36	26	58	G	580	—	—	—	.00089 ✓	
37	28	29	B	530	—	—	—	.00059 ✓	
38	29	30	B	120	—	—	—	.00013 ✓	
39	30	31	B	95	—	—	—	.00011 ✓	
40	31	32	B	85	—	—	—	.0001 ✓	
41	32	33	B	140	—	—	—	.00016 ✓	

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Mine Ventilation Services, Inc.

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VERTICAL EMPLACEMENT
COMMINGLING DHLW - VENT. ANALYSIS

DESIGNED BY GR ROGERS DATE 4/1/86
CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HKD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
42	33	34	B	170	—	—	—	.00019 ✓	
43	34	35	B	150	—	—	—	.00017 ✓	
44	35	36	B	310	4	92	402	.00045 ✓	
45	36	37	B	250	5	115	365	.00041 ✓	
46	37	38	B	160	5	115	275	.00031 ✓	
47	38	39	B	85	—	—	—	.0001 ✓	
48	39	40	B	640	—	—	—	.00072 ✓	
49	40	41	B	640	—	—	—	.00072 ✓	
50	41	42	B	85	—	—	—	.0001 ✓	
51	42	43	B	660	—	—	—	.00074 ✓	
52	43	44	B	660	—	—	—	.00074 ✓	
53	44	45	B	85	—	—	—	.0001 ✓	
54	45	46	B	660	—	—	—	.00074 ✓	
55	46	47	B	660	—	—	—	.00074 ✓	
56	47	48	B	85	—	—	—	200. ✓	STOPPING

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DESIGNED BY G.K. ROGERS DATE 4/1/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HXD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
57	48	49	B	660	5	115	775	.00087	✓
58	49	50	B	660	—	—	—	.00074	✓
59	50	51	B	85	—	—	—	.0001	✓
60	51	52	B	660	5	115	775	.00087	
61	52	53	B	660	8	183	843	.00094	✓
62	53	54	B	85	8	183	268	.0003	✓
63	54	55	B	660	—	—	—	.00074	✓
64	55	56	B	660	5	115	775	.00087	✓
65	56	57	B	85	—	—	—	25.000095	✓ DOOR
66	58	57	B	580	—	—	—	.00065	✓ FIX Q @ 51 REG.
67	61	29	I	65	—	—	—	25	DOOR ✓
68	62	30	I	65	—	—	—	200	STOPPING ✓
69	63	32	I	65	—	—	—	25	DOOR ✓
70	64	38	I	65	—	—	—	200	STOPPING ✓

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HND'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
71	66	42	I	65	—	—	—	200.	STOPPING ✓
72	68	45	I	65	—	—	—	200.	STOPPING ✓
73	48	70	III	65	5	79	144	.00087 ✓	
74	51	72	H	65	5	58	123	.00121 ✓	
75	54	74	H	65	4	47	112	.00109 ✓	
76	56	76	H	65	4	47	112	.00109 ✓	
77	77	58	G	65	—	—	—	.0001 ✓	
78	60	61	D	440	—	—	—	.00082 ✓	
79	61	62	D	350	—	—	—	.00065 ✓	
80	62	63	D	180	—	—	—	.00033 ✓	
81	63	196	D	590	—	—	—	.0011 ✓	
82	196	64	D	590	—	—	—	.0011 ✓	
83	64	288	D	725	—	—	—	.00135 ✓	
84	65	66	D	85	—	—	—	.00016 ✓	

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER: REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
85	66	67	D	660	—	—	—	.00123	✓
86	67	68	D	745	—	—	—	.00139	✓
87	68	69	D	660	—	—	-	.00123	✓
88	69	70	D	745	3	52	797	.00148	✓
89	70	71	D	660	—	—	—	.00123	✓
90	71	72	D	745	3	52	797	.00148	✓
91	72	73	D	660	—	—	—	.00123	✓
92	73	74	D	745	5	86	831	.00155	✓
93	74	75	D	660	—	—	—	.00123	✓
94	75	76	D	660	5	86	746	.00139	✓
95	76	77	E	650	—	—	—	200.	✓ STOPPING
96	79	60	—	—	—			.001	✓ FIX Q @ 50 REG.
97	79	61	I	65	—	—	—	25	✓ DOOR
98	80	62	I	65	—	—	—	200	✓ STOPPING

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99	81	63	I	65	—	—	—	25.	DOOR
100	197	196	I	65	—	—	—	50	2 IN // STOPPING
101	82	64	I	65	—	—	—	200.	STOPPING
102	85	65	I	65	—	—	—	200.	STOPPING
103	86	66	I	65	—	—	—	200	STOPPING
104	87	67	I	65	—	—	—	200	STOPPING
105	89	68	I	65	—	—	—	200	STOPPING
106	90	69	I	65	—	—	—	200	STOPPING
107	92	70	I	65	—	—	—	200	STOPPING
108	93	71	I	65	—	—	—	200	STOPPING
109	95	72	I	65	—	—	—	200	STOPPING
110	96	73	I	65	—	—	—	200	STOPPING
111	98	74	I	65	—	—	—	200	STOPPING
112	99	75	I	65	—	—	—	200	STOPPING
113	100	76	I	65	—	—	—	200	STOPPING

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114	101	77	G	65	10	216	281	.00043	✓
115	79	198	F	265	15	265	530	.00176	✓
116	198	80	F	85	—	—	—	.00028	✓
117	80	81	F	180	—	—	—	.0006	✓
118	81	197	F	500	—	—	—	.00166	✓
119	197	82	F	680	—	—	—	.00226	✓
120	82	83	F	85	—	—	—	.00028	✓
121	83	84	F	640	—	—	—	.00212	✓
122	84	85	F	640	—	—	—	.00212	✓
123	85	86	F	85	—	—	—	.00028	✓
124	86	87	F	660	—	—	—	.00219	✓
125	87	88	F	660	—	—	—	.00219	✓
126	88	89	F	85	—	—	—	.00028	✓
127	89	90	F	660	—	—	—	.00219	✓

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HND'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
128	90	91	F	660	—	—	—	.00219	✓
129	91	92	↓	85	—	—	—	.00028	✓
130	92	93		660	—	—	—	.00219	✓
131	93	94		660	—	—	—	.00219	✓
132	94	95		85	—	—	—	.00028	✓
133	95	96		660	—	—	—	.00219	
134	96	97		660	—	—	—	.00219	✓
135	97	98		85	—	—	—	.00028	✓
136	98	99		660	—	—	—	.00219	✓
137	99	100		660	—	—	—	.00219	✓
138	100	199		85	—	—	—	.00028	✓
139	199	101	F	630	—	—	—	.00209	✓
140	28	114	G	470	—	—	—	25	✓ DOOR
141	114	132	G	210	5	108	318	.00049	✓

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
142	132	147	G	850	–	–	–	.00131	✓
143	147	161	G	210	–	–	–	.00032	✓
144	161	174	G	480	–	–	–	.00074	✓
145	174	175	G	100	–	–	–	.00015	✓
146	175	183	G	670	–	–	–	.00103	✓
147	183	5	G	750	–	–	–	.00115	✓
148	29	115	SHOPS	455	–	–	–	.001 ✓	FIX @ 70 REG
149	103	116	↓	–	–	–	–	.001 –	FIX @ 25
150	104	117	↓	–	–	–	–	.001 –	FIX @ 30
151	117	116	J	150	10	143	293	.00322	✓
152	116	115	J	525	10	143 ✓	668	.00735	✓
153	115	114	J	420	5	72	492	.00541	✓
154	33	103	J	85	–	–	–	25	✓ DOOR

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HND'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
155	34	104		85	—	—	—	25 ✓	Door
156	104	103 *	J	150	—	—	—	.00165	✓
			ESF						✓
157	118	119	J	370	2	28.6	398.6	.00438	✓
158	119	120		190	2	28.6	218.6	.00240	✓
159	120	121		160	2	—	—	25 ✓	DOOR
160	106	105		370	7	100.1	470.1	.00517	✓
161	106	107		190	7	100.1	290.1	.00319	✓
162	107	108		160	2	28.6	188.6	25 .00207	✓ Door
163	118	105		235	6	85.8	320.8	.00353	✓
164	105	35		170	2	28.6	198.6	.00218	✓
165	119	106		235	2	28.6	263.6	.00290	✓
166	106	36		170	7	100.1	270.1	.00297	✓
167	120	107		155	2	28.6	183.6	.00202	✓
168	107	37	J	170	2	28.6	198.6	.00218	✓

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HHD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
169	105	104	J	120	2	28.6	148.6	.00163	ESF
171	31	133	I	650	–	–	–	.00394	FIX @ 15 Rec.
170	133	148	I	840	–	–	–	.00509	
172	148	174	I	500	–	–	–	25	Door
173	32	134	I	650		–	–	25	Door
174	134	149	I	840	–	–	–	.00509	
175	149	175	I	560	–	–	–	25	Door
176	135	162	J	840	–	–	–	.00924	
177	162	183	J	930	–	–	–	.01023	
178	38	108	I	170	–	–	–	.00103	
179	108	121	I	155	–	–	–	.00094	
180	121	136	I	120	–	–	–	25	Door
181	136	176	I	1100	–	–	–	.00667	
182	176	5	I	1100	–	–	–	.00667	

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BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HKD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
183	39	163	I	1445	—	—	—	25	DOOR
184	163	6	I	1445	—	—	—	.00876	
185	40	164	J	1620	—	—	—	200	
186	164	7	J	1620	—	—	—	.01782	
187	41	165	I	1620	—	—	—	25	
188	165	8	I	1620	—	—	—	.00982	
189	42	122	I	340	5	79	419	.00254	
190	122	137	I	430	—	—	—	.00261	
191	137	150	I	430	—	—	—	.00261	
192	150	166	I	430	—	—	—	.00261	
193	166	177	I	490	—	—	—	.00297	
194	177	184	J	590	—	—	—	.00358	
195	184	189	I	360	—	—	—	.00218	
196	189	192	I	140	—	—	—	.00085	
197	192	9	I	30	—	—	—	25	

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HWD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
198	43	123	J	340	—	—	—	.200 ✓	
199	123	138	J	430	—	—	—	.00473 ✓	
200	138	151	J	430	—	—	—	.00473 ✓	
201	151	167	J	430	—	—	—	.00473 ✓	
202	167	178	J	490	—	—	—	.00539 ✓	
203	178	185	J	590	—	—	—	.00649 ✓	
204	185	190	J	360	—	—	—	.00396 ✓	
205	190	193	J	140	5	72	212	.00233 ✓	
206	193	10	J	30	5	72	102	.00112 ✓	
207	44	124	I	340	5	79	419	.00254 ✓	
208	124	139	I	430	—	—	—	.00261 ✓	
209	139	152	I	430	—	—	—	.00261 ✓	
210	152	168	I	430	—	—	—	.00261 ✓	
211	168	179	I	490	—	—	—	.00297 ✓	
212	179	186	I	590	—	—	—	.00354 ✓	

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
213	186	191	I	360	–	–	–	.00218	
214	191	194	I	140	–	–	–	.00085	
215	194	11	I	30	–	–	–	25	
216	45	153	I	1610	–	–	–	25 .00976	
217	153	12	I	1610	–	–	–	.00976	
218	46	154	J	1510	–	–	–	200	
219	154	13	J	1510	–	–	–	.01661	
220	47	155	I	1380	–	–	–	25 .00836	
221	155	14	I	1380	–	–	–	.00836	
222	48	109	I	200	–	–	–	25	
223	109	125	I	140	–	–	–	.00085	
224	125	140	I	280	–	–	–	.0017	
225	140	156	I	500	–	–	–	.00303	
226	156	169	I	500	–	–	–	.00303	
227	169	180	I	565	–	–	–	.00342	

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228	180	187	I	210	–	–	–	.00127	
229	187	15	I	290	–	–	–	.00176	
230	49	110	J	200	3	43	243	.00267	
231	110	126	J	140	3	43	183	.00201	
232	126	141	J	280	–	–	–	.00308	
233	141	157	J	500	–	–	–	.00550	
234	157	170	J	500	–	–	–	.00550	
235	170	181	J	565	–	–	–	.00622	
236	181	188	J	190	–	–	–	.00209	
237	188	16	J	60	–	–	–	.00066	
238	50	111	I	200	–	–	–	25	DOOR
239	111	127	I	140	–	–	–	.00085	
240	127	142	I	280	–	–	–	.0017	
241	142	158	I	500	–	–	–	.00303	
242	158	171	I	500	–	–	–	.00303	

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243	171	182	I	370	-	-	-	00224	
244	182	17	I	100	3	47	147	.00089	
245	51	112	H	200	3	35	235	0023	
246	112	128	H	140	3	35	175	.00171	
247	128	143	I	280	-	-	-	.0017	
248	143	159	I	420	-	-	-	.00255	
249	159	172	I	500	-	-	-	.00303	
250	172	18	I	500	-	-	-	25	DOOR
251	52	113	J	200	-	-	-	25	Door
252	113	129	J	140	-	-	-	.00154	
253	129	144	J	280	-	-	-	.00308	
254	144	160	J	420	-	-	-	00462	
255	160	173	J	500	-	-	-	0055	
256	173	19	J	150	5	72	222	.00224	

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BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER: REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
257	53	145	I	775	—	—	—	.0047	
258	145	20	I	780	5	79	859	.00521	
259	54	146	H	775	—	—	—	.00759	
260	146	21	I	770	5	79	849	.00575	
261	56	130	H	450	3	35	485	.00475	
262	57	131	I	450	3	47	497	.00301	
263	132	133	K	595	—	—	-	25.00191	DOOR
264	147	148	K	370	—			0.6944	DOORS 6 IN 11 25/36
265	133	134	I	85	—	—	—	200	
266	148	149	I	85	—	—	—	200	
267	134	135	K	590	-	—	—	25	
268	135	136	K	590	—	—	—	25	
269	149	162	K	590	—	—	—	0.3925	8 IN 11 .3906 25/64
270	176	162	K	590	—	—	—	0.2084	11 IN 11 25/121

— RESISTANCE FOR 176-162 SHOULD BE 0.2066
— INSIGNIFICANT ERROR

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Mine Ventilation Services, Inc.

JOB NO. 3696A161
SHEET 86 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
COMMINGLING DHLW

DESIGNED BY ER ROGERS DATE 4/1/86
CHECKED BY D. Bruner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
271	136	163	I	85	—	—	—	200	
272	176	163	I	85	—	—	—	22.2222	3 IN // 200/9
						RESISTANCE	SHOULD BE 0.0567	— INSIGNIFICANT ERROR	
273	163	164	K	640	—	—	—	.0588	21 IN // 25/441
						RESISTANCE	SHOULD	BE 0.0517	— INSIGNIFICANT ERROR
274	165	164	K	640	—	—	—	.0538	22 IN // 25/484
275	165	122	I	85	—	—	—	200	
276	165	166	I	85	—	—	—	50	2 IN // 200/4
277	165	189	I	85	—	—	—	50	2 IN // 200/4
278	122	123	K	660	—	—	—	2.7778	3 IN // 25/9
279	124	123	K	660	—	—	—	2.7778	3 IN // 25/9
280	137	138	K	660	—	—	—	2.7778	3 IN // 25/9
281	139	138	K	660	—	—	—	2.7778	3 IN // 25/9
282	150	151	K	660	—	—	—	2.7778	3 IN // 25/9
283	152	151	K	660	—	—	—	2.7778	3 IN // 25/9
284	166	167	K	660	—	—	—	2.7778	3 IN // 25/9
285	168	167	K	660	—	—	—	2.7778	3 IN // 25/9

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 87 OF 737

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
COMMINGLING DALW

DESIGNED BY GR ROGERS DATE 4/1/86
CHECKED BY D Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HHD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
						RESISTANCE SHOULD BE 1.5625			INSIGNIFICANT ERROR 25/16
286	177	178	K	660	—			1.5646	4 IN 11
						RESISTANCE SHOULD BE 1.5625			INSIGNIFICANT ERROR 25/16
287	179	178	K	660	—			1.5646	4 IN 11
						RESISTANCE SHOULD BE 1.5625			INSIGNIFICANT ERROR 25/16
288	184	185	K	660	—			1.5646	4 IN 11
						RESISTANCE SHOULD BE 1.5625			INSIGNIFICANT ERROR 25/16
289	186	185	K	660	—			1.5646	4 IN 11
						RESISTANCE SHOULD BE 0.00241			INSIGNIFICANT ERROR FIX @ 45
290	189	190	K	660	5	90	750	.00328	REG
						RESISTANCE SHOULD BE 0.00241			INSIGNIFICANT ERROR FIX @ 45
291	191	190	K	660	5	90	750	.00328	REG
						RESISTANCE SHOULD BE 0.00241			INSIGNIFICANT ERROR FIX @ 45
292	192	193	K	660	5	90	750	.00328	
						RESISTANCE SHOULD BE 0.00241			INSIGNIFICANT ERROR FIX @ 45
293	194	193	K	660	5	90	750	.00328	
294	124	153	I	85	—	—	—	200	✓
295	168	153	I	85	—	—	—	50	2 IN 11 ✓
296	191	153	I	85	—	—	—	50	2 IN 11
						RESISTANCE SHOULD BE 0.0567			INSIGNIFICANT ERROR 25/441
297	153	154	K	660	—	—	—	.0588	21 IN 11
						RESISTANCE SHOULD BE 0.0693			INSIGNIFICANT ERROR 25/361
298	155	154	K	660	—	—	—	.0714	19 IN 11
299	155	125	I	85	—	—	—	50	2 IN 11 ✓
300	155	156	I	85	—	—	—	200	✓

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 88 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT

COMMINGLING DHLW

DESIGNED BY GR ROGERS DATE 4/1/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HHD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
301	155	180	I	85	—	—	—	50	STOPPINGS 200/4 2 IN //
302	109	110	K	660	—	—	—	25	DOOR
303	111	110	K	660	3	54	714	.00229	OPEN
304	125	126	K	660	—	—	—	25	DOOR
305	127	126	K	660	3	54	714	.00229	OPEN
306	140	141	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
307	142	141	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
308	156	157	K	660	—	—	—	1.5625	DOORS 25/16 4 IN //
309	158	157	K	660	—	—	—	1.5625	DOORS 25/16 4 IN //
310	169	170	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
311	171	170	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
312	180	181	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
313	182	181	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
314	187	188	K	660	—	—	—	6.25	DOORS 25/4 2 IN //

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

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FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT

COMMINGLING DHLW

DESIGNED BY GR ROGERS DATE 4/1/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
315	127	128	I	85	—	—	—	50	STOPPINGS 200/4 2 IN //
316	171	172	I	85	—	—	—	50	STOPPINGS 200/4 2 IN //
317	112	113	K	660	5	90	750	.00241	OPEN
318	128	129	K	660	5	90	750	.00241	OPEN
319	143	144	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
320	159	160	K	660	—	—	—	2.7778	DOORS 25/9 3 IN //
321	172	173	K	660	—	—	—	1.5625	DOORS 25/16 4 IN //
322	145	146	I	85	—	—	—	.00013	OPEN .00052/4 2 IN //
323	131	130	I	85	4	63	148	.0009	OPEN
324	288	65	D	640	—	—	—	.00119	
325	84	288	I	65	—	—	—	200	

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Parsons Brinckerhoff

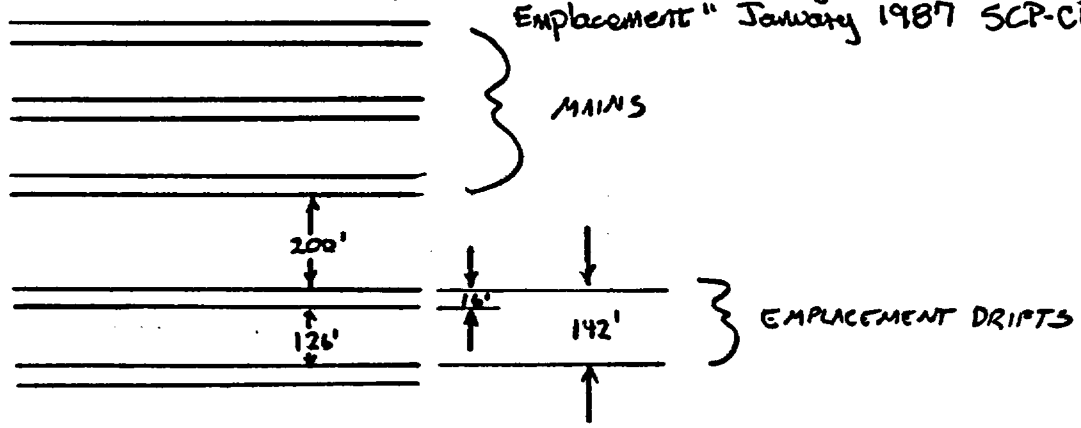
Parsons Brinckerhoff Quade & Douglas, Inc.
Engineers • Architects • Planners

COMPUTATION SHEET

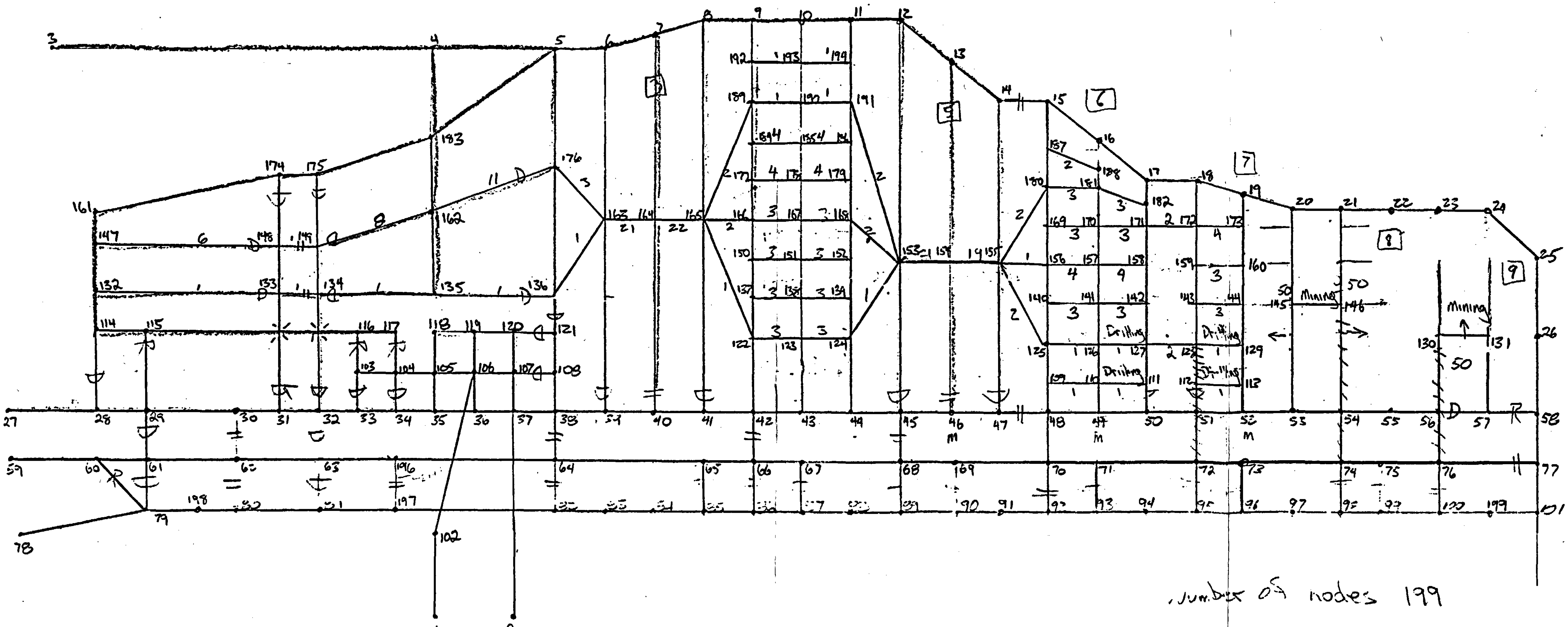
Job No. 3696 A 161
Made by GR ROGERS
Date 3/26/86
Checked by D. Brunner
Date 5/9/86

Subject VERTICAL EMPLACEMENT

NO. OF EMPLACEMENT ROOMS IN FULL MODEL (AS WELL AS 10YR DEV. MODEL)
(MEASUREMENTS TAKEN FROM HORIZONTAL EMPLACEMENT ~~SCHEMATIC~~ Sketch) Sketch since verified by drawing R07002 Rev. 0 "Nuclear Waste Repository in Tuff Subsurface Facility Conceptual Design Underground Facility Layout Commingled Waste Vertical Emplacement" January 1987 SCP-CDR. △1



DISTANCE FROM MAINS TO REPOSITORY BOUNDARY	DISTANCE MINUS 200' BUFFER	No. OF ROOMS ALLOWABLE (DIVIDE BY 142')	(ROUND UP)	PANEL
3100	2900	20.4	21	3A
3250	3050	21.48	22	3B
3250	3050	21.48	22	4A & B
3130	2930	20.6	21	5A
2870	2670	18.8	19	5B
2600	2400	16.9	17	6A
2300	2100	14.79	15	6B
1880	1680	11.83	12	7A
1620	1420	10	10	7B
1530	1330	9.37	10	8A
1650	1450	10.21	11	8B
1900	1700	11.97	12	9
500	300	2.11	3	10
1670	1470	10.35	11	11A
1100	900	6.33	7	11B
2440	2240	15.77	16	12A
2170	1970	13.87	14	12B
2860	2660	18.7	19	13A
2650	2450	17.2	18	13B
3490	3290	23.17	24	14A
3160	2960	20.8	21	14B
3740	3540	24.93	25	15-18 A&B



number of nodes 199

Vertical Emplacement - Development System Schematic
INITIAL INPUT

REDIRECTION ON 4/7/86 DUE TO A DRAFTING ERROR ON A P.B. DRAWING. NOTE: THE 126' DISTANCE SHOWN BETWEEN EMPLACEMENT ROOMS IS ACTUALLY A CENTER TO CENTER DISTANCE. THE NUMBER OF ROOMS PER PANEL ARE RECALCULATED BELOW.

142/126 = 1.1269841 (MULTIPLIER)

PANEL	ROOMS (USING 142') ACTUAL	(ROUNDED)	ROOMS (USING 126') ACTUAL	(ROUNDED)
3A	20.4	(21)	22.99	(23)
3B	21.48	(22)	24.2	(24)
4A	21.48	(22)	24.2	(24)
4B	21.48	(22)	24.2	(24)
5A	20.6	(21)	23.22	(24)
5B	18.8	(19)	21.19	(22)
6A	16.9	(17)	19.05	(20)
6B	14.79	(15)	16.67	(17)
7A	11.83	(12)	13.38^3	(14)
7B	10	(10)	11.27	(12)
8A	9.37	(10)	10.56	(11)
8B	10.21	(11)	11.51	(12)
9	11.97	(12)	13.49	(13)
10	2.11	(3)	2.38	([illegible])
11A	10.35	(11)	11.66	(12)
11B	6.33	(7)	7.13	(8)
12A	15.77	(16)	17.77	(18)
12B	13.87	(14)	15.6	(16)
13A	18.7	(19)	21.07	(22)
13B	17.2	(18)	19.38	(20)
14A	23.17	(24)	26.11	(27)
14B	20.8	(21)	23.44	(24)
15-17 (A+B)	24.93	(25)	28.09	(28)
18	22.0	(22)	24.79	(25)

NOTE: DURING THE VERTICAL EMPLACEMENT MODEL MODIFICATIONS TO VTUFF1 & VTUFF2 ON RE-DIRECTION FROM PB (DRAFTING ERROR) A CHANGE IN THE ES FACILITY LAYOUT & DIMENSIONS WAS NOTICED IN THE DRAWINGS. THE VNETPL (VER. 1.1) FILES VTUFF1 & VTUFF2 WERE ASSEMBLED WITH THE AID OF A DRAWING LABELED GENERAL UNDERGROUND FACILITY LAYOUT DATED MARCH 7, 1986. THE NUMBER OF NODE CONNECTIONS TO THE WASTE MAIN, SHOP, AND PANEL ACCESS DRIFT REMAIN THE SAME, REGARDLESS OF THE DRAWING USED. AN UPDATE OF THE ES FACILITY WAS NOT CONSIDERED NECESSARY DUE TO ~~AN~~ INSIGNIFICANT IMPACT.

Mine Ventilation Services, Inc.

JOB NO. 3696A161
SHEET 94 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
EMPLACEMENT ROOMS

DESIGNED BY GR ROGERS DATE 4/8/86
CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
273	163	164	K PANEL (3A)	640	—	—	—	0.04725	25/(23)² DOORS 23 IN //
274	164	165	K (3B)	640	—	—	—	0.0434	DOORS 24 IN //
284	166	167	K (4A)	660	—	—	—	1.5625	DOORS 4 IN //
282	150	151	K (4A)	660	—	—	—	1.5625	DOORS 4 IN //
285	167	168	K (4B)	660	—	—	—	1.5625	DOORS 4 IN //
283	151	152	K (4B)	660	—	—	—	1.5625	DOORS 4 IN //
297	153	154	K (5A)	660	—	—	—	0.04725	DOORS 23 IN //
298	154	155	K 5B	660	—	—	—	0.05668	DOORS 21 IN //
	(ROOMS NEAR		ES FACILITY)						
264	147	148	K	~510	—	—	~510	0.5102	DOORS 7 IN //
269	149	162	K	~570	—	—	~570	0.25	DOORS 10 IN //
270	162	176	K	~570	—	—	~570	0.1479	DOORS 13 IN //

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 95 OF 737

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFFI ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
EMPLACEMENT ROOMS

DESIGNED BY R ROGERS DATE 4/9/86

CHECKED BY D. Brown DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HND'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
314	187	188	K	660	—	—	660	2.7778	$25/(3)^2$ DOORS 3 in //
312	180	181	K	660	—	—	660	1.5625	DOORS 4 in //
310	169	170	K	660	—	—	660	1.5625	DOORS 4 in //
313	181	182	K	660	—	—	660	1.5625	DOORS 4 in //
311	170	171	K	660	—	—	660	1.5625	DOORS 4 in //
320	159	160	K	660	—	—	660	1.5625	DOORS 4 in //
319	143	144	K	660	—	—	660	1.5625	DOORS 4 in //

C-102

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 96 OF 137

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT MODIFICATIONS TO VTUFF1 ON RE-DIRECTION FROM 16 (DRAFTING ERROR)

DESIGNED BY GR ROGERS DATE 4/8/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
(CROSSCUTS	(PANEL ACCESS DRIFTS	(F) w/o BULT)							$200/(4)^2$
272	176	163	I	85	—	—	—	12.5	STOPPING 4 IN //
275	165	122	I	85	—	—	—	50	STOPPING 2 IN //
294	124	153	I	85	—	—	—	50	STOPPING 2 IN //
271	~~136~~ 121	163	I	85	—	—	—	200	STOPPING
322	145	146	I	85	—	—	85	.0000572	$R/(3)^2 = 0.0005151/9$ OPEN 3 IN //

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 97 OF 737

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
REDIRECTION FROM PB (DRAFTING ERROR)
PANEL ACCESS & MID-PANEL DRIFTS

DESIGNED BY CR ROGERS DATE 4/8/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HND'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
181	136	176	I	940	–	–	940	.00570	
182	176	5	I	940	–	–	940	.00570	
189	42	122	I	326	5	79.15	405.15	.00246	
190	122	137	I	378	–	–	378	.00229	
191	137	150	I	441	–	–	441	.00267	
192	150	166	I	504	–	–	504	.00305	
193	166	177	I	504	–	–	504	.00305	
194	177	184	I	504	–	–	504	.00305	
195	184	189	I	315	–	–	315	.00191	
196	189	192	I	126	–	–	126	.00076	
197	192	9	I	142	–	–	142	25	DOOR
198	43	123	J	326	–	–	326	200	STOPPING
199	123	138	J	378	–	–	378	.00416	
200	138	151	J	441	–	–	441	.00485	
201	151	167	J	504	–	–	504	.00554	

Mine Ventilation Services, Inc.

JOB NO. 3696A161

SHEET 98 OF 737

FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
PANEL ACCESS & MID-PANEL DRIFTS

DESIGNED BY GR ROGERS DATE 4/8/86

CHECKED BY D Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER: REFERENCE	ACTUAL LENGTH (FT)	NO. OF HWD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
202	167	178	J	504	—	—	504	.00554	
203	178	185	J	504	—	—	504	.00554	
204	185	190	J	315	—	—	315	.00347	
205	190	193	J	126	5	71.5	197.5	.00217	
206	193	10	J	142	5	71.5	213.5	.00235	
207	44	124	I	326	5	79.15	405.15	.00246	
208	124	139	I	378	—	—	378	.00229	
209	139	152	I	441	—	—	441	.00267	
210	152	168	I	504	—	—	504	.00305	
211	168	179	I	504	—	—	504	.00305	
212	179	186	I	504	—	—	504	.00305	
213	186	191	I	315	—	—	315	.00191	
214	191	194	I	126	—	—	126	.00076	
215	194	11	I	142	—	—	142	25	DOOR

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

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FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
PANEL ACCESS & MID-PANEL DRIFTS

DESIGNED BY GR ROGERS DATE 4/8/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
222	48	109	I	200	–	–	200	.00121	
223	109	125	I	126	–	–	126	.00076	
224	125	140	I	252	–	–	252	.00153	
225	140	156	I	441	–	–	441	.00267	
226	156	169	I	504	–	–	504	.00305	
227	169	180	I	504	–	–	504	.00305	
228	180	187	I	441	–	–	441	.00267	
229	187	15	I	257	3	47.49	304.49	.00185	
230	49	110	J	200	3	42.9	242.9	.00267	
231	110	126	J	126	3	42.9	168.9	.00186	
232	126	141	J	252	3	42.9	294.9	.00324	
233	141	157	J	441	–	–	441	.00485	
234	157	170	J	504	–	–	504	.00554	
235	170	181	J	504	–	–	504	.00554	
236	181	188	J	415	–	–	415	.00457	

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Mine Ventilation Services, Inc.

JOB NO. 3696A161

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FINAL FILING PAGE NO.

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
PANEL ACCESS + MID-PANEL DRIFTS

DESIGNED BY CK ROGERS DATE 4/8/86

CHECKED BY D. Brunner DATE 5/9/86

BRANCH	JUNCTION FROM	TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HMD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
237	188	16	J	28	–	–	28	.00031	
238	50	111	I	200	–	–	200	.00121	
239	111	127	I	126	–	–	126	.00076	
240	127	142	I	252	–	–	252	.00153	
241	142	158	I	441	–	–	441	.00267	
242	158	171	I	504	–	–	504	.00305	
243	171	182	I	504	–	–	504	.00305	
244	182	17	I	103	3	47.49	150.49	.00091	
245	51	112	I	200	3	47.49	247.49	.00150	
246	112	128	I	126	3	47.49	173.49	.00105	
247	128	143	I	315	–	–	315	.00191	
248	143	159	I	504	–	–	504	.00305	
249	159	172	I	504	–	–	504	.00305	
250	172	18	I	426	–	–	426	.00258	

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Mine Ventilation Services, Inc.

JOB NO. 3696A161
SHEET 101 OF 137

FINAL FILING PAGE NO.

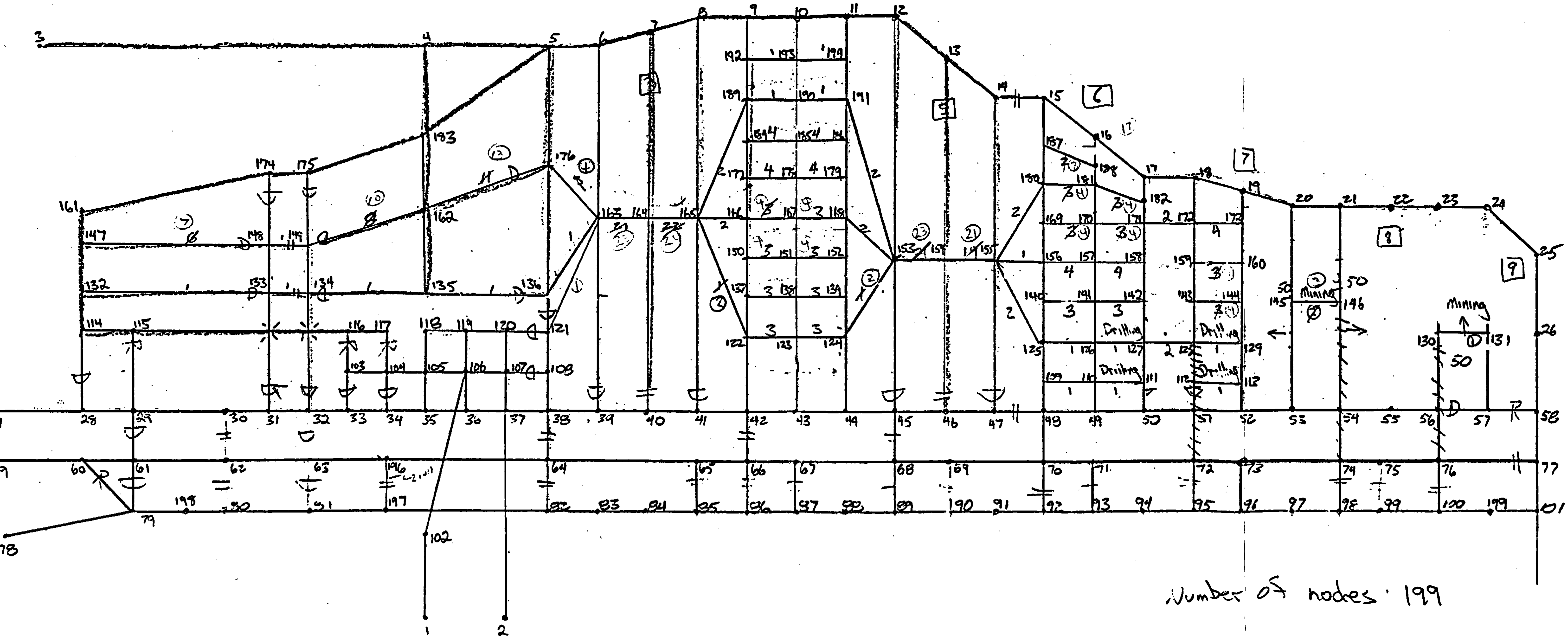
VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PB (DRAFTING ERROR)
PANEL ACCESS & MID-PANEL DRIFTS

DESIGNED BY GR ROGERS DATE 4/8/86
CHECKED BY D. Brenner DATE 5/9/86

BRANCH	JUNCTION FROM	JUNCTION TO	RESISTANCE/LENGTH HYDRAULIC DIAMETER REFERENCE	ACTUAL LENGTH (FT)	NO. OF HAD'S	EQUIVALENT LENGTH (FT)	TOTAL LENGTH (FT)	RESISTANCE (P.U.)	COMMENTS
251	52	113	J	200	—	—	200	.00220	
252	113	129	J	126	—	—	126	.00139	
253	129	144	J	315	—	—	315	.00347	
254	144	160	J	504	—	—	504	.00554	
255	160	173	J	504	—	—	504	.00554	
256	173	19	J	91	5	71.5	162.5	.00179	
261	56	130	H	389	3	35.04	424.04	.00415	
262	57	131	I	389	3	47.49	436.49	.00265	

C-108

DO NOT WRITE OUTSIDE BORDER



Number of nodes · 199

Vertical Emplacement - Development System Schematic

VERTICAL EMPLACEMENT
MODIFICATIONS TO VTUFF1 ON
RE-DIRECTION FROM PO (DRAFTING ERROR)
4/8/86 GR ROGERS
JOB # 3696A161

File Name: VTUFF1
Network Title: VERTICAL EMPLACEMENT-COMMINGLING DHLW
Mine Name: NNWSI
Company: SANDIA NATIONAL LABS
Comments: PARSONS BRINCKERHOFF / MVS

TRIAL 1
VNETPC (VERSION 1.1)

JOB No. 3696A161
DESIGNED
BY: GK ROGERS
4/2/86
Checked by: D. Brown
5/9/86

**** Data Supplied By User ****

Fan Data:

Fan No.	From	To	Operating Pressure in.w.g.	No. Characteristic Pts.
1	78	79	12.000	0
2	4	3	4.000	0

Branch Data:

Branch	From	To	Resistance P.U.	Pressure Dp m. in.wg.	Airflow kcfm
1	1	102	0.0059 ✓		
2	102	106	0.0059 ✓		
3	2	107	0.3047 ✓		
4	2	1	0.0000 ✓		
5	78	79	0.0089 ✓		
6	78	1	0.0000 ✓		
7	60	59	0.0271 ✓		
8	59	1	0.0000 ✓		
9	27	28	0.0197 ✓		
10	27	1	0.0000 ✓		
11	4	3	0.0069 ✓		
12	3	1	0.0000 ✓		
13	4	183	0.0008 ✓		
14	4	5	0.0013 ✓		
15	5	6	0.0002 ✓		
16	6	7	0.0010 ✓		
17	7	8	0.0010 ✓		
18	8	9	0.0013 ← INSIGNIFICANT ERROR – SHOULD BE 0.00013		
19	9	10	0.0012 ✓		
20	10	11	0.0010 ✓		
21	11	12	0.0001 ✓		
22	12	13	0.0011 ✓		
23	13	14	0.0011 ✓		
24	14	15	200.0001 ✓		
25	15	16	0.0011 ✓		
26	16	17	5.0000 ✓		
27	17	18	0.0002 ✓		
28	18	19	0.0011 ✓		
29	19	20	0.0011 ✓		
30	20	21	0.0001 ✓		
31	21	22	0.0010 ✓		

32	22	23	0.0010	
33	23	24	0.0001	
34	24	25	0.0018	
35	25	26	0.0012	
36	26	58	0.0009	
37	28	29	0.0006	
38	29	30	0.0001	
39	30	31	0.0001	
40	31	32	0.0001	
41	32	33	0.0002	
42	33	34	0.0002	
43	34	35	0.0002	
44	35	36	0.0004	
45	36	37	0.0004	
46	37	38	0.0003	
47	38	39	0.0001	
48	39	40	0.0007	
49	40	41	0.0007	
50	41	42	0.0001	
51	42	43	0.0007	
52	43	44	0.0007	
53	44	45	0.0001	
54	45	46	0.0007	
55	46	47	0.0007	
56	47	48	200.0000	
57	48	49	0.0009	
58	49	50	0.0007	
59	50	51	0.0001	
60	51	52	0.0009	
61	52	53	0.0009	
62	53	54	0.0003	
63	54	55	0.0007	
64	55	56	0.0009	
65	56	57	25.0000	
66	58	57	0.0006	51.00 - Fixed
67	61	29	25.0000	
68	62	30	200.0000	
69	63	32	25.0000	
70	64	38	200.0000	
71	66	42	200.0000	
72	68	45	200.0000	
73	48	70	0.0009	
74	51	72	0.0012	
75	54	74	0.0011	
76	56	76	0.0011	
77	77	58	0.0001	
78	60	61	0.0008	
79	61	62	0.0006	
80	62	63	0.0003	
81	63	196	0.0011	
82	196	64	0.0011	
83	64	288	0.0014	
84	65	66	0.0002	
85	66	67	0.0012	
86	67	68	0.0014	
87	68	69	0.0012	

88	69	70	0.0015	
89	70	71	0.0012	
90	71	72	0.0015	
91	72	73	0.0012	
92	73	74	0.0016	
93	74	75	0.0012	
94	75	76	0.0014	
95	76	77	200.0000	
96	79	60	0.0010	50.00 - Fixed
97	79	61	25.0000	
98	80	62	200.0000	
99	81	63	25.0000	
100	197	196	50.0000	
101	82	64	200.0000	
102	85	65	200.0000	
103	86	66	200.0000	
104	87	67	200.0000	
105	89	68	200.0000	
106	90	69	200.0000	
107	92	70	200.0000	
108	93	71	200.0000	
109	95	72	200.0000	
110	96	73	200.0000	
111	98	74	200.0000	
112	99	75	200.0000	
113	100	76	200.0000	
114	101	77	0.0004	
115	79	198	0.0018	
116	198	80	0.0003	
117	80	81	0.0006	
118	81	197	0.0017	
119	197	82	0.0023	
120	82	83	0.0003	
121	83	84	0.0021	
122	84	85	0.0021	
123	85	86	0.0003	
124	86	87	0.0022	
125	87	88	0.0022	
126	88	89	0.0003	
127	89	90	0.0022	
128	90	91	0.0022	
129	91	92	0.0003	
130	92	93	0.0022	
131	93	94	0.0022	
132	94	95	0.0003	
133	95	96	0.0022	
134	96	97	0.0022	
135	97	98	0.0003	
136	98	99	0.0022	
137	99	100	0.0022	
138	100	199	0.0003	
139	199	101	0.0021	
140	28	114	25.0000	
141	114	132	0.0005	
142	132	147	0.0013	
143	147	161	0.0003	

144	161	174	0.0007	
145	174	175	0.0002	
146	175	183	0.0010	
147	183	5	0.0012	
148	29	115	0.0010	70.00 - Fixed
149	103	116	0.0010	25.00 - Fixed
150	104	117	0.0010	30.00 - Fixed
151	117	116	0.0032	
152	116	115	0.0074	
153	115	114	0.0054	
154	33	103	25.0000	
155	34	104	25.0000	
156	104	103	0.0016	
157	118	119	0.0044	
158	119	120	0.0024	
159	120	121	25.0000	
160	106	105	0.0052	
161	106	107	0.0032	
162	107	108	25.0021	
163	118	105	0.0035	
164	105	35	0.0022	
165	119	106	0.0029	
166	106	36	0.0030	
167	120	107	0.0020	
168	107	37	0.0022	
169	105	104	0.0016	
170	133	148	0.0051	
171	31	133	0.0039	15.00 - Fixed
172	148	174	25.0000	
173	32	134	25.0000	
174	134	149	0.0051	
175	149	175	25.0000	
176	135	162	0.0092	
177	162	183	0.0102	
178	38	108	0.0010	
179	108	121	0.0009	
180	121	136	25.0000	
181	136	176	0.0067	
182	176	5	0.0067	
183	39	163	25.0000	
184	163	6	0.0088	
185	40	164	200.0000	
186	164	7	0.0178	
187	41	165	25.0000	
188	165	8	0.0098	
189	42	122	0.0025	
190	122	137	0.0026	
191	137	150	0.0026	
192	150	166	0.0026	
193	166	177	0.0030	
194	177	184	0.0036	
195	184	189	0.0022	
196	189	192	0.0009	
197	192	9	25.0000	
198	43	123	200.0000	
199	123	138	0.0047	

200	138	151	0.0047
201	151	167	0.0047
202	167	178	0.0054
203	178	185	0.0065
204	185	190	0.0040
205	190	193	0.0023
206	193	10	0.0011
207	44	124	0.0025
208	124	139	0.0026
209	139	152	0.0026
210	152	168	0.0026
211	168	179	0.0030
212	179	186	0.0035
213	186	191	0.0022
214	191	194	0.0009
215	194	11	25.0000
216	45	153	25.0000
217	153	12	0.0098
218	46	154	200.0000
219	154	13	0.0166
220	47	155	25.0084
221	155	14	0.0084
222	48	109	25.0000
223	109	125	0.0009
224	125	140	0.0017
225	140	156	0.0030
226	156	169	0.0030
227	169	180	0.0034
228	180	187	0.0013
229	187	15	0.0018
230	49	110	0.0027
231	110	126	0.0020
232	126	141	0.0031
233	141	157	0.0055
234	157	170	0.0055
235	170	181	0.0062
236	181	188	0.0021
237	188	16	0.0007
238	50	111	25.0000
239	111	127	0.0009
240	127	142	0.0017
241	142	158	0.0030
242	158	171	0.0030
243	171	182	0.0022
244	182	17	0.0009
245	51	112	0.0023
246	112	128	0.0017
247	128	143	0.0017
248	143	159	0.0026
249	159	172	0.0030
250	172	18	25.0000
251	52	113	25.0000
252	113	129	0.0015
253	129	144	0.0031
254	144	160	0.0046
255	160	173	0.0055

256	173	19	0.0022	
257	53	145	0.0047	
258	145	20	0.0052	
259	54	46	0.0076	
260	146	21	0.0052	
261	56	130	0.0047	
262	57	131	0.0030	
263	132	133	25.0019	
264	147	148	0.6944	
265	133	134	200.0000	
266	148	149	200.0000	
267	134	135	25.0000	
268	135	136	25.0000	
269	149	162	0.3925	
270	176	162	0.2084	
271	136	163	200.0000	
272	176	163	22.2222	
273	163	164	0.0588	
274	165	164	0.0538	
275	165	122	200.0000	
276	165	166	50.0000	
277	165	189	50.0000	
278	122	123	2.7778	
279	124	123	2.7778	
280	137	138	2.7778	
281	139	138	2.7778	
282	150	151	2.7778	
283	152	151	2.7778	
284	166	167	2.7778	
285	168	167	2.7778	
286	177	178	1.5646	
287	179	178	1.5646	
288	184	185	1.5646	
289	186	185	1.5646	
290	189	190	0.0033	45.00 - Fixed
291	191	190	0.0033	45.00 - Fixed
292	192	193	0.0033	45.00 - Fixed
293	194	193	0.0033	45.00 - Fixed
294	124	153	200.0000	
295	168	153	50.0000	
296	191	153	50.0000	
297	153	154	0.0588	
298	155	154	0.0714	
299	155	125	50.0000	
300	155	156	200.0000	
301	155	180	50.0000	
302	109	110	25.0000	
303	111	110	0.0023	
304	125	126	25.0000	
305	127	126	0.0023	
306	140	141	2.7778	
307	142	141	2.7778	
308	156	157	1.5625	
309	158	157	1.5625	
310	169	170	2.7778	
311	171	170	2.7778	

312	180	181	2.7778
313	182	181	2.7778
314	187	188	6.2500
315	127	128	50.0000
316	171	172	50.0000
317	112	113	0.0024
318	128	129	0.0024
319	143	144	2.7778
320	159	160	2.7778
321	172	173	1.5625
322	145	146	0.0001
323	131	130	0.0009
324	288	65	0.0012
325	84	288	200.0000

**** OUTPUT DATA ****

Annual costs are based on electricity charges of 4.0 cents per kWhr and fan efficiencies of 70.0%
Cost given for an NVP represents money saved by natural ventilation

*** FAN OPERATING POINTS ***

Fan No.	From	To	Pressure in.w.g.	Quantity kcfm	Air Power hp	Op.Cost $/year
1	78	79	12.000	465.14	879.53	328,292
2	4	3	4.000	528.97	333.41	124,449

*** BRANCH RESULTS ***

Branch	From	To	Press.Dp m.in.wg.	Airflow kcfm	Resist. P.U.	AP Loss hp	Op.Cost $/year
1	1	102	297	225.44	0.0059	10.6	3,938.1
2	102	106	297	225.44	0.0059	10.6	3,938.1
3	2	107	603	44.51	0.3047	4.2	1,578.7
4	2	1	0	-44.51	0.0000	0.0	0.0
5	78	79	1936	465.14	0.0089	141.9	52,964.5
6	78	1	0	-465.14	0.0000	0.0	0.0
7	60	59	3871	378.02	0.0271	230.6	86,066.8
8	59	1	0	378.02	0.0000	0.0	0.0
9	27	28	582	171.90	0.0197	15.8	5,884.4
10	27	1	0	-171.90	0.0000	0.0	0.0
11	4	3	1944	528.97	0.0069	162.0	60,482.3
12	3	[illegible]	0	528.97	0.0000	0.0	0.0
13	4	183	-64	-280.02	0.0008	2.8	1,054.1
14	4	5	-79	-248.95	0.0013	3.1	1,156.8
15	5	6	-20	-365.32	0.0002	1.2	429.7
16	6	7	-107	-320.61	0.0010	5.4	2,017.7
17	7	8	-104	-315.19	0.0010	5.2	1,928.0
18	8	9	-152	-342.01	0.0013	8.2	3,057.6
19	9	10	-139	-337.70	0.0012	7.4	2,760.8
20	10	11	-3	-56.17	0.0010	0.0	9.9

21	11	12	0	-52.66	0.0001	0.0	0.0	
22	12	13	-1	-38.09	0.0011	0.0	2.2	
23	13	14	-1	-30.55	0.0011	0.0	1.8	
24	14	15	-6520	-5.71	200.0001	5.9	2,189.6	
25	15	16	0	-26.17	0.0011	0.0	0.0	
26	16	17	-56	-3.35	5.0000	0.0	11.0	
27	17	18	0	-76.68	0.0002	0.0	0.0	
28	18	19	-6	-77.82	0.0011	0.1	27.5	
29	19	20	-19	-133.25	0.0011	0.4	148.9	
30	20	21	-5	-196.38	0.0001	0.2	57.8	
31	21	22	-73	-267.07	0.0010	3.1	1,146.7	
32	22	23	-73	-267.07	0.0010	3.1	1,146.7	
33	23	24	-9	-267.07	0.0001	0.4	141.4	
34	24	25	-129	-267.07	0.0018	5.4	2,026.3	
35	25	26	-82	-267.07	0.0012	3.5	1,288.1	
36	26	58	-63	-267.07	0.0009	2.7	989.6	
37	28	29	15	164.61	0.0006	0.4	145.2	
38	29	30	1	108.11	0.0001	0.0	6.4	
39	30	31	1	112.92	0.0001	0.0	6.6	
40	31	32	0	97.92	0.0001	0.0	0.0	
41	32	33	1	104.20	0.0002	0.0	6.1	
42	33	34	2	103.61	0.0002	0.0	12.2	
43	34	35	1	103.13	0.0002	0.0	6.1	
44	35	36	6	122.48	0.0004	0.1	43.2	
45	36	37	16	202.90	0.0004	0.5	190.9	
46	37	38	30	316.07	0.0003	1.5	557.7	
47	38	39	10	316.88	0.0001	0.5	186.4	
48	39	40	69	309.76	0.0007	3.4	1,257.1	
49	40	41	68	307.41	0.0007	3.3	1,229.5	
50	41	42	9	301.28	0.0001	0.4	159.5	
51	42	43	16	151.00	0.0007	0.4	142.1	
52	43	44	16	149.75	0.0007	0.4	140.9	
53	44	45	0	0.71	0.0001	0.0	0.0	
54	45	46	0	1.14	0.0007	0.0	0.0	
55	46	47	0	-0.58	0.0007	0.0	0.0	
56	47	48	-5908	-5.44	200.0000	5.1	1,888.6	
57	48	49	-22	-159.70	0.0009	0.6	206.6	
58	49	50	-10	-117.72	0.0007	0.2	69.2	
59	50	51	-1	-118.10	0.0001	0.0	6.9	
60	51	52	-9	-107.20	0.0009	0.2	56.8	
61	52	53	-10	-107.39	0.0009	0.2	63.2	
62	53	54	0	-32.32	0.0003	0.0	0.0	
63	54	55	0	-23.31	0.0007	0.0	0.0	
64	55	56	0	-23.31	0.0009	0.0	0.0	
65	56	57	-21	-0.93	25.0000	0.0	1.2	
66*	58	57	460	51.00	0.1772	3.7	1,379.8	-Regulator Required
67	61	29	4557	13.50	25.0000	9.7	3,619.0	
68	62	30	4628	4.81	200.0000	3.5	1,309.4	
69	63	32	4665	13.66	25.0000	10.0	3,748.3	
70	64	38	4949	4.97	200.0000	3.9	1,448.1	

71	66	42	5367	5.18	200.0000	4.4	1,635.3	
72	68	45	5642	5.31	200.0000	4.7	1,762.5	
73	48	70	20	155.06	0.0009	0.5	182.4	
74	51	72	2	45.91	0.0012	0.0	5.4	
75	54	74	2	49.73	0.0011	0.0	5.9	
76	56	76	0	27.69	0.0011	0.0	0.0	
77	77	58	10	318.07	0.0001	0.5	187.1	
78	60	61	-88	-328.02	0.0008	4.5	1,697.8	
79	61	62	-69	-325.90	0.0007	3.5	1,322.6	
80	62	63	-34	-325.35	0.0003	1.7	650.6	
81	63	196	-115	-324.08	0.0011	5.9	2,192.1	
82	196	64	-108	-313.86	0.0011	5.3	1,993.7	
83	64	288	-133	-313.93	0.0014	6.6	2,455.7	
84	65	66	-14	-304.80	0.0002	0.7	251.0	
85	66	67	-114	-305.56	0.0012	5.5	2,048.8	
86	67	68	-126	-301.35	0.0014	6.0	2,233.3	
87	68	69	-112	-302.71	0.0012	5.3	1,994.1	
88	69	70	-132	-299.01	0.0015	6.2	2,321.4	
89	70	71	-24	-140.54	0.0012	0.5	198.4	
90	71	72	-27	-137.33	0.0015	0.6	218.1	
91	72	73	-9	-88.45	0.0012	0.1	46.8	
92	73	74	-11	-85.70	0.0016	0.1	55.4	
93	74	75	-1	-33.48	0.0012	0.0	2.0	
94	75	76	-1	-31.24	0.0014	0.0	1.8	
95	76	77	-493	-1.57	200.0000	0.1	45.6	
96*	79	60	6192	50.00	2.4770	48.8	18,209.5	-Regulator Required FIX 85
97	79	61	6104	15.63	25.0000	15.0	5,610.0	
98	80	62	5709	5.34	200.0000	4.8	1,794.1	
99	81	63	5581	14.94	25.0000	13.1	4,904.7	
100	197	196	5227	10.22	50.0000	8.4	3,143.4	
101	82	64	4811	4.90	200.0000	3.7	1,387.8	
102	85	65	3972	4.46	200.0000	2.8	1,041.1	
103	86	66	3922	4.43	200.0000	2.7	1,021.5	
104	87	67	3538	4.21	200.0000	2.3	875.2	
105	89	68	3115	3.97	200.0000	1.9	723.1	
106	90	69	2746	3.71	200.0000	1.6	598.5	
107	92	70	2330	3.41	200.0000	1.3	467.8	
108	93	71	2060	3.21	200.0000	1.0	388.9	
109	95	72	1759	2.97	200.0000	0.8	306.9	
110	96	73	1512	2.75	200.0000	0.7	244.6	
111	98	74	1238	2.49	200.0000	0.5	181.2	
112	99	75	1007	2.24	200.0000	0.4	132.9	
113	100	76	779	1.97	200.0000	0.2	90.5	
114	101	77	43	319.64	0.0004	2.2	808.4	
115	79	198	280	399.51	0.0018	17.6	6,579.4	
116	198	80	44	399.51	0.0003	2.8	1,033.9	
117	80	81	93	394.17	0.0006	5.8	2,156.1	
118	81	197	238	379.23	0.0017	14.2	5,308.5	
119	197	82	307	369.00	0.0023	17.9	6,662.9	
120	82	83	37	364.10	0.0003	2.1	792.4	

121	83	84	281	364.10	0.0021	16.1	6,017.6	
122	84	85	273	359.43	0.0021	15.5	5,771.3	
123	85	86	35	354.97	0.0003	2.0	730.7	
124	86	87	269	350.54	0.0022	14.9	5,546.2	
125	87	88	262	346.34	0.0022	14.3	5,337.0	
126	88	89	33	346.34	0.0003	1.8	672.2	
127	89	90	256	342.39	0.0022	13.8	5,155.4	
128	90	91	251	338.69	0.0022	13.4	5,000.0	
129	91	92	32	338.69	0.0003	1.7	637.5	
130	92	93	246	335.27	0.0022	13.0	4,851.0	
131	93	94	241	332.06	0.0022	12.6	4,706.9	
132	94	95	30	332.06	0.0003	1.6	585.9	
133	95	96	237	329.10	0.0022	12.3	4,587.4	
134	96	97	233	326.35	0.0022	12.0	4,472.3	
135	97	98	29	326.35	0.0003	1.5	556.6	
136	98	99	229	323.86	0.0022	11.7	4,362.0	
137	99	100	226	321.61	0.0022	11.5	4,275.0	
138	100	199	28	319.64	0.0003	1.4	526.4	
139	199	101	213	319.64	0.0021	10.7	4,004.4	
140	28	114	1329	7.29	25.0000	1.5	570.1	
141	114	132	8	132.29	0.0005	0.2	62.3	
142	132	147	23	133.71	0.0013	0.5	180.9	
143	147	161	6	143.96	0.0003	0.1	50.8	
144	161	174	15	143.96	0.0007	0.3	127.0	
145	174	175	3	145.91	0.0002	0.1	25.7	
146	175	183	22	146.25	0.0010	0.5	189.2	
147	183	5	-15	-116.80	0.0012	0.3	103.0	
148*	29	115	1228	70.00	0.2507	13.5	5,055.8	-Regulator Requirec
149*	103	116	1191	25.00	1.9072	4.7	1,751.3	-Regulator Requireo
150*	104	117	1190	30.00	1.3223	5.6	2,099.7	-Regulator Requireo
151	117	116	2	30.00	0.0032	0.0	3.5	
152	116	115	22	55.00	0.0073	0.2	71.2	
153	115	114	84	125.00	0.0054	1.7	617.6	
154	33	103	8	0.59	25.0000	0.0	0.3	
155	34	104	5	0.48	25.0000	0.0	0.1	
156	104	103	0	24.41	0.0016	0.0	0.0	
157	118	119	-2	-25.84	0.0044	0.0	3.0	
158	119	120	1	21.07	0.0024	0.0	1.2	
159	120	121	59	1.54	25.0000	0.0	5.4	
160	106	105	11	47.45	0.0052	0.1	30.7	
161	106	107	8	50.67	0.0032	0.1	23.8	
162	107	108	58	1.53	25.0021	0.0	5.2	
163	118	105	2	25.84	0.0035	0.0	3.0	
164	105	35	0	19.35	0.0022	0.0	0.0	
165	119	106	-6	-46.90	0.0029	0.0	16.6	
166	106	36	19	80.42	0.0030	0.2	89.9	
167	120	107	0	19.52	0.0020	0.0	0.0	
168	107	37	27	113.17	0.0022	0.5	179.7	

169	105	104	4	53.93	0.0016	0.0	12.7	
170	133	148	0	12.89	0.0051	0.0	0.0	
171*	31	133	1268	15.00	5.6373	3.0	1,118.7	-Regulator Required
172	148	174	94	1.95	25.0000	0.0	10.8	
173	32	134	1363	7.39	25.0000	1.6	592.1	
174	134	149	0	7.14	0.0051	0.0	0.0	
175	149	175	2	0.34	25.0000	0.0	0.0	
176	135	162	0	1.66	0.0092	0.0	0.0	
177	162	183	2	16.97	0.0102	0.0	2.0	
178	38	108	0	4.17	0.0010	0.0	0.0	
179	108	121	0	5.70	0.0009	0.0	0.0	
180	121	136	1312	7.25	25.0000	1.5	559.2	
181	136	176	0	6.96	0.0067	0.0	0.0	
182	176	5	0	0.44	0.0067	0.0	0.0	
183	39	163	1265	7.12	25.0000	1.4	529.4	
184	163	6	17	44.71	0.0088	0.1	44.7	25.0098 ADD DOOR
185	40	164	1105	2.35	200.0000	0.4	152.8	
186	164	7	0	5.42	0.0178	0.0	0.0	
187	41	165	941	6.14	25.0000	0.9	339.6	
188	165	8	-7	-26.82	0.0098	0.0	11.0	25.0098 ADD DOOR
189	42	122	61	155.46	0.0025	1.5	557.8	
190	122	137	53	143.57	0.0026	1.2	447.5	
191	137	150	47	134.78	0.0026	1.0	372.6	
192	150	166	42	126.92	0.0026	0.8	313.5	
193	166	177	39	115.97	0.0030	0.7	266.0	
194	177	184	40	107.02	0.0036	0.7	251.8	
195	184	189	20	97.85	0.0022	0.3	115.1	
196	189	192	2	49.31	0.0009	0.0	5.8	
197	192	9	464	4.31	25.0000	0.3	117.6	
198	43	123	311	1.25	200.0000	0.1	22.8	
199	123	138	1	20.31	0.0047	0.0	1.2	
200	138	151	6	37.34	0.0047	0.0	13.2	
201	151	167	13	52.55	0.0047	0.1	40.2	
202	167	178	23	66.34	0.0054	0.2	89.7	
203	178	185	45	83.67	0.0065	0.6	221.5	
204	185	190	40	101.53	0.0040	0.6	238.9	
205	190	193	85	191.53	0.0023	2.6	957.5	
206	193	10	88	281.52	0.0011	3.9	1,457.1	
207	44	124	56	149.04	0.0025	1.3	490.9	
208	124	139	49	138.14	0.0026	1.1	398.1	
209	139	152	44	129.90	0.0026	0.9	336.2	
210	152	168	39	122.55	0.0026	0.8	281.1	
211	168	179	37	113.06	0.0030	0.7	246.0	
212	179	186	38	104.68	0.0035	0.6	234.0	
213	186	191	20	95.99	0.0022	0.3	112.9	
214	191	194	2	48.51	0.0008	0.0	5.7	
215	194	11	308	3.51	25.0000	0.2	63.7	
216	45	153	594	4.88	25.0000	0.5	170.4	
217	153	12	2	14.57	0.0098	0.0	1.7	25.0098 (ADD DOOR)
218	46	154	594	1.72	200.0000	0.2	60.2	

219	154	13	0	7.54	0.0166	0.0	0.0	
220	47	155	589	4.85	25.0084	0.5	168.1	
221	155	14	5	24.84	0.0084	0.0	7.3	25,0084 (ADD DOOR) 114 OF 137
222	48	109	-15	-0.79	25.0000	0.0	0.7	
223	109	125	0	-0.12	0.0009	0.0	0.0	
224	125	140	0	-10.85	0.0017	0.0	0.0	
225	140	156	0	-8.90	0.0030	0.0	0.0	
226	156	169	0	-12.24	0.0030	0.0	0.0	
227	169	180	0	-10.71	0.0034	0.0	0.0	
228	180	187	0	-21.00	0.0013	0.0	0.0	
229	187	15	0	-20.46	0.0018	0.0	0.0	
230	49	110	-4	-41.98	0.0027	0.0	9.9	
231	110	126	0	-13.68	0.0020	0.0	0.0	
232	126	141	0	16.91	0.0031	0.0	0.0	
233	141	157	1	16.77	0.0055	0.0	1.0	
234	157	170	1	18.16	0.0055	0.0	1.1	
235	170	181	2	20.26	0.0062	0.0	2.4	
236	181	188	1	23.36	0.0021	0.0	1.4	
237	188	16	0	22.82	0.0007	0.0	0.0	
238	50	111	3	0.38	25.0000	0.0	0.1	
239	111	127	0	-28.58	0.0009	0.0	0.0	
240	127	142	-5	-59.34	0.0017	0.0	17.4	
241	142	158	-11	-61.15	0.0030	0.1	39.6	
242	158	171	-12	-64.90	0.0030	0.1	45.8	
243	171	182	-10	-69.10	0.0022	0.1	40.6	
244	182	17	-4	-73.33	0.0009	0.0	17.2	
245	51	112	-7	-56.81	0.0023	0.1	23.4	
246	112	128	-1	-30.77	0.0017	0.0	1.8	
247	128	143	0	-10.46	0.0017	0.0	0.0	
248	143	159	0	-8.81	0.0026	0.0	0.0	
249	159	172	0	-6.26	0.0030	0.0	0.0	
250	172	18	-32	-1.14	25.0000	0.0	2.2	
251	52	113	0	0.19	25.0000	0.0	0.0	
252	113	129	-1	-25.85	0.0015	0.0	1.5	
253	129	144	-6	-46.67	0.0031	0.0	16.5	
254	144	160	-10	-48.32	0.0046	0.1	28.4	
255	160	173	-14	-50.88	0.0055	0.1	41.9	
256	173	19	-6	-55.42	0.0022	0.1	19.6	
257	53	145	-26	-75.08	0.0047	0.3	114.8	
258	145	20	-20	-63.14	0.0052	0.2	74.3	FIX Q @ 50 20-145
259	54	146	-26	-58.74	0.0076	0.2	89.8	
260	146	21	-25	-70.68	0.0052	0.3	103.9	
261	56	130	-11	-50.07	0.0047	0.1	32.4	FIX Q @ 50 21-146
262	57	131	7	50.07	0.0030	0.1	20.6	
263	132	133	-50	-1.42	25.0019	0.0	4.2	
264	147	148	-72	-10.25	0.6944	0.1	43.4	
265	133	134	95	0.69	200.0000	0.0	3.9	
266	148	149	95	0.69	200.0000	0.0	3.9	
267	134	135	22	0.94	25.0000	0.0	1.2	
268	135	136	-13	-0.72	25.0000	0.0	0.6	
269	149	162	21	7.48	0.3925	0.0	9.2	

270	176	162	12	7.62	0.2084	0.0	5.5	
271	136	163	-37	-0.43	200.0000	0.0	0.9	
272	176	163	-37	-1.30	22.2222	0.0	2.8	
273	163	164	-90	-39.32	0.0588	0.6	208.1	
274	165	164	96	42.39	0.0538	0.6	239.4	
275	165	122	-870	-2.09	200.0000	0.3	106.8	
276	165	166	-727	-3.81	50.0000	0.4	163.1	
277	165	189	-625	-3.54	50.0000	0.3	130.0	
278	122	123	267	9.81	2.7778	0.4	154.0	
279	124	123	238	9.26	2.7778	0.3	129.6	
280	137	138	214	8.78	2.7778	0.3	110.6	
281	139	138	188	8.25	2.7778	0.2	91.2	
282	150	151	171	7.86	2.7778	0.2	79.1	
283	152	151	149	7.34	2.7778	0.2	64.3	
284	166	167	141	7.14	2.7778	0.2	59.2	
285	168	167	122	6.65	2.7778	0.1	47.7	
286	177	178	125	8.95	1.5646	0.2	65.8	
287	179	178	109	8.38	1.5646	0.1	53.7	
288	184	185	131	9.17	1.5646	0.2	70.6	
289	186	185	117	8.68	1.5646	0.2	59.8	
290*	189	190	152	45.00	0.0751	1.1	402.3	-Regulator Required
291*	191	190	138	45.00	0.0686	1.0	365.2	-Regulator Required
292*	192	193	235	45.00	0.1163	1.7	622.0	-Regulator Required
293*	194	193	222	45.00	0.1098	1.6	587.6	-Regulator Required
294	124	153	537	1.64	200.0000	0.1	51.8	
295	168	153	404	2.84	50.0000	0.2	67.6	
296	191	153	307	2.48	50.0000	0.1	44.8	
297	153	154	0	-2.73	0.0588	0.0	0.0	
298	155	154	5	8.55	0.0714	0.0	2.5	
299	155	125	-6512	-11.41	50.0000	11.7	4,371.1	
300	155	156	-6512	-5.71	200.0000	5.9	2,185.6	
301	155	180	-6513	-11.41	50.0000	11.7	4,372.2	
302	109	110	-11	-0.67	25.0000	0.0	0.4	
303	111	110	1	28.96	0.0023	0.0	1.7	
304	125	126	-11	-0.68	25.0000	0.0	0.4	
305	127	126	2	31.27	0.0023	0.0	3.7	
306	140	141	-10	-1.95	2.7778	0.0	1.2	
307	142	141	9	1.81	2.7778	0.0	1.0	
308	156	157	-8	-2.37	1.5625	0.0	1.1	
309	158	157	21	3.75	1.5625	0.0	4.6	
310	169	170	-6	-1.53	2.7778	0.0	0.5	
311	171	170	36	3.63	2.7778	0.0	7.7	
312	180	181	-3	-1.13	2.7778	0.0	0.2	
313	182	181	42	4.23	2.7778	0.0	12.2	
314	187	188	-1	-0.54	6.2500	0.0	0.0	
315	127	128	-13	-0.52	50.0000	0.0	0.4	
316	171	172	16	0.57	50.0000	0.0	0.5	

317	112	113	-1	-26.04	0.0024	0.0	1.5
318	128	129	-1	-20.82	0.0024	0.0	1.2
319	143	144	-7	-1.65	2.7778	0.0	0.7
320	159	160	-18	-2.56	2.7778	0.0	2.7
321	172	173	-32	-4.55	1.5625	0.0	8.6
322	145	146	0	-11.94	0.0001	0.0	0.0
323	131	130	2	50.07	0.0009	0.0	5.9
324	288	65	-113	-309.26	0.0012	5.5	2,055.4
325	84	288	4359	4.67	200.0000	3.2	1,197.0

Number of Iterations = 25

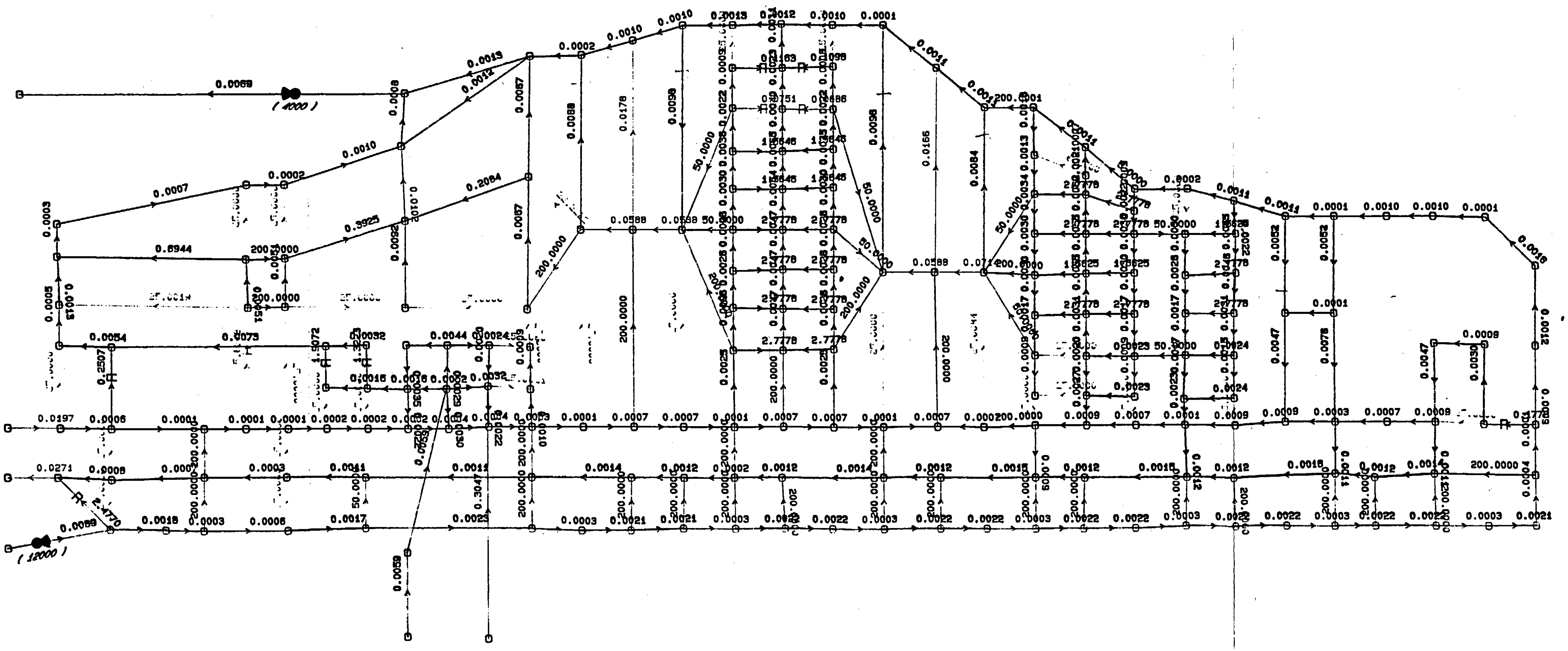
*** REGULATOR AND BOOSTER FAN LIST ***

Branch	From	To	Regulator Resistance Required (P.U.)
66	58	57	0.1765
96	79	60	2.4760
148	29	115	0.2497
149	103	116	1.9062
150	104	117	1.3213
171	31	133	5.6334
290	189	190	0.0718
291	191	190	0.0653
292	192	193	0.1130
293	194	193	0.1065

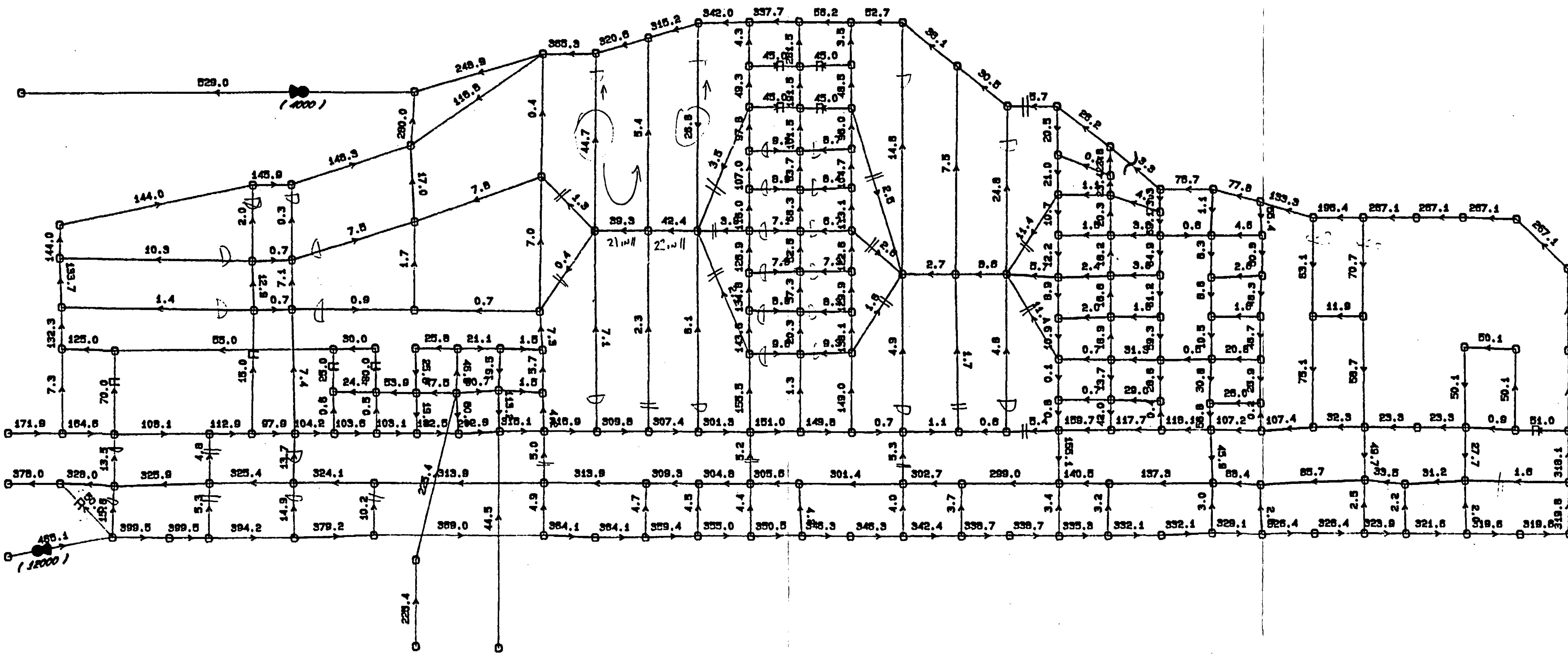
**** NETWORK EXERCISE COMPLETE ****

We hope this run has been successful .... VNETPC

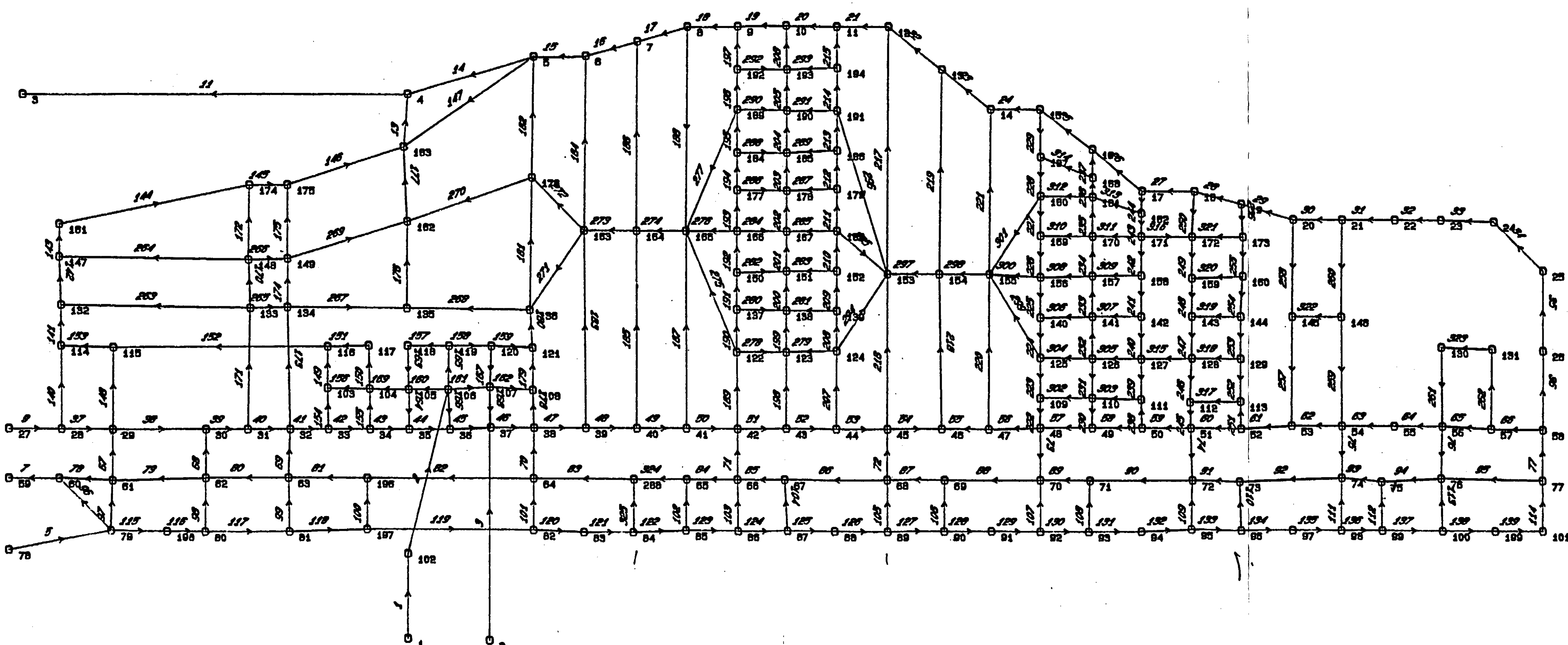
KEY - Resistance P.U.	LOW	- HIGH
————	0	.001
————	.001	.01
————	.01	.1
————	.1	5.1
- - - -	5.1	25.1
- - - -	25.1	400.1



VTUFF1 – Resistance TRIAL 1



VTUFF1 - Airflow TRIAL 1



VTUFF1 - Branch Numbers TRIAL 1

TRIAL 7

File Name: VTUFF1
Network Title: VERTICAL EMPLACEMENT-COMMINGLING DHLW
Mine Name: NNWSI
Company: SANDIA NATIONAL LABS
Comments: PARSONS BRINCKERHOFF / MVS

TRIAL 7 / FINAL

JOB # 3696A 161
DESIGNED BY: GR ROGERS
4/11/86
VNETPC (VER. 1.1)

120 OF 131

**** Data Supplied By User ****

Fan Data:

Fan No.	From	To	Operating Pressure in.w.g.	No. Characteristic Pts.
1	78	79	9.000	0
2	4	3	3.250	0

Branch Data:

Branch	From	To	Resistance P.U.	Pressure Dp m. in.wg.	Airflow kcfm
1	1	102	0.0059		
2	102	106	0.0059		
3	2	107	0.3047		
4	2	1	0.0000		
5	78	79	0.0089		
6	78	1	0.0000		
7	60	59	0.0271		
8	59	1	0.0000		
9	27	28	0.0197		
10	27	1	0.0000		
11	4	3	0.0069		
12	3	1	0.0000		
13	4	183	0.0008		
14	4	5	0.0013		
15	5	6	0.0002		
16	6	7	0.0010		
17	7	8	0.0010		
18	8	9	0.0013 ← RESISTANCE SHOULD BE 0.00013 – INSIGNIFICANT ERROR		
19	9	10	0.0012		
20	10	11	0.0010		
21	11	12	0.0001		
22	12	13	0.0011		
23	13	14	0.0011		
24	14	15	200.0001		
25	15	16	0.0011		
26	16	17	5.0000		
27	17	18	0.0002		
28	18	19	0.0011		
29	19	20	0.0011		
30	20	21	0.0001		
31	21	22	0.0010		

TRIAL 7

32	22	23	0.0010	
33	23	24	0.0001	
34	24	25	0.0018	
35	25	26	0.0012	
36	26	58	0.0009	
37	28	29	0.0006	
38	29	30	0.0001	
39	30	31	0.0001	
40	31	32	0.0001	
41	32	33	0.0002	
42	33	34	0.0002	
43	34	35	0.0002	
44	35	36	0.0004	
45	36	37	0.0004	
46	37	38	0.0003	
47	38	39	0.0001	
48	39	40	0.0007	
49	40	41	0.0007	
50	41	42	0.0001	
51	42	43	0.0007	
52	43	44	0.0007	
53	44	45	0.0001	
54	45	46	0.0007	
55	46	47	0.0007	
56	47	48	200.0000	
57	48	49	0.0009	
58	49	50	0.0007	
59	50	51	0.0001	
60	51	52	0.0009	
61	52	53	0.0009	
62	53	54	0.0003	
63	54	55	0.0007	
64	55	56	0.0009	
65	56	57	25.0000	
66	58	57	0.0006	51.00 - Fixed
67	61	29	200.0000	
68	62	30	200.0000	
69	63	32	200.0000	
70	64	38	200.0000	
71	66	42	200.0000	
72	68	45	200.0000	
73	48	70	0.0009	
74	51	72	0.0012	
75	54	74	0.0011	
76	56	76	0.0011	
77	77	58	0.0001	
78	60	61	0.0008	
79	61	62	0.0006	
80	62	63	0.0003	
81	63	196	0.0011	
82	196	64	0.0011	
83	64	288	0.0014	
84	65	66	0.0002	
85	66	67	0.0012	
86	67	68	0.0014	
87	68	69	0.0012	

88	69	70	0.0015	
89	70	71	0.0012	
90	71	72	0.0015	
91	72	73	0.0012	
92	73	74	0.0016	
93	74	75	0.0012	
94	75	76	0.0014	
95	76	77	200.0000	
96	79	60	0.0010	85.00 - Fixed
97	79	61	200.0000	
98	80	62	200.0000	
99	81	63	200.0000	
100	197	196	50.0000	
101	82	64	200.0000	
102	85	65	200.0000	
103	86	66	200.0000	
104	87	67	200.0000	
105	89	68	200.0000	
106	90	69	200.0000	
107	92	70	200.0000	
108	93	71	200.0000	
109	95	72	200.0000	
110	96	73	200.0000	
111	98	74	200.0000	
112	99	75	200.0000	
113	100	76	200.0000	
114	101	77	0.0004	
115	79	198	0.0018	
116	198	80	0.0003	
117	80	81	0.0006	
118	81	197	0.0017	
119	197	82	0.0023	
120	82	83	0.0003	
121	83	84	0.0021	
122	84	85	0.0021	
123	85	86	0.0003	
124	86	87	0.0022	
125	87	88	0.0022	
126	88	89	0.0003	
127	89	90	0.0022	
128	90	91	0.0022	
129	91	92	0.0003	
130	92	93	0.0022	
131	93	94	0.0022	
132	94	95	0.0003	
133	95	96	0.0022	
134	96	97	0.0022	
135	97	98	0.0003	
136	98	99	0.0022	
137	99	100	0.0022	
138	100	199	0.0003	
139	199	101	0.0021	
140	28	114	25.0000	
141	114	132	0.0005	
142	132	147	0.0013	
143	147	161	0.0003	

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144	161	174	0.0007	
145	174	175	0.0002	
146	175	183	0.0010	
147	183	5	0.0012	
148	29	115	0.0010	70.00 - Fixed
149	103	116	0.0010	25.00 - Fixed
150	104	117	0.0010	30.00 - Fixed
151	117	116	0.0032	
152	116	115	0.0074	
153	115	114	0.0054	
154	33	103	25.0000	
155	34	104	25.0000	
156	104	103	0.0016	
157	118	119	0.0044	
158	119	120	0.0024	
159	120	121	25.0000	
160	106	105	0.0052	
161	106	107	0.0032	
162	107	108	25.0021	
163	118	105	0.0035	
164	105	35	0.0022	
165	119	106	0.0029	
166	106	36	0.0030	
167	120	107	0.0020	
168	107	37	0.0022	
169	105	104	0.0016	
170	133	148	0.0051	
171	31	133	0.0039	15.00 - Fixed
172	148	174	25.0000	
173	32	134	0.0039	10.00 - Fixed
174	134	149	0.0051	
175	149	175	25.0000	
176	135	162	0.0092	
177	162	183	0.0102	10.00 - Fixed
178	38	108	0.0010	
179	108	121	0.0009	
180	121	136	25.0000	
181	136	176	0.0057 ✓	
182	176	5	25.0057 ✓	
183	39	163	0.0088	10.00 - Fixed
184	163	6	25.0088	
185	40	164	200.0000	
186	164	7	0.0178	10.00 - Fixed
187	41	165	25.0098	
188	165	8	25.0000	
189	42	122	0.0025 ✓	
190	122	137	0.0023 ✓	
191	137	150	0.0027 ✓	
192	150	166	0.0030 ✓	
193	166	177	0.0030 ✓	
194	177	184	0.0030 ✓	
195	184	189	0.0019 ✓	
196	189	192	0.0008 ✓	
197	192	9	25.0000 ✓	
198	43	123	200.0000 ✓	
199	123	138	0.0042 ✓	

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200	138	151	0.0049
201	151	167	0.0055
202	167	178	0.0055
203	178	185	0.0055
204	185	190	0.0035
205	190	193	0.0022
206	193	10	0.0024
207	44	124	0.0025
208	124	139	0.0023
209	139	152	0.0027
210	152	168	0.0030
211	168	179	0.0030
212	179	186	0.0030
213	186	191	0.0019
214	191	194	0.0008
215	194	11	25.0000
216	45	153	25.0000
217	153	12	25.0098
218	46	154	200.0000
219	154	13	0.0166
220	47	155	25.0084
221	155	14	25.0084
222	48	109	25.0012
223	109	125	0.0008
224	125	140	0.0015
225	140	156	0.0027
226	156	169	0.0030
227	169	180	0.0030
228	180	187	0.0027
229	187	15	25.0019
230	49	110	0.0027
231	110	126	0.0019
232	126	141	0.0032
233	141	157	0.0049
234	157	170	0.0055
235	170	181	0.0055
236	181	188	0.0046
237	188	16	0.0003
238	50	111	25.0012
239	111	127	0.0008
240	127	142	0.0015
241	142	158	0.0027
242	158	171	0.0030
243	171	182	0.0030
244	182	17	0.0009
245	51	112	0.0015
246	112	128	0.0010
247	128	143	0.0019
248	143	159	0.0030
249	159	172	0.0030
250	172	18	25.0026
251	52	113	25.0022
252	113	129	0.0014
253	129	144	0.0035
254	144	160	0.0055
255	160	173	0.0055

256	173	19	0.0018	
257	53	145	0.0047	
258	20	145	0.0052	50.00 - Fixed
259	54	146	0.0076	
260	21	146	0.0052	50.00 - Fixed
261	56	130	0.0041	
262	57	131	0.0026	
263	132	133	25.0019	
264	147	148	0.5102	
265	133	134	200.0000	
266	148	149	200.0000	
267	134	135	25.0000	
268	135	136	25.0000	
269	149	162	0.2500	
270	176	162	0.1479	
271	121	163	200.0000	
272	176	163	12.5000	
273	163	164	0.0472	
274	165	164	0.0434	
275	165	122	50.0000	
276	165	166	50.0000	
277	165	189	50.0000	
278	122	123	2.7778	
279	124	123	2.7778	
280	137	138	2.7778	
281	139	138	2.7778	
282	150	151	1.5625	
283	152	151	1.5625	
284	166	167	1.5625	
285	168	167	1.5625	
286	177	178	1.5646	
287	179	178	1.5646	
288	184	185	1.5646	
289	186	185	1.5646	
290	189	190	0.0033	45.00 - Fixed
291	191	190	0.0033	45.00 - Fixed
292	192	193	0.0033	45.00 - Fixed
293	194	193	0.0033	45.00 - Fixed
294	124	153	50.0000	
295	168	153	50.0000	
296	191	153	50.0000	
297	153	154	0.0472	
298	155	154	0.0567	
299	155	125	50.0000	
300	155	156	200.0000	
301	155	180	50.0000	
302	109	110	25.0000	
303	111	110	0.0023	20.00 - Fixed
304	125	126	25.0000	
305	127	126	0.0023	20.00 - Fixed
306	140	141	2.7778	
307	142	141	2.7778	
308	156	157	1.5625	
309	158	157	1.5625	
310	169	170	1.5625	
311	171	170	1.5625	

312	180	181	1.5625 ✓	
313	182	181	1.5625 ✓	
314	187	188	2.7778 ✓	
315	127	128	50.0000	
316	171	172	50.0000	
317	113	112	0.0024	20.00 - Fixed
318	129	128	0.0024	20.00 - Fixed
319	143	144	1.5625 ✓	
320	159	160	1.5625 ✓	
321	172	173	1.5625 ✓	
322	145	146	0.0001 ✓	
323	131	130	0.0009	
324	288	65	0.0012	
325	84	288	200.0000	

**** OUTPUT DATA ****

Annual costs are based on electricity charges of 4.0 cents per kWhr and fan efficiencies of 70.0%
Cost given for an NVP represents money saved by natural ventilation

*** FAN OPERATING POINTS ***

Fan No.	From	To	Pressure in.w.g.	Quantity kcfm	Air Power hp	Op.Cost $/year
1	78	79	9.000	411.79	583.99	217,979
2	4	3	3.250	481.25	246.46	91,992

*** BRANCH RESULTS ***

Branch	From	To	Press.Dp m.in.wg.	Airflow kcfm	Resist. P.U.	AP Loss hp	Op.Cost $/year
1	1	102	266	213.17	0.0059	8.9	3,335.1
2	102	106	266	213.17	0.0059	8.9	3,335.1
3	2	107	539	42.07	0.3047	3.6	1,333.7
4	2	1	0	-42.07	0.0000	0.0	0.0
5	78	79	1517	411.79	0.0089	98.4	36,741.5
6	78	1	0	-411.79	0.0000	0.0	0.0
7	60	59	3299	349.02	0.0271	181.4	67,721.3
8	59	1	0	349.02	0.0000	0.0	0.0
9	27	28	525	163.24	0.0197	13.5	5,040.5
10	27	1	0	-163.24	0.0000	0.0	0.0
11	4	3	1609	481.25	0.0069	122.0	45,543.0
12	3	1	0	481.25	0.0000	0.0	0.0
13	4	183	-54	-257.24	0.0008	2.2	817.0
14	4	5	-64	-224.00	0.0013	2.3	843.2
15	5	6	-14	-315.76	0.0002	0.7	260.0
16	6	7	-101	-311.17	0.0010	5.0	1,848.5
17	7	8	-95	-301.17	0.0010	4.5	1,682.8
18	8	9	-115	-297.53	0.0013	5.4	2,012.4
19	9	10	-105	-293.98	0.0012	4.9	1,815.5
20	10	11	-2	-49.00	0.0010	0.0	5.8

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21	11	12	0	-46.20	0.0001	0.0	0.0	
22	12	13	-2	-45.09	0.0011	0.0	5.3	
23	13	14	0	-6.76	0.0011	0.0	0.0	
24	14	15	-5241	-5.12	200.0001	4.2	1,578.1	
25	15	16	0	-6.28	0.0011	0.0	0.0	
26	16	17	-39	-2.83	5.0000	0.0	6.5	
27	17	18	0	-60.82	0.0002	0.0	0.0	
28	18	19	-4	-61.85	0.0011	0.0	14.5	
29	19	20	-13	-112.25	0.0011	0.2	85.8	
30	20	21	-3	-162.25	0.0001	0.1	28.6	
31	21	22	-46	-212.25	0.0010	1.5	574.2	
32	22	23	-46	-212.25	0.0010	1.5	574.2	
33	23	24	-6	-212.25	0.0001	0.2	74.9	
34	24	25	-81	-212.25	0.0018	2.7	1,011.2	
35	25	26	-51	-212.25	0.0012	1.7	636.7	
36	26	58	-40	-212.25	0.0009	1.3	499.3	
37	28	29	14	156.98	0.0006	0.3	129.3	
38	29	30	1	91.39	0.0001	0.0	5.4	
39	30	31	1	95.83	0.0001	0.0	5.6	
40	31	32	0	80.83	0.0001	0.0	0.0	
41	32	33	0	75.29	0.0002	0.0	0.0	
42	33	34	1	74.77	0.0002	0.0	4.4	
43	34	35	0	74.33	0.0002	0.0	0.0	
44	35	36	4	95.99	0.0004	0.1	22.6	
45	36	37	12	171.57	0.0004	0.3	121.1	
46	37	38	23	272.82	0.0003	1.0	369.1	
47	38	39	7	273.45	0.0001	0.3	112.6	
48	39	40	49	263.45	0.0007	2.0	759.3	
49	40	41	49	262.05	0.0007	2.0	755.2	
50	41	42	6	258.36	0.0001	0.2	91.2	
51	42	43	12	129.26	0.0007	0.2	91.2	
52	43	44	12	128.32	0.0007	0.2	90.6	
53	44	45	0	-0.65	0.0001	0.0	0.0	
54	45	46	0	0.23	0.0007	0.0	0.0	
55	46	47	0	-1.17	0.0007	0.0	0.0	
56	47	48	-4810	-4.90	200.0000	3.7	1,387.4	
57	48	49	-15	-131.45	0.0009	0.3	116.0	
58	49	50	-7	-101.89	0.0007	0.1	41.9	
59	50	51	-1	-101.38	0.0001	0.0	6.0	
60	51	52	-6	-87.26	0.0009	0.1	30.8	
61	52	53	-7	-87.27	0.0009	0.1	35.9	
62	53	54	0	-31.07	0.0003	0.0	0.0	
63	54	55	0	-26.33	0.0007	0.0	0.0	
64	55	56	0	-26.33	0.0009	0.0	0.0	
65	56	57	-19	-0.88	25.0000	0.0	1.0	
66*	58	57	293	51.00	0.1130	2.4	878.9	-Regulator Required
67	61	29	3897	4.41	200.0000	2.7	1,011.8	
68	62	30	3943	4.44	200.0000	2.8	1,029.8	
69	63	32	3968	4.45	200.0000	2.8	1,039.6	
70	64	38	4159	4.56	200.0000	3.0	1,115.5	

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71	66	42	4446	4.72	200.0000	3.3	1,233.0	
72	68	45	4632	4.81	200.0000	3.5	1,311.2	
73	48	70	13	125.72	0.0009	0.3	96.1	
74	51	72	1	38.42	0.0012	0.0	2.3	
75	54	74	1	39.06	0.0011	0.0	2.3	
76	56	76	0	24.67	0.0011	0.0	0.0	
77	77	58	6	263.25	0.0001	0.2	92.9	
78	60	61	-57	-264.02	0.0008	2.4	885.1	
79	61	62	-45	-263.89	0.0007	1.9	698.4	
80	62	63	-22	-263.93	0.0003	0.9	341.5	
81	63	196	-76	-264.04	0.0011	3.2	1,180.3	
82	196	64	-71	-255.62	0.0011	2.9	1,067.4	
83	64	288	-88	-256.14	0.0014	3.6	1,325.7	
84	65	66	-9	-248.63	0.0002	0.4	131.6	
85	66	67	-76	-249.70	0.0012	3.0	1,116.2	
86	67	68	-84	-246.23	0.0014	3.3	1,216.5	
87	68	69	-75	-247.80	0.0012	2.9	1,093.1	
88	69	70	-88	-244.75	0.0015	3.4	1,266.8	
89	70	71	-16	-116.22	0.0012	0.3	109.4	
90	71	72	-19	-113.58	0.0015	0.3	126.9	
91	72	73	-6	-72.72	0.0012	0.1	25.7	
92	73	74	-7	-70.47	0.0016	0.1	29.0	
93	74	75	-1	-29.37	0.0012	0.0	1.7	
94	75	76	-1	-27.54	0.0014	0.0	1.6	
95	76	77	-319	-1.26	200.0000	0.1	23.7	
96*	79	60	4182	85.00	0.5789	56.0	20,907.4	-Regulator Required
97	79	61	4124	4.54	200.0000	3.0	1,101.5	
98	80	62	3867	4.40	200.0000	2.7	1,000.2	
99	81	63	3783	4.35	200.0000	2.6	957.8	
100	197	196	3544	8.42	50.0000	4.7	1,754.9	
101	82	64	3261	4.04	200.0000	2.1	774.6	
102	85	65	2692	3.67	200.0000	1.6	581.0	
103	86	66	2658	3.65	200.0000	1.5	570.0	
104	87	67	2397	3.46	200.0000	1.3	488.2	
105	89	68	2110	3.25	200.0000	1.1	403.2	
106	90	69	1859	3.05	200.0000	0.9	333.4	
107	92	70	1577	2.81	200.0000	0.7	260.5	
108	93	71	1392	2.64	200.0000	0.6	216.0	
109	95	72	1186	2.44	200.0000	0.5	169.9	
110	96	73	1017	2.26	200.0000	0.4	134.9	
111	98	74	829	2.04	200.0000	0.3	99.3	
112	99	75	671	1.83	200.0000	0.2	72.3	
113	100	76	515	1.61	200.0000	0.1	48.6	
114	101	77	30	264.51	0.0004	1.3	466.7	
115	79	198	182	322.25	0.0018	9.2	3,449.5	
116	198	80	29	322.25	0.0003	1.5	549.6	
117	80	81	60	317.85	0.0006	3.0	1,121.7	
118	81	197	163	313.50	0.0017	8.1	3,005.5	
119	197	82	210	305.08	0.0023	10.1	3,768.2	
120	82	83	25	301.04	0.0003	1.2	442.7	

121	83	84	192	301.04	0.0021	9.1	3,399.6	
122	84	85	187	297.20	0.0021	8.[illegible]	3,268.8	
123	85	86	24	293.53	0.0003	1.1	414.3	
124	86	87	184	289.88	0.0022	8.4	3,137.2	
125	87	88	179	286.42	0.0022	8.1	3,015.5	
126	88	89	22	286.42	0.0003	1.0	370.6	
127	89	90	175	283.17	0.0022	7.8	2,914.6	
128	90	91	171	280.12	0.0022	7.5	2,817.4	
129	91	92	21	280.12	0.0003	0.9	346.0	
130	92	93	168	277.31	0.0022	7.3	2,740.2	
131	93	94	165	274.68	0.0022	7.1	2,665.6	
132	94	95	21	274.68	0.0003	0.9	339.3	
133	95	96	162	272.24	0.0022	6.9	2,594.0	
134	96	97	159	269.98	0.0022	6.8	2,524.8	
135	97	98	20	269.98	0.0003	0.9	317.6	
136	98	99	157	267.95	0.0022	6.6	2,474.3	
137	99	100	155	266.11	0.0022	6.5	2,426.0	
138	100	199	19	264.51	0.0003	0.8	295.6	
139	199	101	146	264.51	0.0021	6.1	2,271.4	
140	28	114	979	6.26	25.0000	1.0	360.4	
141	114	132	8	131.26	0.0005	0.2	61.8	
142	132	147	23	132.90	0.0013	0.5	179.8	
143	147	161	6	146.16	0.0003	0.1	51.6	
144	161	174	15	146.16	0.0007	0.3	128.9	
145	174	175	3	148.27	0.0002	0.1	26.2	
146	175	183	23	151.85	0.0010	0.5	205.4	
147	183	5	-10	-95.40	0.0012	0.1	56.1	
148*	29	115	880	70.00	0.1797	9.7	3,623.1	-Regulator Required
149*	103	116	847	25.00	1.3568	3.3	1,245.4	-Regulator Required
150*	104	117	846	30.00	0.9401	4.0	1,492.8	-Regulator Required
151	117	116	2	30.00	0.0032	0.0	3.5	
152	116	115	22	53.00	0.0073	0.2	71.2	
153	115	114	84	125.00	0.0054	1.7	617.6	
154	33	103	6	0.52	25.0000	0.0	0.2	
155	34	104	4	0.43	25.0000	0.0	0.1	
156	104	103	0	24.48	0.0016	0.0	0.0	
157	118	119	-3	-27.34	0.0044	0.0	4.9	
158	119	120	0	16.10	0.0024	0.0	0.0	
159	120	121	45	1.36	25.0000	0.0	3.6	
160	106	105	11	47.77	0.0052	0.1	30.9	
161	106	107	6	45.78	0.0032	0.0	16.2	
162	107	108	43	1.35	25.0021	0.0	3.6	
163	118	105	2	27.34	0.0035	0.0	3.3	
164	105	35	1	21.66	0.0022	0.0	1.3	
165	119	106	-5	-44.04	0.0029	0.0	12.9	
166	106	36	16	75.58	0.0030	0.2	71.1	
167	120	107	0	14.75	0.0020	0.0	0.0	
168	107	37	22	101.25	0.0022	0.4	131.0	

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169	105	104	4	54.05	0.0016	0.0	12.7	
170	133	148	1	14.36	0.0051	0.0	0.8	
171*	31	133	903	15.00	4.0176	2.1	796.7	-Regulator Required
172	148	174	112	2.12	25.0000	0.0	14.0	
173*	32	134	700	10.00	7.0071	1.1	411.7	-Regulator Required
174	134	149	0	8.58	0.0051	0.0	0.0	
175	149	175	318	3.57	25.0000	0.2	66.8	
176	135	162	0	0.82	0.0092	0.0	0.0	
177*	162	183	338	10.00	3.3857	0.5	198.8	-Regulator Required
178	38	108	0	3.93	0.0010	0.0	0.0	
179	108	121	0	5.28	0.0009	0.0	0.0	
180	121	136	658	5.13	25.0000	0.5	198.7	
181	136	176	0	4.73	0.0057	0.0	0.0	
182	176	5	332	3.64	25.0057	0.2	71.2	
183*	39	163	441	10.00	4.4164	0.7	259.4	-Regulator Required
184	163	6	526	4.59	25.0088	0.4	142.0	
185	40	164	392	1.40	200.0000	0.1	32.3	
186*	164	7	424	10.00	4.2487	0.7	249.4	-Regulator Required
187	41	165	341	3.69	25.0098	0.2	74.1	
188	165	8	331	3.64	25.0000	0.2	70.9	
189	42	122	44	133.82	0.0025	0.9	346.3	
190	122	137	35	124.15	0.0023	0.7	255.6	
191	137	150	37	117.81	0.0027	0.7	256.4	
192	150	166	37	110.73	0.0030	0.6	241.0	
193	166	177	32	103.17	0.0030	0.5	194.2	
194	177	184	29	98.66	0.0030	0.5	168.3	
195	184	189	17	94.98	0.0019	0.3	95.0	
196	189	192	1	48.55	0.0008	0.0	2.9	
197	192	9	315	3.55	25.0000	0.2	65.8	
198	43	123	177	0.94	200.0000	0.0	9.8	
199	123	138	0	14.90	0.0042	0.0	0.0	
200	138	151	3	27.03	0.0049	0.0	4.8	
201	151	167	9	40.40	0.0055	0.1	21.4	
202	167	178	14	50.83	0.0055	0.1	41.9	
203	178	185	19	58.83	0.0055	0.2	65.7	
204	185	190	14	64.98	0.0035	0.1	53.5	
205	190	193	52	154.98	0.0022	1.3	474.0	
206	193	10	141	244.98	0.0023	5.4	2,031.6	
207	44	124	40	128.97	0.0025	0.8	303.4	
208	124	139	32	119.64	0.0023	0.6	225.2	
209	139	152	34	113.85	0.0027	0.6	227.7	
210	152	168	35	107.56	0.0031	0.6	221.4	
211	168	179	30	100.58	0.0030	0.5	177.5	
212	179	186	28	97.09	0.0030	0.4	159.9	
213	186	191	17	94.63	0.0019	0.3	94.6	
214	191	194	1	47.80	0.0008	0.0	2.8	

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215	194	11	196	2.80	25.0000	0.1	32.3	
216	45	153	386	3.93	25.0000	0.2	89.3	
217	153	12	30	1.11	25.0038	0.0	2.0	
218	46	154	391	1.40	200.0000	0.1	32.2	
219	154	13	24	38.33	0.0166	0.1	54.1	
220	47	155	348	3.73	25.0084	0.2	76.4	
221	155	14	67	1.64	25.0084	0.0	6.5	
222	48	109	17	0.83	25.0012	0.0	0.8	
223	109	125	0	2.01	0.0008	0.0	0.0	
224	125	140	0	-6.95	0.0015	0.0	0.0	
225	140	156	0	-3.43	0.0027	0.0	0.0	
226	156	169	0	-3.81	0.0030	0.0	0.0	
227	169	180	0	0.86	0.0030	0.0	0.0	
228	180	187	0	-4.63	0.0027	0.0	0.0	
229	187	15	-33	-1.16	25.0019	0.0	2.2	
230	49	110	-2	-29.56	0.0027	0.0	3.5	
231	110	126	0	-10.74	0.0019	0.0	0.0	
232	126	141	0	8.08	0.0032	0.0	0.0	
233	141	157	0	7.07	0.0049	0.0	0.0	
234	157	170	0	6.34	0.0055	0.0	0.0	
235	170	181	0	6.30	0.0055	0.0	0.0	
236	181	188	0	6.93	0.0046	0.0	0.0	
237	188	16	0	3.45	0.0003	0.0	0.0	
238	50	111	-6	-0.52	25.0012	0.0	0.2	
239	111	127	0	-20.52	0.0008	0.0	0.0	
240	127	142	-2	-40.94	0.0015	0.0	4.8	
241	142	158	-5	-43.45	0.0027	0.0	12.8	
242	158	171	-6	-47.41	0.0030	0.0	16.7	
243	171	182	-8	-52.71	0.0030	0.1	24.8	
244	182	17	-3	-57.39	0.0009	0.0	10.2	
245	51	112	-4	-52.54	0.0015	0.0	12.4	
246	112	128	-1	-32.54	0.0010	0.0	1.9	
247	128	143	0	-12.12	0.0019	0.0	0.0	
248	143	159	0	-9.41	0.0030	0.0	0.0	
249	159	172	0	-5.97	0.0030	0.0	0.0	
250	172	18	-26	-1.03	25.0026	0.0	1.6	
251	52	113	0	0.01	25.0022	0.0	0.0	
252	113	129	0	-19.99	0.0014	0.0	0.0	
253	129	144	-5	-39.99	0.0035	0.0	11.8	
254	144	160	-10	-42.70	0.0055	0.1	25.1	
255	160	173	-11	-46.14	0.0055	0.1	29.9	
256	173	19	-4	-50.40	0.0018	0.0	11.9	
257	53	145	-14	-56.20	0.0047	0.1	46.3	
258*	20	145	23	50.00	0.0095	0.2	67.6	-Regulator Required
259	54	146	-14	-43.80	0.0076	0.1	36.1	
260*	21	146	27	50.00	0.0109	0.2	79.4	-Regulator Required
261	56	130	-10	-50.12	0.0041	0.1	29.5	
262	57	131	6	50.12	0.0026	0.0	17.7	
263	132	133	-67	-1.54	25.0019	0.0	6.5	

TRIAL 7
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264	147	148	-89	-13.25	0.5102	0.2	69.4	
265	133	134	-202	-1.01	200.0000	0.0	12.0	
266	148	149	-203	-1.01	200.0000	0.0	12.0	
267	134	135	4	0.42	25.0000	0.0	0.1	
268	135	136	-4	-0.40	25.0000	0.0	0.1	
269	149	162	3	4.00	0.2500	0.0	0.7	
270	176	162	3	5.18	0.1479	0.0	0.9	
271	121	163	449	1.50	200.0000	0.1	39.6	
272	176	163	-209	-4.10	12.5000	0.1	50.4	
273	163	164	0	2.81	0.0472	0.0	0.0	
274	165	164	1	5.79	0.0434	0.0	0.3	
275	165	122	-290	-2.41	50.0000	0.1	41.1	
276	165	166	-180	-1.90	50.0000	0.1	20.1	
277	165	189	-101	-1.42	50.0000	0.0	8.5	
278	122	123	146	7.25	2.7778	0.2	62.3	
279	124	123	124	6.70	2.7778	0.1	48.9	
280	137	138	111	6.34	2.7778	0.1	41.4	
281	139	138	92	5.78	2.7778	0.1	31.3	
282	150	151	78	7.08	1.5625	0.1	32.5	
283	152	151	61	6.29	1.5625	0.1	22.6	
284	166	167	49	5.65	1.5625	0.0	16.3	
285	168	167	35	4.77	1.5625	0.0	9.8	
286	177	178	31	4.51	1.5646	0.0	8.2	
287	179	178	19	3.49	1.5646	0.0	3.9	
288	184	185	21	3.69	1.5646	0.0	4.6	
289	186	185	9	2.46	1.5646	0.0	1.3	
290*	189	190	18	45.00	0.0092	0.1	47.6	-Regulator Required
291*	191	190	7	45.00	0.0035	0.1	18.5	-Regulator Required
292*	192	193	69	45.00	0.0341	0.5	182.6	-Regulator Required
293*	194	193	57	45.00	0.0284	0.4	150.9	-Regulator Required
294	124	153	345	2.63	50.0000	0.1	53.4	
295	168	153	243	2.21	50.0000	0.1	31.5	
296	191	153	166	1.83	50.0000	0.0	17.8	
297	153	154	4	9.49	0.0472	0.0	2.2	
298	155	154	42	27.45	0.0567	0.2	67.8	
299	155	125	-5140	-10.14	50.0000	8.2	3,065.5	
300	155	156	-5140	-5.07	200.0000	4.1	1,532.7	
301	155	180	-5141	-10.14	50.0000	8.2	3,066.1	
302	109	110	-34	-1.18	25.0000	0.0	2.3	
303*	111	110	14	20.00	0.0352	0.0	16.5	-Regulator Required
304	125	126	-34	-1.18	25.0000	0.0	2.4	
305*	127	126	14	20.00	0.0355	0.0	16.5	-Regulator Required
306	140	141	-34	-3.53	2.7778	0.0	7.0	
307	142	141	17	2.52	2.7778	0.0	2.5	
308	156	157	-34	-4.68	1.5625	0.0	9.4	
309	158	157	24	3.96	1.5625	0.0	5.6	

310	169	170	-34	-4.67	1.5625	0.0	9.3	
311	171	170	33	4.62	1.5625	0.0	9.0	
312	180	181	-33	-4.65	1.5625	0.0	9.0	
313	182	181	43	5.28	1.5625	0.0	13.3	
314	187	188	-33	-3.47	2.7778	0.0	6.7	
315	127	128	8	0.42	50.0000	0.0	0.2	
316	171	172	23	0.68	50.0000	0.0	0.9	
317*	113	112	2	20.00	0.0052	0.0	2.3	-Regulator Required
318*	129	128	1	20.00	0.0038	0.0	1.2	-Regulator Required
319	143	144	-11	-2.71	1.5625	0.0	1.8	
320	159	160	-18	-3.44	1.5625	0.0	3.6	
321	172	173	-28	-4.26	1.5625	0.0	7.0	
322	145	146	0	-6.20	0.0001	0.0	0.0	
323	131	130	2	50.12	0.0009	0.0	5.9	
324	288	65	-75	-252.30	0.0012	3.0	1,112.9	
325	84	288	2956	3.84	200.0000	1.8	668.5	

Number of Iterations = 62

*** REGULATOR AND BOOSTER FAN LIST ***

Branch	From	To	Regulator Resistance Required (P.U.)
66	58	57	0.1123
96	79	60	0.5779
148	29	115	0.1787
149	103	116	1.3558
150	104	117	0.9391
171	31	133	4.0137
173	32	134	7.0032
177	162	183	3.3755
183	39	163	4.4076
186	164	7	4.2309
258	20	145	0.0043
260	21	146	0.0057
290	189	190	0.0059
291	191	190	0.0002
292	192	193	0.0308
293	194	193	0.0251
303	111	110	0.0329
305	127	126	0.0332
317	113	112	0.0028
318	129	128	0.0014

The following table gives the frictional pressure relative to 0 m.in.wg. at junction No. 1
The table may be used to find neutral points and the pressure difference available to produce flow between any two junctions in the network.
** The value 99999 indicates an inaccessible junction **

Junction	Pressure	Junction	Pressure	Junction	Pressure	Junction	Pressure
1	0	2	0	3	0	4	-1641
5	-1573	6	-1559	7	-1458	8	-1363
9	-1248	10	-1143	11	-1141	12	-1141
13	-1139	14	-1139	15	4102	16	4102
17	4141	18	4141	19	4145	20	4158
21	4161	22	4207	23	4253	24	4259
25	4340	26	4391	27	0	28	-525
29	-539	30	-540	31	-541	32	-541
33	-541	34	-542	35	-544	36	-548
37	-560	38	-583	39	-590	40	-639
41	-688	42	-694	43	-706	44	-718
45	-718	46	-718	47	-718	48	4092
49	4107	50	4114	51	4115	52	4121
53	4128	54	4128	55	4128	56	4128
57	4147	58	4431	59	0	60	3299
61	3358	62	3403	63	3427	64	3576
65	3743	66	3752	67	3828	68	3914
69	3989	70	4079	71	4095	72	4114
73	4120	74	4127	75	4128	76	4128
77	4437	78	0	79	7483	80	7270
81	7210	82	6837	83	6812	84	6620
85	6435	86	6410	87	6225	88	6046
89	6024	90	5848	91	5677	92	5656
93	5487	94	5322	95	5300	96	5137
97	4978	98	4956	99	4799	100	4643
101	4467	102	-266	103	-547	104	-547
105	-543	106	-532	107	-538	108	-583
109	4075	110	4109	111	4120	112	4119
113	4121	114	-1504	115	-1419	116	-1395
117	-1393	118	-541	119	-537	120	-538
121	-583	122	-741	123	-887	124	-763
125	4070	126	4104	127	4118	128	4110
129	4111	130	4138	131	4141	132	-1512
133	-1444	134	-1241	135	-1245	136	-1241
137	-776	138	-887	139	-795	140	4070
141	4104	142	4120	143	4110	144	4116
145	4142	146	4142	147	-1535	148	-1444
149	-1241	150	-813	151	-890	152	-829
153	-1108	154	-1112	155	-1070	156	4070
157	4104	158	4128	159	4110	160	4126
161	-1541	162	-1244	163	-1032	164	-1032
165	-1031	166	-851	167	-900	168	-865
169	4070	170	4104	171	4134	172	4110
173	4137	174	-1556	175	-1559	176	-1241
177	-883	178	-914	179	-895	180	4071
181	4104	182	4147	183	-1587	184	-912
185	-933	186	-923	187	4071	188	4104
189	-930	190	-948	191	-941	192	-931
193	-1000	194	-942	196	3503	197	7047
198	7301	199	4624	288	3664		

NETWORK EXERCISE COMPLETE

We hope this run has been successful .... VNETPC

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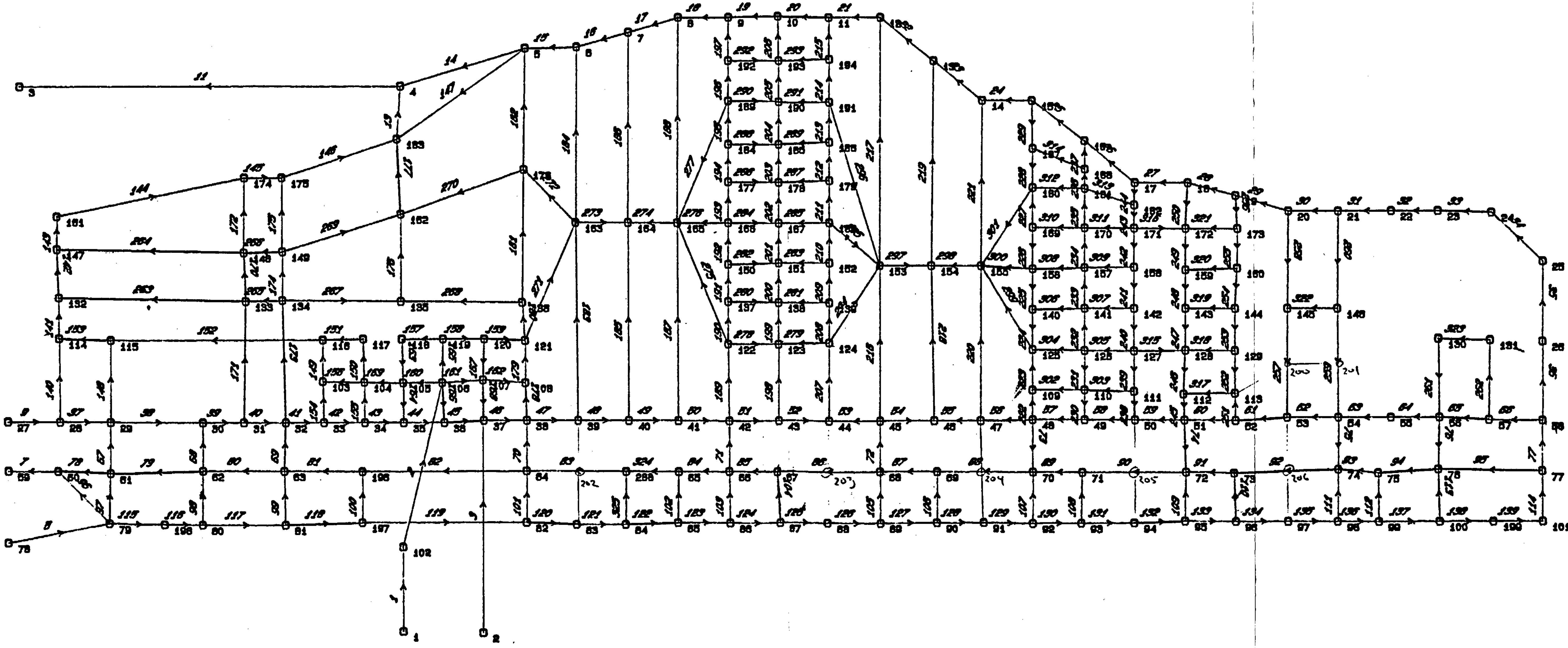
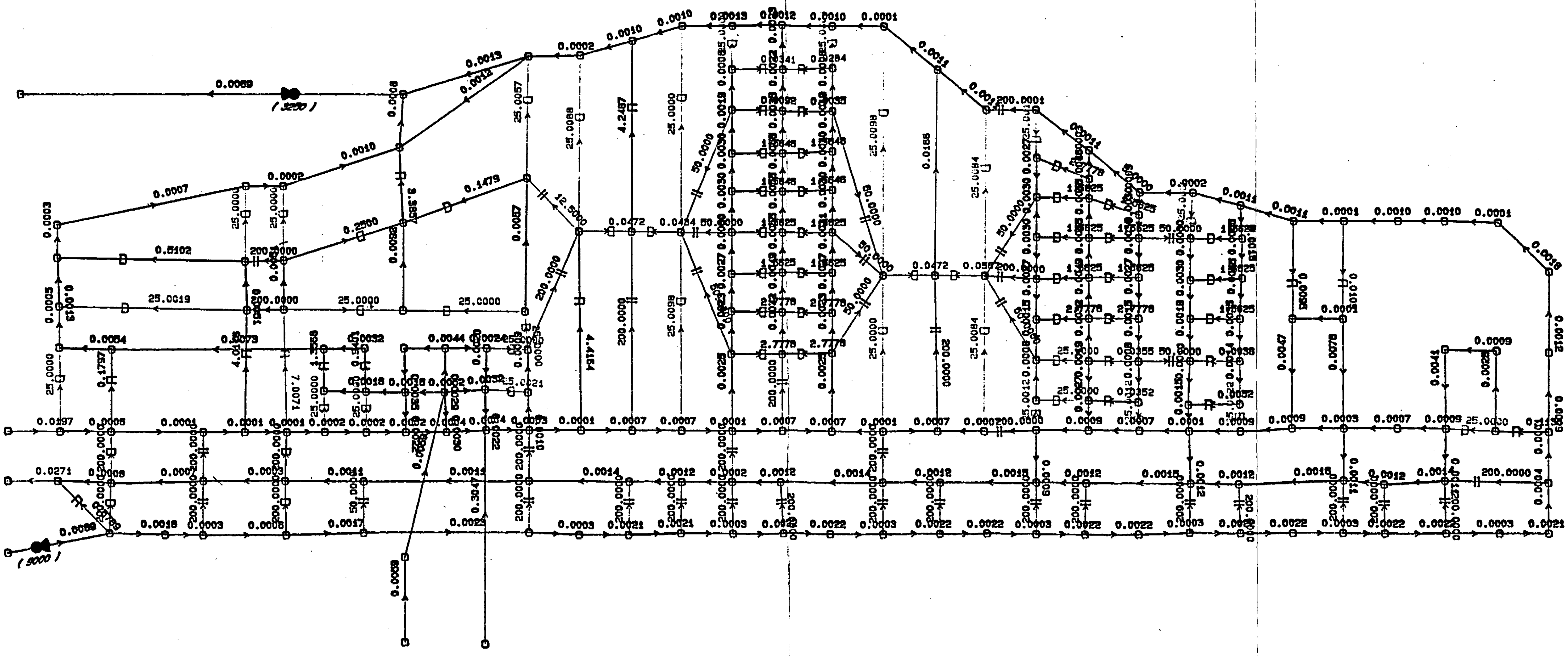


vtuff1 - Branch Numbers

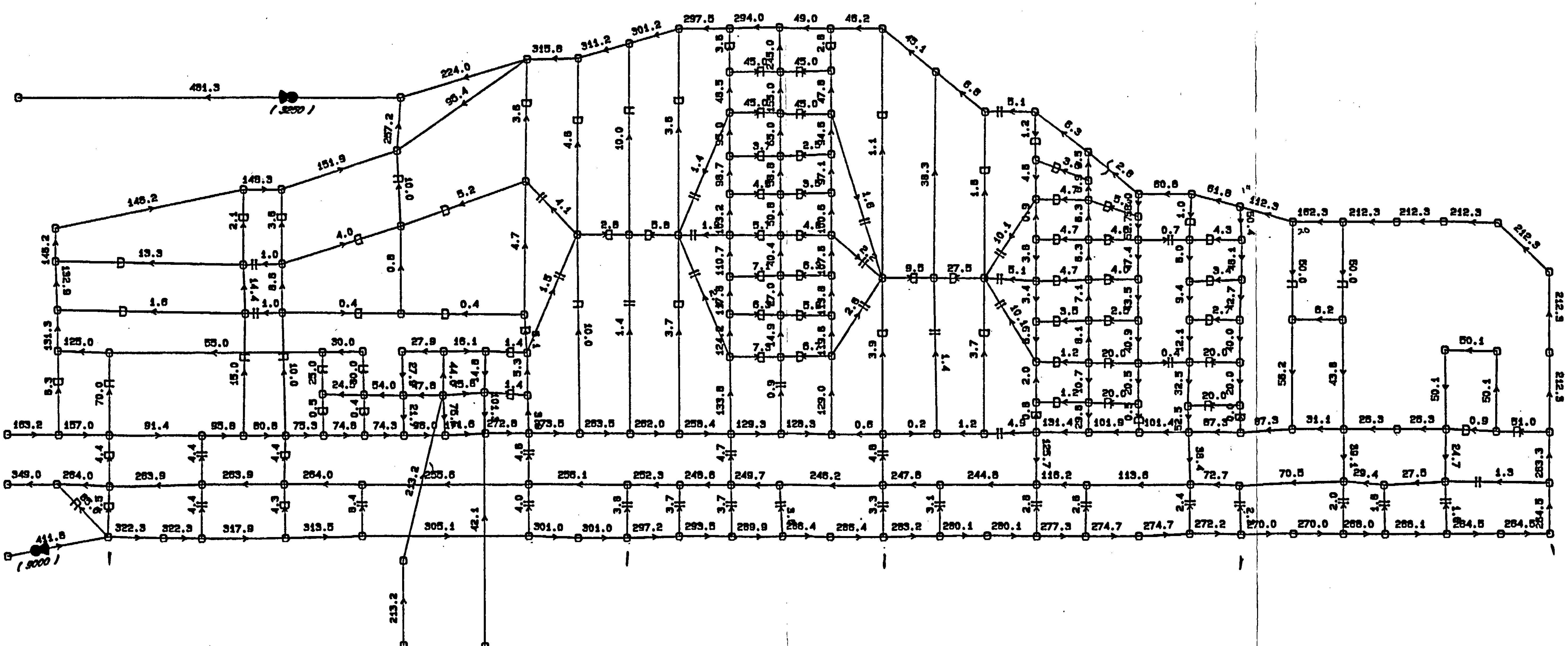
TRIAL 7
VNETPC (VERSION 1.1)
JOB # 3696A161
DESIGNED BY: GR ROGERS
4/11/86

KEY - Resistance P.U.	LOW	- HIGH
	0	.001
	.001	.01
	.01	.1
	.1	5.1
	5.1	25.1
	25.1	400.1



vtuff1 - Resistance

TRIAL 7
VNETPC (VERSION 1.1)
JOB # 3696A161
DESIGNED BY: CR ROGERS
4/11/86



vtuff1 — Airflow

TRIAL 7 Final
VNETPC (VERSION 1.1)
JOB # 3696A161
DESIGNED BY: CK ROGERS
4/1/86

Objective

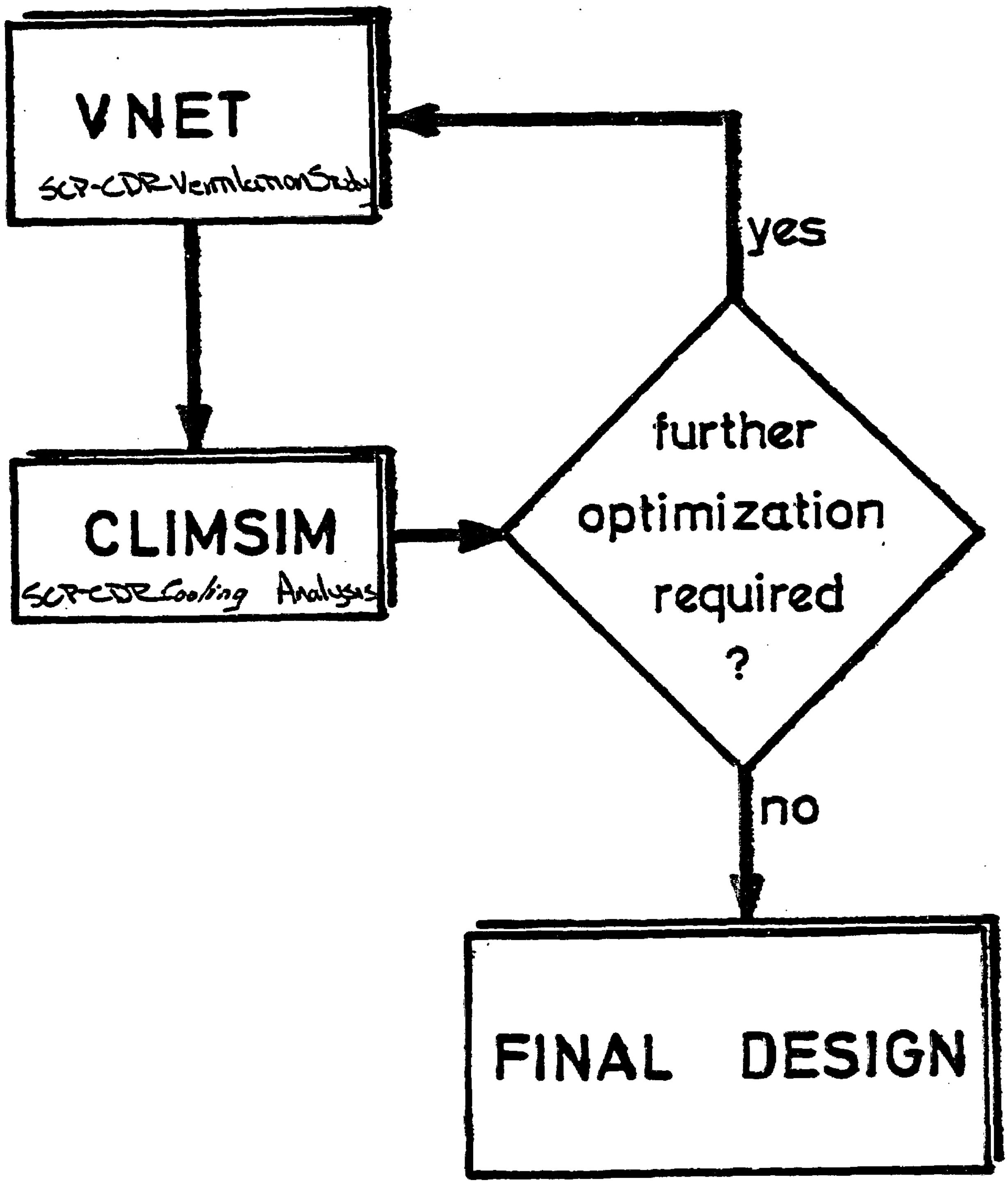
The objective of this cooling analysis is to assess the climatic conditions of the air entering all working areas. These areas include, for the development system, the mining, drilling and haulage areas, and for the emplacement system, the emplacement, partial retrieval (if applicable) and transport areas.

Procedure

The procedure employed to establish the underground environmental conditions consists of using data supplied from the SCP-CDR ventilation analysis, rock thermal parameters and surface climatic conditions. The computer program used for this analysis is the CLIMSIM (Climatic Simulation) code. The CLIMSIM program assumes heat travels by two-dimensional radial conduction to or from an airway. The theoretical and practical background of CLIMSIM is available. The program uses SI units only.

To understand the application of CLIMSIM it is best to look at the required input and the output of a CLIMSIM simulation. Page C illustrates the input/output of CLIMSIM. The modelling procedure consists of modelling a series of airways from the surface through to the underground area of interest. The first airway (or branch) modelled is one which connects the surface to the underground. For this branch the inlet conditions are the surface climate. The airway dimensions and airflows are taken from the SCP-CDR ventilation analysis. The results of the first branch analysis are used as input to the second branch analysis. Again the airway dimensions and airflows are taken from the ventilation analysis for the second airway. This process continues until the branch of interest is modelled.

VNET-CLIMSIM Modelling Procedure



CLIMSIM INPUT

Initial parameters for the prediction of heat and humidity

Physical description of Twelve Foot ES Shaft

Length = 311 m, Depth in = 0 m, Depth out = 311 m
Cross-sectional area = 10.5 m^2, Wetness factor = .005
Airway friction coefficient = .003 kg/m^3
Age = 20 years, 0 weeks, 0 days, 0 hours

Ventilation at intake

Quantity = 316.15 (m^3/s), Pressure = 88 (kPa)
Wet bulb temp. = 15.2 Deg C, Dry bulb temp. = 30.3 Deg C

Thermal Parameters

V.R.T. at inlet = 10 Deg C, Geothermal step = 20.73 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 319.763 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 6 output stations

Plant

No plant for this simulation

CLIMSIM OUTPUT

Predicted Environment: Twelve Foot ES Shaft

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.30	15.20	6.22	20.18	88.000	1.006	45.95	10.0	6152	19.73	18.[illegible]
52	30.77	15.38	6.22	19.75	88.382	1.006	46.44	12.5	6116	19.83	19.[illegible]
104	31.25	15.60	6.23	19.32	88.768	1.009	46.93	15.0	6068	20.13	19.[illegible]
156	31.72	15.81	6.23	18.91	89.154	1.012	47.42	17.5	6023	20.42	19.[illegible]
207	32.20	16.02	6.24	18.50	89.541	1.015	47.91	20.0	5977	20.71	20.[illegible]
259	32.67	16.22	6.24	18.11	89.930	1.017	48.40	22.5	5932	21.00	20.[illegible]
311	33.15	16.42	6.25	17.72	90.320	1.020	48.90	25.0	5888	21.29	20.[illegible]

Assumptions

The assumptions and constraints employed for this analysis are described as follows:

- Heat transfer from the rock is radially towards the airway (canister loading)
- The canister thermal load does not effect the main airways or shafts
- The mean summer surface conditions are estimated and used in this analysis. Mean conditions are acceptable because the underground environment does not completely realize the variations in conditions on surface due to conduction of heat to and from the rock mass.
- The geothermal gradient is estimated using a surface VRT of 10 °C, linearly increasing to a horizon temperature of 25 °C.
- The surrounding rock will not release significant amounts of water into the airway although partially saturated at 80%. The wetness factor used for this analysis is .02 for drifts. .005 for shafts.
- The thermal properties of the repository horizon are used in the analysis of conditions through the shafts and ramps.

General Environmental Criteria

Unless otherwise noted in the development or waste emplacement ventilation sections, the underground climate in all working areas shall meet the following environmental criteria:

Air Cooling Power (ACP)** >= 500 W/m^2
Dry Bulb Temperature (td) <= 40 C (104 F)

All meteorological design parameters necessary to determine the underground climate are estimated from Sandia report SAND84-0440/2, "Meteorological Design Parameters for the Canidate Site of a Radioactive-Waste Repository at Yucca Mountain, Nevada", December, 1984.

Cooling Analysis for Vertical Emplacement

The cooling analysis is performed with the climatic simulation code, CLIMSIM, initiating at the surface and proceeding through the main airways to the mining and emplacement operations.

The development system will be analyzed first, initiating at the surface, down the development intake shaft, along the service main, around the perimeter drift, to the mining and drilling analysis. One mining panel will be assessed and the results interpolated to the other mining panel. The drilling panel will also be assessed and the center main evaluated to the surface.

The emplacement system will be evaluated starting at the surface of the E.S. and the waste ramp. Climatic evaluations will proceed along the waste main and through the emplacement operations in one panel.

The drift sizes, drift lengths and airflow rates are obtained from the ventilation simulations.

Surface Conditions and rock properties

VRT at repository horizon = 25°c (Based on interpolated results from RIB).
Depth of repository horizon at the ES shafts = 1020 ft. = 311m (SCP-CDR)
Assuming a surface VRT of 10°c, the geothermal step is 311m/(25-10°c) = 20.7 m/°c

Conductivity = 2.07 W/m°c (Based on RIB)
Diffusivity = 312.385 ft²/yr = 0.0033 m²/hr (Computed from k/ρCp × 3600 s/hr),
density = 2340. kg/m³ (Based on RIB), Cp = 961.54 J/kg°C (Computed from RIB)

Elevations:

Waste ramp - surface = 3687', Base = 3100'; Δ = 587.0' = 178.9m

Tuff Ramp - surface = 3914', Base = 3100'; Δ = 814.0' = 248.1m

Men + Materials - surface = 4140', Base = 3055'; Δ = 1,085.0' = 322.5m

ES SHAFTS - Δ = 1020.0' = 310.9m

Surface Climatic Conditions:

Mean	Dry Bulb °c	Wet Bulb °c	Pressure (kPa)
Summer	30.3	15.2	88.0
Winter	9.5	4.0	88.4

Parsons Brinckerhoff

Parsons Brinckerhoff Quade & Douglas, Inc.
Engineers • Architects • Planners

COMPUTATION SHEET

Job No. 3696 A161
Made by D. Bruns
Date 4/14/86
Checked by GK ROGERS
Date 5/6/86

Subject Vertical Emp. Cooling Analysis

Drift Sizes

R.L.	Drift Type	Area ft²	Area m²	Perimeter ft.	Perimeter m	Friction Factor lbs min²/ft⁴ x10¹⁰	kg/m³
A	Waste Ramp	281	26.11	62.35	19.00	30	.0056
B	Waste Main	425	39.48	74.20	22.62	60	.0111
C	Tuff Ramp	400	37.16	86.00	26.21	60	.0111
D	Tuff Main (w/Belt)	386	35.30	88.50	26.97	70	.0130
E	Tuff Main (w/o Belt)	398	36.98	73.50	22.40	70	.0130
F	Service Main	303	28.15	68.55	20.89	70	.0130
G	Perimeter Drift	372	34.56	68.75	20.96	60	.0111
H	Panel Access (w/Belt)	217	20.16	74.30	22.65	70	.0130
I	Panel Access (w/o Belt)	237	22.02	59.90	18.26	70	.0130
J	Exhaust Drift (N10 Panel)	185	17.19	51.73	15.77	70	.0130
K	Emplacement Drift	305	28.34	67.70	20.63	70	.0130

Age

10 yrs. Development - this is the age of the drifts at the base of the M+M shaft. For simplicity the age of the workings decrease linearly from north to south. 'Development Schedule' utilized is identical to that used for Horiz. Emplacement.

Equipment Utilized

1. LHD - Diesel, 277 hp = 206.6 kW
2. Jumbo - electric, 210 hp = 157 kW
3. Bolter - electric, 210 hp = 157 kW
4. Feeder Breakers at Conveyor heads, electric, 150 hp = 112 kW
5. Conveyors in Tuff main, motors at base of ramp & every 2400', electric 200 hp = 149 kW
6. TBM, 19', electric at 1300 hp = 919 kW
7. Conveyor for TBM, 5000' @ 175 hp = 130 kW
8. Pilot hole drill + vacuum system (1 for every 2 reamer drills) = 342 + 200 = 542 hp = 404 kW
9. Reamer drill w/vacuum 220 + 210 hp = 430 hp = 321 kW

Development System

78-79 - M&M shaft - input

L = 322.5 m
A = 27.13 m²
per = 21.21 m
k = .0176 kg/m³
Q = 411.8 kcfm
= 194.3 m³/s

twbi = 15.2°C
tdbi = 30.3°C
P = 88 kPa + 2.241 kPa (Pfan) = 90.24 kPa
VRT = 10°C
mean age = 11y in, 10y out = 96,360 and 87,600 hrs.
WF = .005
geothermal step = 21.46 m/°C

M&M shaft (output)

twb = 16.54°C (61.8, 91.3°F)
tdb = 32.95°C
P = 93.3 kPa
ACP = 2530 W/m²

Service Main (79-84)

Six - Branches
A = 28.15 m²
per. = 20.89 m
k = .013 kg/m³

WF = .02
VRT = 25°C
twbi = 16.54°C
tdbi = 32.95°C
Pi = 93.3 kPa

Age in = 87600 hrs
Age out = 61,320 hrs

depth in = out = 311 m, step = 20.7 m/°C

	L	Q (kcfm)
79-198	265'	322.3
198-80	85'	322.3
80-81	180'	317.9
81-197	500'	313.5
197-82	680'	305.1
82-83	85'	301
83-84	640'	301

L = 2,435' = 742.2 m
Q̄ = 312 kcfm = 147.2 m³/s

Output
twb = 16.50°C (61.7, 87.3°F)
tdb = 30.70°C
P = 93.13 kPa

84-89

	L	Q (kcfm)
84-85	640'	297.2
85-86	85'	293.5
86-87	610'	289.9
87-89	795'	286.4

2,130' = 649.2 m
Q̄ = 291.8 kcfm = 137.7 m³/s

A = 28.15 m²
per. = 20.89 m
WF = .02
twbi = 16.5°C
tdbi = 30.7°C
Pi = 93.13 kPa

Age in = 61,320 hrs.
Age out = 4.5y = 39,420 hrs.

Output
twb = 16.48°C (61.7, 84.2°F)
tdb = 29.0°C
P = 93.0 kPa

Initial parameters for the prediction of heat and humidity

Physical description of M&M SHAFT

Length = 322.5 m, Depth in = 0 m, Depth out = 322.5 m
Perimeter = 21.21 m, Cross-sectional area = 27.13 m^2
Wetness factor = .005 , Airway friction coefficient = .0176 kg/m^3
Age at inlet 96300 (hrs), Age at outlet 87600 (hrs)

Ventilation at intake

Quantity = 194.3 (m^3/s), Pressure = 90.24 (kPa)
Wet bulb temp. = 15.2 Deg C, Dry bulb temp. = 30.3 Deg C

Thermal Parameters

V.R.T. at inlet = 10 Deg C, Geothermal step = 21.46 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 446.210 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 6 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696 A161 Sheet 5 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE __________

Description: 10 yr Development CHECKED BY: GR DATE __________

Predicted Environment: M&M SHAFT

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.30	15.20	5.91	19.68	90.240	1.032	45.18	10.0	2665	19.73	18.66
54	30.74	15.41	5.93	19.38	90.752	1.032	45.67	12.5	2646	19.86	19.02
108	31.17	15.63	5.95	19.08	91.264	1.036	46.17	15.0	2623	20.15	19.38
161	31.61	15.86	5.98	18.78	91.779	1.041	46.67	17.5	2600	20.45	19.74
215	32.06	16.09	6.00	18.49	92.296	1.045	47.17	20.0	2577	20.74	20.09
269	32.50	16.32	6.02	18.21	92.816	1.049	47.68	22.5	2553	21.03	20.44
323	32.95	16.54	6.05	17.93	93.337	1.054	48.18	25.0	2530	21.33	20.79

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Job No. 3696A161 Sheet 6 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Dunn DATE 4/14/86

Description: 10 yr Development CHECKED BY: CK ROGERS DATE 5/6/86

Initial parameters for the prediction of heat and humidity

Physical description of 79-84 SERVICE

Length = 742.2 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.89 m, Cross-sectional area = 28.15 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 87600 (hrs), Age at outlet 61320 (hrs)

Ventilation at intake

Quantity = 147.2 (m^3/s), Pressure = 93.3 (kPa)
Wet bulb temp. = 16.54 Deg C, Dry bulb temp. = 32.95 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 240.645 kJ/hr/m/Deg C

Distance between temperature outputs = 100 m - 7 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO.

Job No. 3696A161 Sheet 7 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: DB DATE

Description: 10 yr. Development CHECKED BY : GR DATE

Predicted Environment: 79-84 SERVICE

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	32.95	16.54	6.02	17.85	93.300	1.058	48.13	25.0	2119	21.46	20.79
106	32.61	16.54	6.16	18.59	93.275	1.058	48.11	25.0	2119	21.40	20.56
212	32.27	16.54	6.28	19.33	93.251	1.059	48.09	25.0	2119	21.30	20.34
318	31.94	16.53	6.41	20.08	93.226	1.060	48.07	25.0	2120	21.19	20.12
424	31.62	16.53	6.53	20.83	93.201	1.060	48.05	25.0	2120	21.10	19.90
530	31.31	16.51	6.65	21.58	93.177	1.061	48.03	25.0	2122	20.99	19.68
636	31.00	16.50	6.77	22.34	93.152	1.062	48.01	25.0	2123	20.89	19.45
742	30.70	16.50	6.89	23.11	93.127	1.063	48.00	25.0	2123	20.80	19.24

Initial parameters for the prediction of heat and humidity

Physical description of 84-89 SERVICE

Length = 649.2 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.89 m, Cross-sectional area = 28.15 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 61320 (hrs), Age at outlet 39420 (hrs)

Ventilation at intake

Quantity = 137.7 (m^3/s), Pressure = 93.13 (kPa)
Wet bulb temp. = 16.5 Deg C, Dry bulb temp. = 30.7 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 225.114 kJ/hr/m/Deg C

Distance between temperature outputs = 100 m - 6 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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PAGE NO. _____

Job No. 3696 A161   Sheet 9 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: D.B.   DATE ________

Description: 10 yr Development   CHECKED BY : G.R.   DATE ________

Predicted Environment: 84-89 SERVICE

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.70	16.50	6.92	23.21	93.130	1.063	48.07	25.0	2047	20.76	19.23
108	30.40	16.50	7.03	24.00	93.108	1.063	48.05	25.0	2047	20.71	19.01
216	30.11	16.50	7.15	24.78	93.086	1.064	48.03	25.0	2047	20.62	18.79
325	29.82	16.50	7.26	25.57	93.064	1.065	48.02	25.0	2047	20.53	18.57
433	29.54	16.49	7.37	26.36	93.041	1.065	48.00	25.0	2048	20.44	18.35
541	29.27	16.49	7.47	27.16	93.019	1.066	47.99	25.0	2049	20.36	18.13
649	29.00	16.48	7.58	27.95	92.997	1.067	47.98	25.0	2050	20.27	17.91

Service Main, Cont.

89-96

Juncts.	L	Q (kcfm)
89-90	660'	283.2
90-92	745'	280.1
92-93	660'	277.3
93-95	745'	274.7
95-96	660'	272.2
	3,470'	$\bar{Q}$ = 277.5 kcfm
	1057.7 m	= 130.9 m³/s

twbi = 16.48°C Agein = 39,420 hrs
tdbi = 29.0°C Ageout = 16,644 hrs.
Pi = 93.0 kPa

Output
twb = 16.44°C (61.6, 80.1°F)
tdb = 26.70°C
P = 92.8 kPa

96-101

Juncts.	L.	Q(kcfm)
96-98	745'	270
98-99	660'	268
99-100	660'	266.1
100-101	715'	264.5
	L_T = 2,780	$\bar{Q}$ = 267.2 kcfm
	= 847.3 m	= 126 m³/s

twbi = 16.44°C Age in = 16,644 hrs.
tdbi = 26.70°C Age out = 2,920 hrs.
P = 92.8 kPa

Output
twb = 16.44°C (61.6, 77.4°F)
tdb = 25.21°C
P = 92.65 kPa

101-TBM

The perimeter drift is the same size as that for the horizontal case. The envisioned heading will be the same length and the TBM heat load to the airstream will be determined by a CLIMSIM run with the TBM @ 20% utilizati[on]. The amount of air required for the TBM is 20 m³/s as determined in the horizontal analyses.

L = 309.8 m
A = 34.56 m²
per = 20.96 m
k = .0111 kg/m³
twbi = 16.44°C
tdbi = 25.21°C
WF = .05

inlet age = 504 hrs, outlet 0 hrs.

No heat transfer between air + the duct is assumed.
For simulation - exhaust over lap system and TBM is at 290 m

TBM load: 972 kW @ 20% power utilization
conveyor motor: 13.08 kW
heat loss along belt = 290(.225 kW/m) = 65.3 kW

two = 20.26°C
tdbo = 36.57°C
Mixture at 101
(20.26 - 16.44)(20/126.1) + 16.44 = 17.0[...]
(36.57 - 25.21)(20/126.1) + 25.21 = 27.[...]

Initial parameters for the prediction of heat and humidity

Physical description of 89-96 SERVICE

Length = 1057.7 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.89 m, Cross-sectional area = 28.15 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 39420 (hrs), Age at outlet 16644 (hrs)

Ventilation at intake

Quantity = 130.9 (m^3/s), Pressure = 93 (kPa)
Wet bulb temp. = 16.48 Deg C, Dry bulb temp. = 29 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 213.997 kJ/hr/m/Deg C

Distance between temperature outputs = 100 m - 11 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696 A161 Sheet 12 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DR DATE __________

Description: 10 yr. Development CHECKED BY : GR DATE __________

Predicted Environment: 89-96 SERVICE

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.00	16.48	7.61	28.07	93.000	1.067	48.06	25.0	1994	20.24	17.91
96	28.77	16.48	7.70	28.78	92.982	1.067	48.04	25.0	1994	20.19	17.71
192	28.54	16.48	7.79	29.49	92.964	1.068	48.03	25.0	1994	20.13	17.52
288	28.32	16.48	7.88	30.20	92.947	1.068	48.02	25.0	1994	20.06	17.33
385	28.10	16.48	7.96	30.90	92.929	1.069	48.01	25.0	1994	19.99	17.14
481	27.89	16.47	8.04	31.61	92.911	1.069	48.00	25.0	1995	19.92	16.95
577	27.68	16.47	8.13	32.31	92.893	1.070	47.99	25.0	1996	19.86	16.77
673	27.47	16.47	8.21	33.01	92.875	1.070	47.99	25.0	1996	19.80	16.58
769	27.27	16.46	8.29	33.71	92.857	1.071	47.98	25.0	1997	19.73	16.40
865	27.08	16.46	8.37	34.41	92.839	1.071	47.98	25.0	1997	19.67	16.21
962	26.89	16.46	8.44	35.11	92.821	1.072	47.97	25.0	1997	19.61	16.03
1058	26.70	16.44	9.52	35.80	92.803	1.072	47.97	25.0	1998	19.55	15.85

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Job No. 3696A161 Sheet 13 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/14/86

Description: 10 yr Development CHECKED BY: GR ROGERS DATE 5/6/86

Initial parameters for the prediction of heat and humidity

Physical description of 96-101 SERVICE MAIN

Length = 847.3 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.89 m, Cross-sectional area = 28.15 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 16644 (hrs), Age at outlet 2920 (hrs)

Ventilation at intake

Quantity = 126 (m^3/s), Pressure = 92.8 (kPa)
Wet bulb temp. = 16.44 Deg C, Dry bulb temp. = 26.7 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 205.987 kJ/hr/m/Deg C

Distance between temperature outputs = 100 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161   Sheet 14 of 150

Job Title Vent. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yr Development   CHECKED BY : GR   DATE ________

Predicted Environment: 96-101 SERVICE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.70	16.44	8.53	35.87	92.800	1.072	48.00	25.0	1958	19.52	15.85
106	26.50	16.44	8.61	36.63	92.782	1.072	48.00	25.0	1958	19.48	15.65
212	26.30	16.44	8.69	37.39	92.763	1.073	47.99	25.0	1958	19.42	15.45
318	26.11	16.44	8.77	38.15	92.745	1.073	47.99	25.0	1958	19.37	15.26
424	25.92	16.44	8.85	38.90	92.727	1.074	47.99	25.0	1959	19.31	15.07
530	25.73	16.44	8.92	39.65	92.709	1.074	47.99	25.0	1959	19.25	14.88
635	25.56	16.44	9.00	40.39	92.690	1.075	47.99	25.0	1959	19.20	14.69
741	25.38	16.44	9.07	41.12	92.672	1.075	47.99	25.0	1959	19.15	14.51
847	25.21	16.44	9.14	41.85	92.654	1.075	47.99	25.0	1959	19.10	14.32

Initial parameters for the prediction of heat and humidity

Physical description of 101 tbm

Length = 304.8 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.96 m, Cross-sectional area = 34.56 m^2
Wetness factor = .05 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 504 (hrs), Age at outlet 0 (hrs)

Ventilation at intake

Quantity = 20 (m^3/s), Pressure = 92.8 (kPa)
Wet bulb temp. = 16.44 Deg C, Dry bulb temp. = 25.21 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 22.740 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 6 output stations

Heat Sources

Spot heat sources

No.	Distance From intake end (m)	Sensible Heat Load (kW)
1	290	13

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
2	290	972.00	20.0	Electric

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	65.30	290

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Job No. 3696A161 Sheet 148 of 150

Job Title Vent. Emp. Cooling DESIGNED BY: [signature] DATE 4/14/86

Description: 10 yr. Development CHECKED BY: GB DATE ________

Predicted Environment: 101 tbm

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	25.21	16.44	9.15	41.95	92.800	1.077	48.00	25.0	776	19.07	18.23
Start linear source no. 1 sensible heat = 65.3 kW For 290 m											
51	25.59	16.60	9.21	41.30	92.800	1.077	48.55	25.0	773	19.17	18.52
102	25.95	16.77	9.28	40.73	92.800	1.076	49.07	25.0	767	19.39	18.80
152	26.29	16.93	9.35	40.20	92.800	1.074	49.58	25.0	761	19.59	19.06
203	26.61	17.09	9.41	39.72	92.800	1.073	50.07	25.0	756	19.80	19.32
254	26.92	17.25	9.48	39.29	92.799	1.072	50.55	25.0	751	19.99	19.56
After spot source no. 1 sensible heat = 13.08 kW, latent heat = 0.00 kW											
After spot source no. 2 sensible heat = 204.63 kW, latent heat = 0.00 kW											
305	36.57	20.26	9.55	22.91	92.799	1.071	60.47	25.0	674	22.18	25.38

101-58 Perimeter drift

A = 34.56 m² k = .011 kg/m³
per = 20.91 m
L = 65 + 65' = 39.6 m
Q = 263.3 + 264.5/2 = 263.9 kcfm = 124.5 m³/s
twbi = 16.98 °C
tdbi = 26.99 °C } should be 17.04/27.01, insignificant error.
Pi = 92.65 kPa
Age (mean) = 3,290 hrs.

Equipment
Conveyor from TBM to main conveyor at junction 129 generates a 0.225 kW/m · 19.8 m = 4.5 kW linear load. (As determined from horizontal analysis.)

Output
twb = 16.98 °C (62.6, 80.5 °F)
tdb = 26.97 °C
P = 92.65 kPa

58-57 Wastemain to workings

A = 39.48 m² L = 580' = 177 m
per = 22.62 m k = .0111 kg/m³
Q = 51 kcfm = 24.07 m³/s
twbi = 16.98 °C Pi = 92.65 kPa
tdbi = 26.97 °C
Age (mean) = 732 hrs.

Output (57)
twb = 16.93 °C (62.5, 79.8 °F)
tdb = 26.53 °C

58-21 - Perimeter to workings

A = 34.56 m² k = .011 kg/m³
per = 20.91 m
L = 670×2 + 90 + 1130 + 750 + 580 = 3,890' = 1,186 m
Q = 212.3 kcfm = 100.2 m³/s
twbi = 16.93 °C
tdbi = 26.53 °C
Pi = 92.65 kPa
Age in = 3,660 hrs.
Age out = 8,760 hrs.

Output (21)
twb = 16.93 °C (62.5, 77.2 °F)
tdb = 25.12 °C

21-20 perimeter

L = 85' = 25.9 m - This length will not significantly affect conditions.
Q = 162.3 kcfm = 76.6 m³/s Conditions at 20 are therefore: twb = 16.93 °C
tdb = 25.12 °C

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Job No. 3696A161 | Sheet 16 of 150

Job Title Vert. Emp. Cooling Analysis | DESIGNED BY: D. Brunne DATE 4/14/86

Description: 10 yr Development | CHECKED BY: GR ROGERS DATE 5/6/86

Initial parameters for the prediction of heat and humidity

Physical oescription of 101-58 PERIMETER DRIFT

Length = 39.6 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.96 m, Cross-sectional area = 34.56 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 3290 (hrs), Age at outlet 3290 (hrs)

Ventilation at intake

Quantity = 124.5 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.98 Deg C, Dry bulb temp. = 26.99 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 141.554 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 8 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	4.50	20

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Job No. 3696A161 Sheet 17 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: DB DATE ----------

Description: 10 yr Development CHECKED BY : GR DATE ----------

Predicted Environment: 101-58 PERIMETER DRIFT

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.99	16.98	9.11	37.54	92.650	1.069	49.70	25.0	1709	19.98	16.21
Start linear source no. 1 sensible heat = 4.5 kW For 19.8 m											
5	26.99	16.98	9.11	37.55	92.650	1.069	49.71	25.0	1709	19.97	16.21
10	26.99	16.98	9.11	37.55	92.649	1.069	49.72	25.0	1709	19.97	16.21
15	26.99	16.98	9.11	37.56	92.649	1.069	49.73	25.0	1709	19.97	16.21
20	26.99	16.98	9.12	37.57	92.648	1.069	49.73	25.0	1709	19.97	16.21
25	26.99	16.98	9.12	37.60	92.648	1.069	49.73	25.0	1709	19.98	16.20
30	26.98	16.98	9.12	37.62	92.648	1.069	49.73	25.0	1709	19.97	16.20
35	26.97	16.98	9.13	37.65	92.647	1.069	49.73	25.0	1709	19.97	16.19
40	26.97	16.98	9.13	37.68	92.647	1.069	49.73	25.0	1709	19.97	16.18

Job No. 3696A161 Sheet 18 of 150

Job Title Vent Emp. Cooling Analysis DESIGNED BY: D. Bruner DATE 4/14/86

Description: 10 yr Development CHECKED BY : G ROGERS DATE 5/6/86

Initial parameters for the prediction of heat and humidity

Physical description of 58-57 WASTE MAIN

Length = 177 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 732 (hrs), Age at outlet 732 (hrs)

Ventilation at intake

Quantity = 24.07 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.98 Deg C, Dry bulb temp. = 26.97 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 23.957 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 7 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 19 of 150

Job Title Vert Emp Cooling Analysis DESIGNED BY: D.R. DATE

Description: 10 yr Development CHECKED BY : G.R. DATE

Predicted Environment: 58-57 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.97	16.98	9.12	37.62	92.650	1.069	49.70	25.0	770	19.98	19.45
25	26.90	16.98	9.13	37.82	92.650	1.069	49.67	25.0	771	19.89	19.41
51	26.84	16.98	9.14	38.02	92.650	1.069	49.63	25.0	771	19.88	19.37
76	26.77	16.97	9.16	38.23	92.650	1.070	49.60	25.0	772	19.85	19.33
101	26.71	16.95	9.17	38.42	92.650	1.070	49.57	25.0	772	19.82	19.28
126	26.65	16.95	9.18	38.62	92.650	1.070	49.54	25.0	772	19.81	19.25
152	26.59	16.94	9.20	38.81	92.650	1.070	49.51	25.0	773	19.78	19.21
177	26.53	16.93	9.21	39.00	92.650	1.071	49.49	25.0	773	19.76	19.17

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Job No. 3696A161 Sheet 20 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.Brummer DATE 4/14/86

Description: 10 yr Development CHECKED BY : GR ROGERS DATE 5/6/86

Initial parameters for the prediction of heat and humidity

Physical description of 58-21 PERIMETER

Length = 1186 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.96 m, Cross-sectional area = 34.56 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 3660 (hrs), Age at outlet 8760 (hrs)

Ventilation at intake

Quantity = 100.2 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 26.53 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 113.925 kJ/hr/m/Deg C

Distance between temperature outputs = 100 m - 12 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. _____

Job No. 3696A161 Sheet 21 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE __________

Description: 10 yr. Development CHECKED BY : GR DATE __________

Predicted Environment: 58-21 PERIMETER

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.53	16.93	9.23	39.10	92.650	1.071	49.55	25.0	1530	19.81	16.36
99	26.40	16.93	9.28	39.61	92.645	1.071	49.54	25.0	1530	19.78	16.24
198	26.27	16.93	9.33	40.13	92.640	1.071	49.53	25.0	1530	19.74	16.12
297	26.14	16.93	9.38	40.63	92.635	1.072	49.52	25.0	1530	19.71	16.00
395	26.02	16.93	9.43	41.13	92.630	1.072	49.51	25.0	1531	19.67	15.88
494	25.90	16.93	9.48	41.63	92.625	1.072	49.50	25.0	1531	19.63	15.77
593	25.78	16.93	9.52	42.12	92.620	1.073	49.50	25.0	1531	19.60	15.65
692	25.66	16.93	9.57	42.61	92.615	1.073	49.50	25.0	1531	19.56	15.54
791	25.55	16.93	9.62	43.10	92.610	1.073	49.49	25.0	1531	19.53	15.43
890	25.44	16.93	9.66	43.58	92.605	1.074	49.49	25.0	1531	19.50	15.32
988	25.33	16.93	9.70	44.05	92.600	1.074	49.49	25.0	1532	19.47	15.21
1087	25.23	16.93	9.75	44.52	92.595	1.074	49.49	25.0	1532	19.43	15.11
1186	25.12	16.93	9.79	44.99	92.590	1.075	49.49	25.0	1532	19.40	15.00

20-19 Perimeter drift, cont.

A = 34.56 m²   L = 705' = 214.9 m
per = 20.96 m   Q = 112.3 kcfm = 52.99 ≈ 53 m³/s
k = .0111 kg/m³   twbi = 16.93°C
WF = .02   tdbi = 25.12°C
Pi = 92.65 kPa
Age (mean) = 1.8 y = 15,718 hrs.

Output
twb = 16.93°C (62.5, 76.9°F)
tdb = 24.90°C

19-18-17 Perimeter drift
L = 705' + 100' = 805' = 245.4 m
Q = 61.8 + 60.8/2 = 61.3 kcfm = 28.93 m³/s
twbi = 16.93°C
tdbi = 24.90°C
mean age = 2 yrs. = 17,520 hrs.

Output
twb = 16.93°C (62.5, 76.4°F)
tdb = 24.17°C

Summary of Development area inlet Conditions

Description	Junction	Airflow	Twb	Tdb
2 panel mains	57	51 kcfm	16.93°C	26.53°C
6 Emplacement Drifts	20, 21	50 kcfm	16.93°C	25.12°C
Drilling (2 Emp.)	19	50.4 kcfm	16.93°C	24.90°C
Drilling (2 Emp.)	17	58.0 kcfm	16.93°C	24.67°C

Initial parameters for the prediction of heat and humidity

Physical description of 20-19 PERIMETER

Length = 215 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.96 m, Cross-sectional area = 34.56 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 15768 (hrs), Age at outlet 15768 (hrs)

Ventilation at intake

Quantity = 53 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 25.12 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 60.260 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 9 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 24 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY: GR DATE ________

Predicted Environment: 20-19 PERIMETER

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	25.12	16.93	9.82	45.14	92.650	1.075	49.55	25.0	1125	19.39	16.85
24	25.10	16.93	9.83	45.25	92.650	1.075	49.55	25.0	1125	19.39	16.83
48	25.07	16.93	9.84	45.36	92.649	1.075	49.55	25.0	1125	19.38	16.81
72	25.05	16.93	9.85	45.48	92.649	1.076	49.55	25.0	1125	19.37	16.79
96	25.02	16.93	9.86	45.59	92.649	1.076	49.55	25.0	1125	19.36	16.77
119	25.00	16.93	9.87	45.70	92.648	1.076	49.55	25.0	1125	19.36	16.75
143	24.98	16.93	9.88	45.81	92.648	1.076	49.55	25.0	1125	19.35	16.74
167	24.95	16.93	9.89	45.92	92.648	1.076	49.56	25.0	1125	19.34	16.72
191	24.93	16.93	9.90	46.03	92.647	1.076	49.56	25.0	1125	19.34	16.70
215	24.90	16.93	9.91	46.14	92.647	1.076	49.56	25.0	1125	19.33	16.68

Initial parameters for the prediction of heat and humidity

Physical description of 19-17 PERIMETER

Length = 245.4 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.96 m, Cross-sectional area = 34.56 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 17520 (hrs), Age at outlet 17520 (hrs)

Ventilation at intake

Quantity = 28.93 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.9 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 32.893 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 5 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696 A161 Sheet 26 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 19-17 PERIMETER

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.90	16.93	9.91	46.15	92.650	1.076	49.55	25.0	872	19.32	17.76
49	24.85	16.93	9.93	46.38	92.650	1.076	49.55	25.0	872	19.32	17.73
98	24.81	16.93	9.95	46.60	92.650	1.076	49.56	25.0	872	19.31	17.69
147	24.76	16.93	9.97	46.82	92.649	1.076	49.56	25.0	872	19.30	17.66
196	24.72	16.93	9.99	47.04	92.649	1.077	49.57	25.0	872	19.28	17.63
245	24.67	16.93	10.01	47.26	92.649	1.077	49.58	25.0	872	19.27	17.60

57-131 Panel Access w/o Belt

$L = 450' = 137.2m$
$Q = 50.1$ kcfm $= 23.6 m^3/s$
$A = 22.02 m^2$
Per. = 18.26m
WF = .02 , k = .013
mean age = 732 hrs.
$t_{wbi} = 16.93°C$
$t_{dbi} = 26.53°C$

Output (131)

$t_{wb} = 16.92°C$
$t_{db} = 26.14°C$

131 - Heading

Drilling
$L = 750' = 228.6m$
$A = 22.02 m^2$
per = 18.26m
WF = .05
age in = 732 hrs.
age out = 0
$t_{wbi} = 16.92°C$
$t_{dbi} = 26.14°C$

Equipment Loading - 1 Jumbo
Criteria - 60 fpm = 237·60 = 14.22 kcfm = 6.7 m^3/s
Jumbo @ 157 kW electric with a 35% utilization.

Auxiliary vent system will be exhausting. For simulation purposes, the jumbo is placed 5m from the face and a climatic analysis is performed assuming the air continues to the face. No heat transfer to or from the duct will be accounted for and the conditions determined at the face will be that of the air discharging from the duct.

Output
$t_{wb} = 19.36°C$
$t_{db} = 32.83°C$
ACP = 586 w/m^2

mixture ratio = 6.7/23.6 = 0.284
conditions of mixed air.
$t_{wb} = (19.36-16.92)(0.284) + 16.92 = 17.61°C$ (63.7, 825.4)
$t_{db} = (32.83-26.14)(0.284) + 26.14 = 28.04°C$

23.6 @ 16.92/26.14
6.7 @ 19.36/32.83

Initial parameters for the prediction of heat and humidity

Physical description of 57-131 PANEL ACCESS

Length = 137 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 732 (hrs), Age at outlet 732 (hrs)

Ventilation at intake

Quantity = 23.6 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 26.53 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 49.322 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 5 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A61 Sheet 29 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 Yr Development CHECKED BY : GR DATE ________

Predicted Environment: 57-131 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.53	16.93	9.23	39.10	92.650	1.071	49.55	25.0	958	19.81	18.54
27	26.45	16.93	9.26	39.38	92.650	1.071	49.52	25.0	958	19.78	18.48
55	26.37	16.93	9.28	39.66	92.649	1.071	49.50	25.0	959	19.75	18.43
82	26.29	16.93	9.30	39.94	92.649	1.071	49.48	25.0	959	19.73	18.37
110	26.22	16.92	9.32	40.21	92.649	1.071	49.46	25.0	959	19.70	18.32
137	26.14	16.92	9.35	40.48	92.648	1.072	49.44	25.0	960	19.68	18.27

Initial parameters for the prediction of heat and humidity

Physical description of 131 - HEADING

Length = 228.6 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 732 (hrs), Age at outlet 0 (hrs)

Ventilation at intake

Quantity = 6.7 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.92 Deg C, Dry bulb temp. = 26.14 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 14.002 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 9 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	223	157.00	35.0	Electric

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Job No. 3696 A161 Sheet 31 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 16 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 131 - HEADING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	26.14	16.92	9.38	40.64	92.650	1.072	49.52	25.0	632	19.69	19.38
25	25.97	16.92	9.44	41.30	92.650	1.072	49.49	25.0	633	19.61	19.28
51	25.81	16.92	9.50	41.92	92.650	1.073	49.47	25.0	633	19.57	19.19
76	25.67	16.92	9.55	42.53	92.650	1.073	49.45	25.0	633	19.54	19.11
102	25.53	16.92	9.60	43.11	92.650	1.074	49.45	25.0	634	19.50	19.03
127	25.40	16.92	9.66	43.68	92.650	1.074	49.45	25.0	634	19.47	18.95
152	25.29	16.92	9.71	44.22	92.650	1.074	49.46	25.0	634	19.44	18.88
178	25.17	16.92	9.76	44.75	92.650	1.075	49.47	25.0	635	19.41	18.81
203	25.07	16.92	9.81	45.26	92.650	1.075	49.49	25.0	635	19.39	18.75
After spot source no. 1 sensible heat = 57.84 kW, latent heat = 0.00 kW											
229	32.83	19.36	9.86	29.04	92.650	1.076	57.45	25.0	586	21.07	23.67

131 - 130

L = 85' = 26m
Q = 23.1 m³/s

} The conditions of the air will not vary significantly along this drift with this airflow.

130 - heading

L = 750' = 228.6 m
A = 22.02 m²
per. = 18.26 m
twbi = 17.61°C
tdbi = 28.04°C
Age = 732 hrs.
Age in = 0 hrs.
WF = .05
K = .013 kg/m³

Q = 34.6 kcfm
= 16.34 m³/s

Equipment

1 - 207 kW diesel LHD @ 35% utilization of load., 3 l of water generated per liter of fuel. Located @ 114 m in drift.

Output

Q = 16.34 m³/s
twb = 20.78°C
tdb = 34.51°C
ACP = 679 W/m²

Mixture ratio:
16.34/23.1 = 0.707
twb = (20.78 − 17.61) 0.707 + 17.61 = 19.85°C (67.7, 90.7°F)
tdb = (34.51 − 28.04) .707 + 28.04 = 32.6°C

130 - 56 Panel Access w/belt

L = 137.2 m   Q = 23.1 m³/s
A = 20.11 m²
per. = 22.65 m
WF = .02
Age (mean) 732 hrs

twbi = 19.85°C
tdbi = 32.6°C

Equipment

1 - Feeder breaker - 112 kW @ 35% power utilization.
1 - 149 kW motor @ conveyor @ 90% utilization.
(149)(0.9) = 134.1 kW   10% loss @ motor = 13.4 kW
Remaining along belt = 134.1 − 13.4 = 120.7 kW
Total belt length = 137.2 + 19.8 = 157 m
Load/m = 120.7/157 = 0.768 kW/m · 137.2 = 105 kW

Output (56)

twb = 21.35°C   (70.4, 99.0°F)
tdb = 37.24°C

Initial parameters for the prediction of heat and humidity

Physical description of 130 - HEADING

Length = 228.6 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 732 (hrs), Age at outlet 0 (hrs)

Ventilation at intake

Quantity = 16.34 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 17.61 Deg C, Dry bulb temp. = 28.04 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 34.149 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 9 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	114	207.00	35.0	Diesel

Amount of water emitted by diesel = 3 liters water/liter fuel

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Job No. 3696A161 Sheet 34 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 Yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 130 - HEADING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	28.04	17.61	9.48	36.72	92.650	1.065	51.67	25.0	803	20.74	20.13
25	27.84	17.61	9.54	37.38	92.650	1.065	51.61	25.0	804	20.64	20.01
51	27.64	17.59	9.59	38.04	92.650	1.066	51.55	25.0	805	20.58	19.89
76	27.46	17.58	9.65	38.67	92.650	1.066	51.51	25.0	806	20.52	19.77
102	27.28	17.56	9.71	39.30	92.649	1.067	51.46	25.0	807	20.46	19.66
After spot source no. 1 sensible heat = 160.60 kW, latent heat = 44.43 kW											
127	36.09	20.97	10.81	26.52	92.649	1.067	63.08	25.0	708	22.80	25.41
152	35.67	20.95	10.89	27.35	92.649	1.037	62.85	25.0	670	25.19	25.23
178	35.27	20.89	10.97	28.16	92.649	1.038	62.64	25.0	673	25.04	25.04
203	34.88	20.83	11.05	28.97	92.649	1.039	62.44	25.0	676	24.90	24.85
229	34.51	20.78	11.13	29.77	92.649	1.040	62.25	25.0	679	24.76	24.67

Initial parameters for the prediction of heat and humidity

Physical description of 130-56 PANEL ACCESS

Length = 137.2 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 732 (hrs), Age at outlet 732 (hrs)

Ventilation at intake

Quantity = 23.1 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 19.85 Deg C, Dry bulb temp. = 32.6 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 52.731 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 5 output stations

Heat Sources

Spot heat sources

No.	Distance From intake end (m)	Sensible Heat Load (kW)
1	0	13

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
2	0	112.00	35.0	Electric

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	105.00	137

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Job No. 3696A161 Sheet 36 of 150

Job Title Vent. Emp Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr. Development CHECKED BY : G.R. DATE

Predicted Environment: 130-56 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	32.60	19.85	10.62	31.62	92.650	1.049	59.06	25.0	855	23.67	23.07
After spot source no. 1 sensible heat = 13.40 kW, latent heat = 0.00 kW											
Start linear source no. 1 sensible heat = 105 kW For 137.2 m											
After spot source no. 2 sensible heat = 41.26 kW, latent heat = 0.00 kW											
27	35.37	20.66	10.66	27.21	92.650	1.049	61.97	25.0	830	24.09	24.73
55	35.86	20.84	10.70	26.61	92.649	1.039	62.58	25.0	811	24.99	25.02
82	36.33	21.00	10.75	26.04	92.649	1.037	63.18	25.0	802	25.24	25.29
110	36.79	21.15	10.80	25.51	92.648	1.036	63.76	25.0	794	25.48	25.55
137	37.24	21.32	10.85	25.01	92.648	1.034	64.34	25.0	786	25.73	25.81

56-76 Panel Access w/belt

$l = 20m$ $Q = 11.11 m^3/s$

$A = 20.16 m^2$

per = 22.65

$k = .0130 \ kg/m^3$

Age = 2167 (mean)

$t_{wbi} = 21.32°C$

$t_{dbi} = 37.24°C$

Equipment:

Conveyor (20 · 0.768 kW/m) = 15.36 kW

linear source

Output (76)

$t_{wb} = 21.56°C$

$t_{db} = 38.10°C$

56-54 Waste Main

$Q = 26.3$ kcfm = 12.41 m^3/s

No Equipment, Leakage from 57 neglected.

$L = 660 \times 2 = 1{,}320' = 402m$

$A = 39.48 m^2$

per = 22.62 m

$k = .0111 \ kg/m^3$

Age = 2167 hrs in, 10,512 hrs. out

$t_{wbi} = 21.32°C$

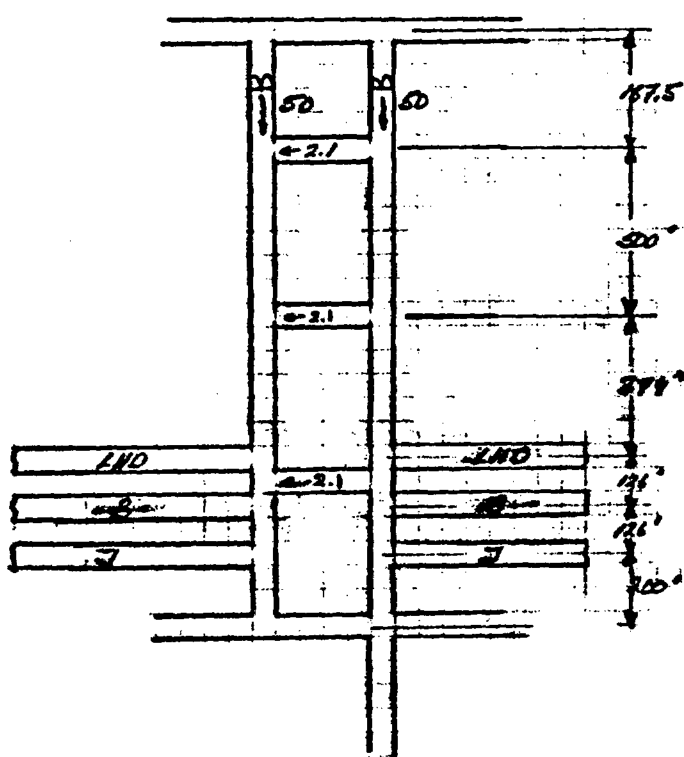
$t_{dbi} = 37.24°C$

(70.4, 99.0 °F)

Output (54)

$t_{wb} = 20.48°C$ (68.8, 92.0 °F)

$t_{db} = 33.33°C$



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Job No. 3696A161 Sheet 38 of 150

Job Title Vent Emp Cooling Analysis DESIGNED BY: D.Brunner DATE 4/15/86

Description: 10yr Development CHECKED BY : GR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 56-76 PANEL ACCESS

Length = 20 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 2167 (hrs), Age at outlet 2167 (hrs)

Ventilation at intake

Quantity = 11.66 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.32 Deg C, Dry bulb temp. = 37.24 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 26.617 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 4 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	15.36	20

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Job No. 3696A161 Sheet 39 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE

Description: 10yr Development CHECKED BY : GR DATE

Predicted Environment: 56-76 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.24	21.32	10.83	24.94	92.650	1.033	64.28	25.0	590	26.10	26.1(
Start linear source no. 1 sensible heat = 15.36 kW For 20 m											
5	37.46	21.37	10.84	24.67	92.650	1.033	64.52	25.0	594	25.81	26.21
10	37.67	21.43	10.85	24.41	92.650	1.032	64.76	25.0	591	25.91	26.31
15	37.89	21.50	10.86	24.15	92.650	1.031	65.01	25.0	588	26.02	26.4?
20	38.10	21.56	10.87	23.89	92.650	1.031	65.25	25.0	586	26.12	26.5?

Initial parameters for the prediction of heat and humidity

Physical description of 56-54 waste main

Length = 402 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 2167 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 12.41 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.32 Deg C, Dry bulb temp. = 37.24 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 12.352 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 41 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 56-54 waste main

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.24	21.32	10.83	24.94	92.650	1.033	64.28	25.0	486	26.10	26.25
50	36.56	21.18	10.87	25.99	92.650	1.033	63.69	25.0	500	25.39	25.94
101	35.96	21.04	10.91	26.95	92.650	1.035	63.19	25.0	504	25.18	25.66
151	35.43	20.92	10.95	27.85	92.650	1.037	62.75	25.0	509	24.97	25.40
201	34.95	20.80	10.99	28.70	92.650	1.039	62.35	25.0	513	24.78	25.16
251	34.50	20.70	11.03	29.52	92.650	1.040	61.99	25.0	517	24.60	24.94
302	34.08	20.61	11.06	30.31	92.650	1.042	61.66	25.0	521	24.43	24.73
352	33.70	20.52	11.10	31.07	92.650	1.043	61.35	25.0	524	24.27	24.53
402	33.33	20.44	11.13	31.81	92.650	1.045	61.07	25.0	528	24.12	24.34

21 - LHD Heading Panel access w/o belt

L = 187.5 + 500 + 374 = 1,061.5 ' = 323.5 m
A = 22.02 m²
per. = 18.26 m
k = .0130 kg/m³
t_{wbi} = 16.93 °C
t_{dbi} = 25.12 °C
$\bar{Q}$ = 50 + 47.9 + 45.8 /3 = 47.9 kcfm = 22.6 m³/s
mean age = 10,512 hrs.

Output
t_{wb} = 16.93 °C
t_{db} = 24.62 °C

LHD Heading

L = 660 ' = 201.1 m emplacement drifts driven just to breakout
A = 28.34 m²
per = 20.33 m
k = .0130 kg/m³
Q = 34.63 kcfm = 18.34 m³/s
t_{wbi} = 16.93 °C
t_{dbi} = 24.62 °C
Age = 10,512, 10 hrs.

Equipment
1 - 207 kW diesel LHD @ 35% utilization of load. 3 L water generated per liter of fuel. Located midway (approx. 100 m.

Output
t_{wb} = 20.37 °C
t_{db} = 32.35 °C

Mixture ratio : 34.8 / 50 - 4.2 = 0.76

t_{wb} = (20.37 − 16.93) 0.76 + 16.93 = 19.5 °C
t_{db} = (32.35 − 24.62) 0.76 + 24.62 = 30.5 °C

LHD - Bolter Access w/Belt

L = 126 ' = 38.4 m
Q = 45.8 + 43.6 /2 = 44.7 kcfm = 21.1 m³/s
k = .0130
t_{wbi} = 19.5 °C
t_{dbi} = 30.5 °C
age = 10,512 hrs. mean
A = 20.16 m²
per = 22.65 m

Equipment
1 - Feeder breaker @ 35% (112 kW)
1 - 149 kW motor @ 90% util.
13.4 kW @ motor
120.7 kW along belt.
belt length = 38.4 × 2 + 61 + 20 = 157.8 m
0.765 kW/m · 38.4 = 29.4 kW

Output
t_{wb} = 20.52 °C
t_{db} = 33.92 °C
ACP = 794 W/m²

Initial parameters for the prediction of heat and humidity

Physical description of 21-1hd heading panel access

Length = 323.5 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 22.6 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 25.12 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.232 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 6 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 44 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr Development CHECKED BY : G.R. DATE

Predicted Environment: 21-lhd heading panel access

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	25.12	16.93	9.82	45.14	92.650	1.075	49.55	25.0	945	19.39	17.62
54	25.03	16.93	9.85	45.55	92.649	1.075	49.55	25.0	945	19.39	17.55
108	24.94	16.93	9.89	45.96	92.649	1.076	49.56	25.0	945	19.36	17.49
162	24.86	16.93	9.93	46.36	92.648	1.076	49.56	25.0	945	19.33	17.43
216	24.78	16.93	9.96	46.75	92.648	1.076	49.57	25.0	945	19.31	17.37
270	24.70	16.93	10.00	47.14	92.647	1.076	49.58	25.0	946	19.29	17.31
324	24.62	16.93	10.04	47.53	92.647	1.077	49.59	25.0	946	19.26	17.25

Initial parameters for the prediction of heat and humidity

Physical description of LHD HEADING

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10 (hrs)

Ventilation at intake

Quantity = 16.34 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.62 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 26.534 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	100	207.00	35.0	Diesel

Amount of water emitted by diesel = 3 liters water/liter fuel

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Job No. 3696A161 Sheet 46 of 150

Job Title VertEmp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: LHD HEADING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.62	16.93	10.02	47.47	92.650	1.077	49.55	25.0	764	19.24	18.00
25	24.54	16.93	10.06	47.86	92.650	1.077	49.56	25.0	764	19.24	17.95
50	24.46	16.93	10.10	48.26	92.650	1.077	49.57	25.0	764	19.22	17.90
75	24.39	16.93	10.13	48.64	92.650	1.078	49.58	25.0	764	19.20	17.85
After spot source no. 1 sensible heat = 160.60 kW, latent heat = 44.43 kW											
101	33.20	20.41	11.21	32.26	92.650	1.077	61.11	25.0	673	21.62	24.05
126	32.97	20.41	11.27	32.83	92.650	1.046	61.03	25.0	634	24.12	23.95
151	32.76	20.41	11.32	33.40	92.650	1.047	60.96	25.0	635	24.06	23.86
176	32.55	20.39	11.38	33.96	92.650	1.048	60.89	25.0	636	23.99	23.75
201	32.35	20.37	11.44	34.52	92.649	1.048	60.82	25.0	637	23.92	23.65

Initial parameters for the prediction of heat and humidity

Physical description of LHD-BOLTER ACCESS W/BELT

Length = 38.4 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 21.1 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 19.5 Deg C, Dry bulb temp. = 30.5 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 48.166 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 8 output stations

Heat Sources

Spot heat sources

No.	Distance From intake end (m)	Sensible Heat Load (kW)
1	0	13

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
2	0	112.00	35.0	Electric

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	29.40	38

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Job No. 3696 A161 Sheet 48 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: LHD-BOLTER ACCESS W/BELT

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.50	19.50	10.99	36.88	92.650	1.056	57.87	25.0	842	22.80	21.90
After spot source no. 1 sensible heat = 13.40 kW, latent heat = 0.00 kW											
Start linear source no. 1 sensible heat = 29.4 kW For 38.4 m											
After spot source no. 2 sensible heat = 41.26 kW, latent heat = 0.00 kW											
5	33.03	20.23	11.00	31.98	92.650	1.056	60.44	25.0	819	23.26	23.52
10	33.16	20.27	11.01	31.77	92.650	1.047	60.59	25.0	806	24.03	23.60
14	33.29	20.31	11.02	31.56	92.650	1.046	60.74	25.0	804	24.09	23.68
19	33.41	20.36	11.02	31.35	92.650	1.046	60.88	25.0	802	24.16	23.76
24	33.54	20.40	11.03	31.15	92.650	1.046	61.03	25.0	800	24.23	23.84
29	33.67	20.44	11.04	30.95	92.650	1.045	61.18	25.0	798	24.29	23.92
34	33.80	20.48	11.04	30.75	92.650	1.045	61.32	25.0	796	24.36	24.00
38	33.92	20.52	11.05	30.56	92.649	1.044	61.47	25.0	794	24.42	24.07

Subject: Vert. Emplacement Cooling Analysis

Bolter heading

L = 201 m
A = 28.34 m²
per = 20.63 m
k = .0130
twbi = 20.52°C
tdbi = 33.92°C
Age = 10,512, 11 hrs.
Q = 6.7 m³/s

Equipment

1 - Bolter @ 157 kW @ 35% utilization located @ 185 m

Output

twb = 22.33°C   ACP = 411 w/m²
tdb = 39.36°C

Mixture Ratio

6.7 / 20.6 = 0.325

twb = (22.33 − 20.52) 0.325 + 20.52 = 21.1 °C
tdb = (39.36 − 33.92) 0.325 + 33.92 = 35.7 °C

Bolter - Jumbo Access

L = 126' = 38.4 m
Q = 20.6 m³/s
A = 20.11 m²
per = 22.65 m
k = .013 kg/m³
twbi = 21.1°C
tdbi = 35.7°C   Age = 10,512 mean

Equipment

0.765 kW/m · 38.4 = 29.4 kW - belt

Output

twb = 21.41°C
tdb = 36.71°C

Jumbo Heading

L = 201 m
A = 28.34 m²
per = 20.63 m
k = .0130
twbi = 21.41°C
tdbi = 36.71°C
Age = 10,512, 34 hrs
Q = 6.7 m³/s

Equipment

1 - Jumbo @ 157 kW @ 35% util

Output

twb = 23.05°C
tdb = 41.55°C

Mixture Ratio

6.7 / 20.6 = 0.325

twb = (23.05 − 21.41) 0.325 + 21.41 = 21.94°C
tdb = (41.55 − 36.71) 0.325 + 36.71 = 38.28°C

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Job No. 3696A161 Sheet 50 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/15/86

Description: 10yr Development CHECKED BY : GK ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of BOLTER HEADING

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 16 (hrs)

Ventilation at intake

Quantity = 6.7 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 20.52 Deg C, Dry bulb temp. = 33.92 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 10.880 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	195	157.00	35.0	Electric

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Job No. 3696A161 Sheet 51 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: BOLTER HEADING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	33.92	20.52	11.03	30.49	92.650	1.044	61.40	25.0	486	24.54	24.69
25	33.54	20.47	11.09	31.33	92.650	1.044	61.17	25.0	492	24.16	24.51
50	33.17	20.42	11.16	32.16	92.650	1.045	60.96	25.0	495	24.03	24.33
75	32.82	20.36	11.22	32.97	92.650	1.046	60.76	25.0	497	23.90	24.16
101	32.49	20.31	11.28	33.77	92.650	1.047	60.58	25.0	499	23.78	24.00
126	32.18	20.25	11.34	34.56	92.650	1.049	60.41	25.0	501	23.66	23.84
151	31.88	20.21	11.40	35.33	92.650	1.050	60.24	25.0	504	23.55	23.68
176	31.59	20.16	11.46	36.09	92.650	1.051	60.09	25.0	506	23.44	23.54
After spot source no. 1 sensible heat = 57.84 kW, latent heat = 0.00 kW											
201	39.36	22.33	11.51	23.64	92.650	1.052	68.10	25.0	461	24.89	27.48

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Job No. 3696A161 Sheet 52 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/15/86

Description: 10 yr. Development CHECKED BY : G.R. ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of BOLTER-JUMBO PANEL ACCESS

Length = 38.4 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 20.6 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.1 Deg C, Dry bulb temp. = 35.7 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.024 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 8 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	29.40	38

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. -----

Job No. 3696A161 Sheet 53 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: BOLTER-JUMBO PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	35.70	21.10	11.14	27.90	92.650	1.038	63.48	25.0	755	25.48	25.14
Start linear source no. 1 sensible heat = 29.4 kW For 38.4 m											
5	35.83	21.12	11.15	27.73	92.650	1.038	63.63	25.0	756	25.39	25.20
10	35.95	21.17	11.15	27.56	92.650	1.037	63.78	25.0	754	25.46	25.27
14	36.08	21.21	11.16	27.39	92.650	1.037	63.93	25.0	752	25.53	25.35
19	36.21	21.25	11.17	27.22	92.650	1.036	64.07	25.0	749	25.59	25.42
24	36.33	21.29	11.18	27.05	92.650	1.036	64.22	25.0	747	25.66	25.49
29	36.46	21.33	11.19	26.89	92.650	1.036	64.37	25.0	745	25.72	25.56
34	36.58	21.37	11.20	26.73	92.650	1.035	64.52	25.0	743	25.79	25.63
38	36.71	21.41	11.21	26.57	92.650	1.035	64.66	25.0	741	25.85	25.70

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. -----

Job No. 3696A161 Sheet 54 of 150

Job Title Vent Emp Cooling Analysis DESIGNED BY: D. Bryant DATE 4/15/86

Description: 10 yr. Development CHECKED BY : CR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of JUMBO HEADING

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 24 (hrs)

Ventilation at intake

Quantity = 6.7 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.41 Deg C, Dry bulb temp. = 36.71 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 10.880 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	195	157.00	35.0	Electric

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PAGE NO. -----

Job No. 3696A161 Sheet 55 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE __________

Description: 10 yr Development CHECKED BY : G.R. DATE __________

Predicted Environment: JUMBO HEADING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	36.71	21.41	11.18	26.50	92.650	1.034	64.61	25.0	453	26.00	26.15
25	36.23	21.35	11.26	27.39	92.650	1.034	64.30	25.0	461	25.51	25.95
50	35.77	21.26	11.33	28.27	92.650	1.036	64.01	25.0	465	25.33	25.74
75	35.33	21.20	11.40	29.14	92.650	1.037	63.75	25.0	468	25.17	25.55
101	34.92	21.12	11.47	29.99	92.650	1.039	63.50	25.0	471	25.01	25.35
126	34.52	21.06	11.54	30.83	92.650	1.040	63.26	25.0	474	24.87	25.17
151	34.14	21.00	11.60	31.67	92.650	1.041	63.04	25.0	477	24.73	24.99
176	33.78	20.94	11.67	32.49	92.650	1.043	62.83	25.0	479	24.59	24.82
After spot source no. 1 sensible heat = 57.84 kW, latent heat = 0.00 kW											
201	41.55	23.05	11.73	21.43	92.650	1.044	70.87	25.0	435	25.98	28.49

Jumbo - 54

L = 200' = 60.97 m
Q = 20.6 m³/s
A = 20.16 m²
per. = 22.65 m
k = .013 kg/m³
Age = 10,512 mean
twbi = 21.94°C, tdbi = 38.28°C

Equipment

0.765 · 60.97 = 46.64 kW Belt.

Output

twb = 22.41°C   72.3, 103.12
tdb = 39.79°C

Junction 54

Mixture 26.3 + 43.8 = 70.1 kcfm
43.8/70.1 = 0.625
twb = (22.41 − 20.44) 0.625 + 20.44 = 21.67°C   (71, 99.3 °F)
tdb = (39.79 − 33.33) 0.625 + 33.33 = 37.37°C

54-74

L = 20 m
Q = 39.1 = 18.45 m³/s
A = 20.16 m²
per = 22.65 m
k = .013 kg/m³
Age = 10,512 hrs. mean
twbi = 21.67°C
tdbi = 37.37°C

Equipment

0.765 · 20 = 15.3 kW − belt

Output

twb = 21.84°C
tdb = 37.95°C

54-53 Waste Main

Q = 31.1 kcfm = 14.7 m³/s
A = 39.48 m²
per = 22.82 m
k = .0111 kg/m³
Age = 15,330 hrs. mean
L = 85' = 25.9 m. — This length will not significantly affect the conditions of the air and will be neglected.

Junction 53

twb = 21.67°C
tdb = 37.37°C

MVS, Inc. CLIMSIM VERSION 1.1 — FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 57 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Skinner DATE 4/16/86

Description: 10 yr Development CHECKED BY: CK Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of JUMBO HEADING TO 54

Length = 60.97 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 20.6 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.94 Deg C, Dry bulb temp. = 38.28 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.024 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 2 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	46.64	61

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. -----

Job No. 3696A161 Sheet 58 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: JUMBO HEADING TO 54

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	38.28	21.94	11.33	24.66	92.650	1.029	66.57	25.0	712	26.84	26.56
Start linear source no. 1 sensible heat = 46.64 kW For 60.97 m											
30	39.04	22.17	11.39	23.79	92.650	1.029	67.49	25.0	706	26.88	26.94
61	39.79	22.41	11.45	22.97	92.649	1.026	68.40	25.0	693	27.27	27.32

Initial parameters for the prediction of heat and humidity

Physical description of 54-74

Length = 20 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 10512 (hrs), Age at outlet 10512 (hrs)

Ventilation at intake

Quantity = 18.45 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.67 Deg C, Dry bulb temp. = 37.37 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 42.117 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 4 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	15.30	20

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Job No. 3696A161 Sheet 60 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: 54-74

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.37	21.67	11.30	25.83	92.650	1.032	65.57	25.0	692	26.38	26.13
Start linear source no. 1 sensible heat = 15.3 kW For 20 m											
5	37.52	21.69	11.31	25.65	92.650	1.032	65.74	25.0	694	26.27	26.20
10	37.66	21.74	11.32	25.47	92.650	1.032	65.91	25.0	691	26.35	26.28
15	37.80	21.79	11.33	25.29	92.650	1.031	66.08	25.0	689	26.42	26.36
20	37.95	21.84	11.34	25.12	92.650	1.031	66.24	25.0	687	26.49	26.43

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Engineers • Architects • Planners

COMPUTATION SHEET

Job No. 3696 All.1
Made by [signature]
Date 4/11/86
Checked by GK ROGERS
Date 5/7/86

Subject Vent. Emp. Cooling Analysis

20-145-53

This panel access drift, from which 3 headings (emplacement drifts) are driven, is similar to 21-146-54 in respect to airflow, equipment loading in headings and size. However, a belt and feeder breaker as situated in 146-154, are not present in 145-53. The conditions leaving the 146-54 panel access drift will be warmer than that reaching 53. For this simulation, the conditions reaching 53 will be taken as that from the 146-54 drift.

Conditions Reaching 53:
$t_{wb} = 22.41°C \quad Q = 56.2\ kcfm = 26.52 m^3/s$
$t_{db} = 39.79°C$

Mixture at 53: $26.52\ m^3/s$ @ $22.41/39.79$
$14.7\ m^3/s$ @ $21.67/37.37$ } $26.52/(26.52+14.7) = 0.64$

$t_{wb} = (22.41 - 21.67)0.64 + 21.67 = 22.14°C$
$t_{db} = (39.79 - 37.37)0.64 + 37.37 = \underline{38.92°C}$ (71.9, 102.1°F)

53-52-51 Waste Main

$A = 39.48 m^2 \quad Q = 87.3\ kcfm = 41.2 m^3/s$
per = 22.62 m $\quad t_{wbi} = 22.14°C$
$k = .0111\ kg/m^3 \quad t_{dbi} = 38.92°C$
mileage = 17,520 hrs. $P = 92.1\ kPa$
$L = 660' \times 2 = 1320' = 402\ m$

Output
$t_{wb} = 21.9°C$ (71.4, 98.9°F)
$t_{db} = 37.18°C$

MVS, Inc. CLIMSIM VERSION 1.1 | FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 62 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: D. Brunner DATE 4/16/86

Description: 16 yr. Development CHECKED BY: G. Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 53-51 WASTE MAIN

Length = 402 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 17520 (hrs), Age at outlet 17520 (hrs)

Ventilation at intake

Quantity = 41.2 (m^3/s), Pressure = 92.6 (kPa)
Wet bulb temp. = 22.14 Deg C, Dry bulb temp. = 38.92 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 41.006 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 63 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: DB DATE ____

Description: 10yr Development CHECKED BY : GR DATE ____

Predicted Environment: 53-51 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	38.92	22.14	11.38	23.92	92.600	1.026	67.35	25.0	708	27.17	26.88
50	38.69	22.12	11.43	24.31	92.600	1.026	67.22	25.0	710	27.03	26.78
101	38.46	22.09	11.47	24.70	92.599	1.027	67.10	25.0	713	26.94	26.68
151	38.24	22.06	11.51	25.09	92.599	1.028	66.98	25.0	714	26.86	26.59
201	38.02	22.02	11.56	25.48	92.599	1.028	66.86	25.0	717	26.76	26.48
251	37.81	22.00	11.60	25.87	92.599	1.029	66.74	25.0	718	26.68	26.39
302	37.59	21.96	11.64	26.26	92.598	1.030	66.63	25.0	721	26.59	26.29
352	37.38	21.94	11.68	26.65	92.598	1.031	66.51	25.0	722	26.52	26.20
402	37.18	21.90	11.72	27.05	92.598	1.031	66.40	25.0	725	26.43	26.10

Subject: Vent. Emp. Cooling Analysis

19 - 129 Mid Panel Access to drilling area

	L	Q
19 - 173	91'	50.4
173 - 160	504'	46.1
160 - 144	504'	42.7
144 - 129	315'	40.0

L_T = 1,414' = 431m

$\bar{Q}$ = 44.8 kcfm = 21.14 m³/s

A = 17.19 m²

per = 15.77m

k = .013 kg/m³

Age (mean) = 2.1 y = 18,396 hrs

twbi = 16.93°C

tdbi = 24.90°C

Pi = 92.65 kPa

Output

twb = 16.93°C (62.5, 75.6°F)

tdb = 24.23°C

129-128 - drilling Emp. room

L = 660' = 201m

A = 28.34m²

per = 20.63m

k = .013 kg/m³

twbi = 16.93°C

tdbi = 24.23°C

wf = .05

Q = 20 kcfm = 9.44 m³/s

Age (mean) = 1y = 8,760 hrs.

Equipment

1 - pilot hole drill w/vacuum system @ 175m running at 25% utilization @ 909 kW

1 - Reamer drill w/vacuum at 60m running at 25% utilization @ 327 kW

Output

twb = 22.11°C (71.8, 105.0°F)

tdb = 40.54°C

129 - 113 Mid Panel Access

L = 200' = 60.96m

Q = 9.44 m³/s

A = 17.19m²

per = 15.77m

k = .013

Age = 18,396 hrs

twbi = 16.93°C

tdbi = 24.23°C

Output

twb = 16.93°C (62.5, 75.5°F)

tdb = 24.16°C

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Job No. 3696 A161 Sheet 65 of 150

Job Title Vert. Emp. Cooling Analys DESIGNED BY: DBrunner DATE 4/11/86

Description: 10 yr Development CHECKED BY : GK ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of ~~53-51 WASTE MAIN~~ 19-129 Mid Panel Access

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Length = 431 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 15.77 m, Cross-sectional area = 17.19 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 18396 (hrs), Age at outlet 18396 (hrs)

Ventilation at intake

Quantity = 21.14 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.9 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 56.595 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 9 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1

FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 66 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ____

Description: 10 yr Development CHECKED BY : G.R. DATE ____

Predicted Environment: ~~53-51 WASTE MAIN~~ 19-129 Mid Panel Access

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.90	16.93	9.91	46.15	92.650	1.076	49.55	25.0	1020	19.32	17.14
48	24.82	16.93	9.94	46.54	92.649	1.076	49.56	25.0	1020	19.32	17.07
96	24.74	16.93	9.98	46.93	92.648	1.076	49.56	25.0	1020	19.30	17.01
144	24.66	16.93	10.01	47.31	92.648	1.077	49.57	25.0	1020	19.27	16.95
192	24.58	16.93	10.05	47.69	92.647	1.077	49.58	25.0	1021	19.25	16.89
239	24.51	16.93	10.08	48.06	92.646	1.077	49.59	25.0	1021	19.23	16.83
287	24.44	16.93	10.12	48.43	92.645	1.077	49.60	25.0	1021	19.21	16.78
335	24.37	16.93	10.15	48.80	92.645	1.078	49.61	25.0	1021	19.19	16.72
383	24.30	16.93	10.18	49.16	92.644	1.078	49.62	25.0	1021	19.17	16.67
431	24.23	16.93	10.22	49.52	92.643	1.078	49.63	25.0	1021	19.15	16.61

MVS, Inc. CLIMSIM VERSION 1.1

FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 67 of 150

Job Title Vent. Emp. Cooling Analysis DESIGNED BY: DBrunner DATE 4/16/86

Description: 10 yr Development CHECKED BY : CR Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 129-128 DRILLING EMP. ROOM

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 8760 (hrs), Age at outlet 8760 (hrs)

Ventilation at intake

Quantity = 9.44 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.23 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 15.329 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	50	321.00	25.0	Electric
2	175	404.00	25.0	Electric

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ____

Job No. 3696 A161 Sheet 68 of 150

Job Title Vent. Emp Cooling Analysis DESIGNED BY: D.B. DATE ____

Description: 10 yr. Development CHECKED BY : G.R. DATE ____

Predicted Environment: 129-128 DRILLING EMP. ROOM

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.23	16.93	10.18	49.36	92.650	1.078	49.55	25.0	652	19.12	18.18
25	24.17	16.93	10.22	49.71	92.650	1.078	49.58	25.0	652	19.14	18.14
After spot source no. 1 sensible heat = 84.47 kW, latent heat = 0.00 kW											
50	32.21	19.46	10.26	31.26	92.650	1.079	57.79	25.0	600	20.90	23.41
75	31.93	19.46	10.32	31.94	92.650	1.050	57.65	25.0	566	23.07	23.29
101	31.65	19.42	10.38	32.62	92.650	1.051	57.52	25.0	568	22.96	23.15
126	31.39	19.38	10.43	33.30	92.650	1.052	57.40	25.0	569	22.86	23.01
151	31.13	19.34	10.49	33.97	92.650	1.053	57.28	25.0	571	22.76	22.88
After spot source no. 2 sensible heat = 106.32 kW, latent heat = 0.00 kW											
176	41.07	22.16	10.55	19.80	92.650	1.054	67.47	25.0	509	24.67	27.89
201	40.54	22.11	10.64	20.53	92.650	1.020	67.15	25.0	465	27.32	27.70

Initial parameters for the prediction of heat and humidity

Physical description of 129-113 MID PANEL ACCESS

Length = 60.96 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 15.77 m, Cross-sectional area = 17.19 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 18396 (hrs), Age at outlet 18396 (hrs)

Ventilation at intake

Quantity = 9.44 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.23 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 25.272 kJ/hr/m/Deg C

Distance between temperature outputs = 15 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO.

Job No. 3696A161 Sheet 70 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr Development CHECKED BY : G.R. DATE

Predicted Environment: 129-113 MID PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.23	16.93	10.18	49.36	92.650	1.078	49.55	25.0	753	19.12	17.79
15	24.21	16.93	10.19	49.46	92.650	1.078	49.56	25.0	753	19.13	17.78
30	24.20	16.93	10.21	49.56	92.650	1.078	49.57	25.0	753	19.13	17.76
46	24.18	16.93	10.22	49.66	92.650	1.078	49.58	25.0	753	19.12	17.75
61	24.16	16.93	10.23	49.76	92.650	1.079	49.59	25.0	753	19.12	17.74

113-112 - drilling Emp. room.

L = 660' = 201m
A = 28.34 m²
per = 20.63m
k = .013 kg/m³
twbi = 16.93 °C
tdbi = 24.16 °C
WF = .05
age (mean) = 8,760 hrs.
Q = 9.44 m³/s

Equipment

7 Reamer drill @ 175m @ 25% utilization - 321 kW

Output

twb = 19.51 °C (67.1, 89.3 °F)
tdb = 31.82 °C

Conditions at 128

20 kcfm @ 22.11/40.54 °C mixes with 12 kcfm which has leaked from the mid panel access drift. For this simulation, we will assume that the conditions of this air will be similar to that at junction 129, due to low VRT and no equipment loading. Thus 12 cfm is @ 16.93/24.23

mixture ratio = 12/(12+20) = 0.375

twb = -(22.11 - 16.93) 0.375 + 22.11 = 20.17 °C
tdb = -(40.54 - 24.23) 0.375 + 40.54 = 34.42 °C

128-112 Panel Access w/belt

L = 140' = 42.7m
A = 20.16 m²
per = 22.65 m
Q = 32.5 kcfm = 15.34 m³/s
WF = .02
Age = 22 yr = 19,272 hrs.
twbi = 20.17 °C
tdbi = 31.42 °C

Output
twb = 20.99 °C
tdb = 32.11 °C

Equipment

2 drills, a pilot & ream drill, will produce chips which will be stored in bins & transported to the conveyor. No breaker is assumed at conveyor head due to more uniform chip size.
Conveyor @ 149 kW @ 90% utilization
13.4 kW @ motor, 120.7 kW generated along belt. Total belt length = 42.7 + 61 + 20 = 123.7 m = 0.976 kW/m
41.68 kW along belt.

Initial parameters for the prediction of heat and humidity

Physical description of 113-112 DRILLING

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 8760 (hrs), Age at outlet 8760 (hrs)

Ventilation at intake

Quantity = 9.44 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.16 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 15.329 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 4 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	175	321.00	25.0	Electric

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Job No. 3696A161 Sheet 73 of 150

Job Title Vert Emp Cooling Analysis DESIGNED BY: D.B. DATE ____

Description: 10 yr Development CHECKED BY : G.R. DATE ____

Predicted Environment: 113-112 DRILLING

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.16	16.93	10.21	49.70	92.650	1.079	49.55	25.0	652	19.10	18.13
50	24.04	16.93	10.28	50.41	92.650	1.079	49.61	25.0	652	19.12	18.06
101	23.93	16.95	10.36	51.09	92.650	1.079	49.67	25.0	652	19.10	17.99
151	23.83	16.96	10.43	51.75	92.650	1.079	49.73	25.0	652	19.09	17.93
After spot source no. 1 sensible heat = 84.47 kW, latent heat = 0.00 kW											
201	31.82	19.51	10.49	32.68	92.650	1.080	57.98	25.0	599	20.84	23.26

Initial parameters for the prediction of heat and humidity

Physical description of 128-112 panel access

Length = 43 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 19272 (hrs), Age at outlet 19272 (hrs)

Ventilation at intake

Quantity = 15.34 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 20.17 Deg C, Dry bulb temp. = 34.42 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 35.017 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 9 output stations

Heat Sources

Spot heat sources

No.	Distance From intake end (m)	Sensible Heat Load (kW)
1	0	13

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	41.70	43

112-51 Panel Access w/belt

L = 61m
Q = 52.5 kcfm = 24.8 m³/s
A = 20.16 m²
per = 22.15m
k = .013 kg/m³
mean age = 19,272 hrs.
twbi = 20.45°C
tdbi = 35.07°C } should be 20.43 / 35.09 not considered significant
Equipment = 0.976 · 61 = 59.5 kW -belt

Mixture @ 112

9.44 / (15.34 + 9.44) = 0.381

twb = (19.51 - 20.99) 0.381 + 20.99 = 20.43
tdb = (31.82 - 37.31) 0.38 + 37.31 = 35.09

Output
twb = 21.01°C
tdb = 36.87°C

Junction 51

41.2 m³/s @ 21.9/37.18 mixes with 24.8 m³/s @ 21.01/36.87°

mixture ratio = 24.8 / (24.8 + 41.2) = 0.376

twb = (21.01 - 21.9) 0.376 + 21.9 = 21.6°C (70.9, 98.7°F)
tdb = (36.87 - 37.18) 0.376 + 37.18 = 37.06°C

51-72

L = 20m   Q = 38.4 kcfm = 18.12 m³/s
A = 20.16 m²
per. = 22.65m
mean age = 19,272 hrs.
twbi = 21.6°C
tdbi = 37.06°C
Equipment = 0.976 kW/m · 20 = 19.5 kW

Output
twb = 21.83°C (71.3, 100.2°F)
tdb = 37.89°C

Initial parameters for the prediction of heat and humidity

Physical description of 112-51 PANEL ACCESS

Length = 61 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 19272 (hrs), Age at outlet 19272 (hrs)

Ventilation at intake

Quantity = 24.8 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 20.45 Deg C, Dry bulb temp. = 35.07 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 56.612 kJ/hr/m/Deg C

Distance between temperature outputs = 15 m - 4 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	59.50	61

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Job No. 3696 A161 Sheet 79 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr Development CHECKED BY : G.R. DATE ________

Predicted Environment: 112-51 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	35.07	20.45	10.45	27.13	92.650	1.040	61.15	25.0	850	24.84	24.45
Start linear source no. 1 sensible heat = 59.5 kW for 61 m											
15	35.53	20.58	10.47	26.52	92.650	1.040	61.68	25.0	847	24.86	24.71
31	35.98	20.72	10.50	25.94	92.649	1.039	62.20	25.0	839	25.09	24.97
46	36.43	20.87	10.53	25.37	92.649	1.037	62.73	25.0	831	25.33	25.23
61	36.87	21.01	10.56	24.82	92.649	1.036	63.24	25.0	824	25.56	25.48

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Job No. 3696A161 Sheet 80 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: D. Brunner DATE 4/16/86

Description: 10 yr Development CHECKED BY : GK Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 51-72

Length = 20 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.65 m, Cross-sectional area = 20.16 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 19272 (hrs), Age at outlet 19272 (hrs)

Ventilation at intake

Quantity = 18.12 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.6 Deg C, Dry bulb temp. = 37.06 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 41.363 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 4 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	19.50	20

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Job No. 3696A161 Sheet 81 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr Development CHECKED BY : G.R. DATE

Predicted Environment: 51-72

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.06	21.60	11.32	26.32	92.650	1.033	65.31	25.0	691	26.24	25.99
Start linear source no. 1 sensible heat = 19.5 kW For 20 m											
5	37.27	21.65	11.33	26.05	92.650	1.033	65.54	25.0	691	26.16	26.09
10	37.48	21.71	11.34	25.78	92.650	1.032	65.77	25.0	688	26.26	26.20
15	37.68	21.77	11.35	25.51	92.650	1.032	66.01	25.0	685	26.37	26.31
20	37.89	21.83	11.36	25.25	92.650	1.031	66.24	25.0	682	26.47	26.41

Subject: Vent Emp. Cooling Analysis

51 - 50-49 Waste Main

Q = 101.7 kcfm = 48 m³/s
A = 39.48 m²
per = 22.62 m
k = .0111 kg/m³
twbi = 21.6 °C
tdbi = 37.06 °C
mean age = 2.3y = 20,148 hrs.
L = 660+85 = 745' = 227 m

Output
twb = 21.5 °C
tdb = 36.25 °C

17 - 127 Panel Access

	L	Q (kcfm)
17 - 182	103'	58.0
182 - 171	504'	52.7
171 - 158	504'	47.4
158 - 142	441'	43.5
142 - 127	252'	40.9
	L_T = 1,804' = 550 m	Q = 48.5 kcfm = 22.9 m³/s

A = 22.02 m²
per = 18.26 m
k = .013 kg/m³
mean age = 2.4y = 21,024 hrs.
WF = .02
twbi = 18.93 °C
tdbi = 24.67 °C

Output
twb = 16.96 °C
tdb = 23.97 °C
(62.5, 75.1 °F)

127-126 Emp. Room

L = 660' = 201 m
A = 28.34 m²
per = 20.63 m
k = .013
mean age = 2y = 17,520 hrs.
twbi = 16.96 °C
tdbi = 23.97 °C
WF = .05
Q = 9.44 m³/s

Equipment
1 - pilot drill w/ vacuum 175 m @ 25% util. (404 kW)
1 - reamer w/ vacuum 50 m @ 25% util. (321 kW)

Output
twb = 22.18 °C
tdb = 40.69 °C

Job No. 3696A161 Sheet 83 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: D Brunner DATE 4/16/86

Description: 10 yr Development CHECKED BY : GR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 51-49 WASTE MAIN

Length = 227 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 20148 (hrs), Age at outlet 20148 (hrs)

Ventilation at intake

Quantity = 48 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.6 Deg C, Dry bulb temp. = 37.06 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.774 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 9 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 84 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr Development CHECKED BY : 6R. DATE

Predicted Environment: 51-49 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.06	21.60	11.32	26.32	92.650	1.033	65.31	25.0	789	26.24	25.83
25	36.97	21.60	11.34	26.50	92.650	1.033	65.26	25.0	790	26.14	25.79
50	36.88	21.59	11.36	26.68	92.650	1.033	65.22	25.0	791	26.11	25.74
76	36.78	21.58	11.38	26.86	92.649	1.034	65.17	25.0	792	26.07	25.70
101	36.69	21.56	11.40	27.04	92.649	1.034	65.13	25.0	793	26.04	25.66
126	36.60	21.55	11.42	27.22	92.649	1.034	65.09	25.0	793	26.00	25.61
151	36.51	21.54	11.44	27.40	92.649	1.035	65.04	25.0	794	25.97	25.57
177	36.42	21.53	11.46	27.58	92.649	1.035	65.00	25.0	795	25.93	25.53
202	36.34	21.52	11.48	27.76	92.648	1.035	64.96	25.0	796	25.90	25.48
227	36.25	21.50	11.50	27.94	92.648	1.035	64.92	25.0	797	25.87	25.44

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Job No. 3696 A161 Sheet 85 of 150

Job Title Wet Emp. Cooling Analysis DESIGNED BY: [signature] DATE 4/16/86

Description: 10 YR Development CHECKED BY : CR Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 17-127 PANEL ACCESS

Length = 550 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 21024 (hrs), Age at outlet 21024 (hrs)

Ventilation at intake

Quantity = 22.9 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.93 Deg C, Dry bulb temp. = 24.67 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.859 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 11 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 86 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10yr Development CHECKED BY : G.R. DATE ________

Predicted Environment: 17-127 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	24.67	16.93	10.00	47.23	92.650	1.077	49.55	25.0	951	19.25	17.26
50	24.60	16.93	10.03	47.59	92.649	1.077	49.56	25.0	951	19.25	17.21
100	24.53	16.93	10.07	47.94	92.649	1.077	49.57	25.0	951	19.23	17.16
150	24.46	16.93	10.10	48.29	92.648	1.077	49.58	25.0	951	19.21	17.11
200	24.39	16.93	10.13	48.63	92.648	1.078	49.59	25.0	952	19.19	17.06
250	24.33	16.93	10.16	48.97	92.647	1.078	49.60	25.0	952	19.17	17.01
300	24.26	16.93	10.20	49.31	92.647	1.078	49.61	25.0	952	19.16	16.96
350	24.20	16.93	10.23	49.64	92.646	1.078	49.63	25.0	952	19.14	16.91
400	24.14	16.94	10.26	49.97	92.646	1.078	49.64	25.0	952	19.13	16.87
450	24.08	16.94	10.29	50.30	92.645	1.079	49.66	25.0	952	19.11	16.83
500	24.02	16.94	10.32	50.62	92.645	1.079	49.67	25.0	952	19.09	16.78
550	23.97	16.96	10.35	50.94	92.644	1.079	49.69	25.0	952	19.08	16.74

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Job No. 3696 A161 Sheet 81 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D Brunner DATE 4/16/86

Description: 10 yr Development CHECKED BY : GR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 127-126 EMP. ROOM

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 17520 (hrs), Age at outlet 17520 (hrs)

Ventilation at intake

Quantity = 9.44 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.96 Deg C, Dry bulb temp. = 23.97 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 15.329 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 4 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	50	321.00	25.0	Electric
2	175	404.00	25.0	Electric

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Job No. 3696A161 Sheet 88 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr. Development CHECKED BY : G.R. DATE ________

Predicted Environment: 127-126 EMP. ROOM

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	23.97	16.96	10.33	50.84	92.650	1.079	49.64	25.0	652	19.06	18.02
After spot source no. 1 sensible heat = 84.47 kW, latent heat = 0.00 kW											
50	31.95	19.48	10.40	32.16	92.650	1.079	57.87	25.0	600	20.85	23.31
101	31.44	19.46	10.52	33.45	92.650	1.051	57.65	25.0	566	23.03	23.07
151	30.97	19.40	10.63	34.73	92.650	1.053	57.45	25.0	569	22.85	22.83
After spot source no. 2 sensible heat = 106.32 kW, latent heat = 0.00 kW											
201	40.69	22.18	10.74	20.56	92.650	1.054	67.56	25.0	508	24.67	27.79

126-110 Panel Access (mid)

L = 126' = 38.4m twbi = 22.18°C
A = 17.19m² tdbi = 40.69°C
per = 15.77m (inputed as 40.64 0.12% error.)
Q = 10.7 kcfm = 5.0m³/s
k = .013
mean age = 24,090 hrs.
wF = .02

Output
twb = 22.03°C
tdb = 39.84°C

127-111 Panel Access

L = 38m age = 21,024 Q = 20.5 kcfm = 9.7m³/s
A = 22.02m² twbi = 16.96°C
per = 18.26m tdbi = 23.97°C

Output
twb = 16.96°C
tdb = 23.94°C

111-110 Emp. Room

L = 660' = 201m
A = 28.34m²
per = 20.63m
k = .013 kg/m³
mean age = 17,520 hrs.
twbi = 16.96°C
tdbi = 23.94°C
WF = .05
Q = 9.44 m³/s

Output
twb = 19.42°C
tdb = 30.86°C

Equipment
1- reamer w/vacuum @ 100m
25% util. @ 321 kW

Junction 110
5/5+9.44 = 0.346

twb = (22.03-19.42).346 + 19.42 = 20.3°C
tdb = (39.84-30.86).346 + 30.86 = 33.97°C

110-49 Mid Panel Access

L = 200' = 60.96m twbi = 20.3°C
A = 17.19m² tdbi = 33.97°C
per = 15.77m
k = .013 kg/m³
mean age = 24,090 hrs
WF = .02
Q = 29.6 kcfm = 13.97m³/s

Output
twb = 20.25°C
tdb = 33.57°C

Junction 49
29.6/29.6 + 101.9 = 0.225

twb = (20.25 - 21.5).225 + 21.5 = 20.99°C *
tdb = (33.57 - 36.25).225 + 36.25 = 35.6°C

(-89.7, 96.1 °F)

* should be 21.22°C
1.2% effect on
wet bulb conditions.

Job No. 3696A161 Sheet 90 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: D. Brunner DATE 4/16/86

Description: 10 yr. Development CHECKED BY : (R ROGERS) DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 126-110 MID PANEL

Length = 38 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 15.77 m, Cross-sectional area = 17.19 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 24090 (hrs), Age at outlet 24090 (hrs)

Ventilation at intake

Quantity = 5 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 22.18 Deg C, Dry bulb temp. = 40.64 (40.69) Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 13.386 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161 Sheet 91 of 150

Job Title Vert Emp Cooling Analysis DESIGNED BY: D.B. DATE ________

Description: 10 yr Development CHECKED BY : G.R. DATE ________

Predicted Environment: 126-110 MID PANEL

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	40.64	22.18	10.72	20.59	92.650	1.022	67.47	25.0	440	27.72	27.78
5	40.54	22.18	10.73	20.72	92.650	1.022	67.38	25.0	448	27.24	27.75
10	40.44	22.16	10.74	20.84	92.650	1.022	67.30	25.0	449	27.20	27.71
14	40.34	22.14	10.75	20.97	92.650	1.022	67.22	25.0	450	27.16	27.67
19	40.23	22.11	10.76	21.10	92.650	1.023	67.14	25.0	451	27.12	27.63
24	40.14	22.09	10.77	21.23	92.650	1.023	67.06	25.0	452	27.07	27.59
29	40.04	22.07	10.77	21.36	92.650	1.023	66.98	25.0	453	27.03	27.55
33	39.94	22.05	10.78	21.49	92.650	1.024	66.90	25.0	454	26.99	27.51
38	39.84	22.03	10.79	21.62	92.650	1.024	66.82	25.0	455	26.95	27.46

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Job No. 3696 A161 Sheet 92 of 150

Job Title Vent. Emp Cooling Analysis DESIGNED BY: D Browne DATE 4/6/86

Description: 10 yr. Development CHECKED BY : R Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 127-111 PANEL ACCESS

Length = 38 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 21024 (hrs), Age at outlet 21024 (hrs)

Ventilation at intake

Quantity = 9.7 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.96 Deg C, Dry bulb temp. = 23.97 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 20.272 kJ/hr/m/Deg C

Distance between temperature outputs = 5 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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FINAL FILING PAGE NO. ____

Job No. 3696A161 Sheet 93 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 127-111 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	23.97	16.96	10.33	50.84	92.650	1.079	49.64	25.0	704	19.06	17.82
5	23.97	16.96	10.33	50.86	92.650	1.079	49.65	25.0	703	19.08	17.82
10	23.96	16.96	10.34	50.89	92.650	1.079	49.65	25.0	703	19.08	17.82
14	23.96	16.96	10.34	50.91	92.650	1.079	49.65	25.0	703	19.08	17.81
19	23.96	16.96	10.34	50.94	92.650	1.079	49.66	25.0	703	19.08	17.81
24	23.95	16.96	10.34	50.96	92.650	1.079	49.66	25.0	703	19.08	17.81
29	23.95	16.96	10.35	50.99	92.650	1.079	49.66	25.0	703	19.08	17.81
33	23.95	16.96	10.35	51.01	92.650	1.079	49.67	25.0	703	19.08	17.80
38	23.94	16.96	10.35	51.03	92.650	1.079	49.67	25.0	703	19.08	17.80

Job No. 3696A161 Sheet 94 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: D Brunner DATE 4/14/86

Description: 10 yr Development CHECKED BY : R Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 111-110 EMP. DRIFT

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .05 , Airway friction coefficient = .013 kg/m^3
Age at inlet 17520 (hrs), Age at outlet 17520 (hrs)

Ventilation at intake

Quantity = 9.44 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 16.96 Deg C, Dry bulb temp. = 23.94 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 15.329 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	100	321.00	25.0	Electric

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Job No. 3696 A161 Sheet 95 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: DB. DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 111-110 EMP. DRIFT

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	23.94	16.96	10.34	50.99	92.650	1.079	49.64	25.0	652	19.05	18.00
25	23.88	16.96	10.38	51.33	92.650	1.079	49.67	25.0	652	19.08	17.96
50	23.83	16.96	10.41	51.66	92.650	1.079	49.70	25.0	652	19.07	17.93
75	23.78	16.96	10.44	51.99	92.650	1.080	49.73	25.0	652	19.05	17.89
After spot source no. 1 sensible heat = 84.47 kW, latent heat = 0.00 kW											
101	31.81	19.50	10.48	32.64	92.650	1.080	57.93	25.0	600	20.81	23.25
126	31.56	19.50	10.54	33.28	92.650	1.051	57.82	25.0	565	23.02	23.14
151	31.33	19.48	10.59	33.92	92.650	1.052	57.72	25.0	567	22.94	23.02
176	31.09	19.44	10.65	34.55	92.650	1.053	57.62	25.0	568	22.85	22.90
201	30.86	19.42	10.70	35.18	92.650	1.054	57.52	25.0	570	22.77	22.78

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Job No. 3696A161   Sheet 96 of 150

Job Title Vent: Emp. Cooling Analysis   DESIGNED BY: [signature]   DATE 4/16/86

Description: 10 yr Development   CHECKED BY: CR ROGERS   DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 110-49 MID PANEL

Length = 61 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 15.77 m, Cross-sectional area = 17.19 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 24090 (hrs), Age at outlet 24090 (hrs)

Ventilation at intake

Quantity = 13.97 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 20.3 Deg C, Dry bulb temp. = 33.97 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 37.400 kJ/hr/m/Deg C

Distance between temperature outputs = 15 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING

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Job No. 3696 Allel Sheet 97 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 16 yr. Development CHECKED BY : G.R. DATE

Predicted Environment: 110-49 MID PANEL

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	33.97	20.30	10.69	29.49	92.650	1.044	60.63	25.0	721	24.40	24.17
15	33.87	20.30	10.71	29.71	92.650	1.044	60.57	25.0	722	24.30	24.12
31	33.77	20.28	10.73	29.93	92.650	1.044	60.52	25.0	723	24.26	24.07
46	33.67	20.27	10.75	30.16	92.650	1.045	60.46	25.0	724	24.22	24.02
61	33.57	20.25	10.77	30.38	92.650	1.045	60.41	25.0	725	24.18	23.97

49-48 - Waste Main

L = 660' = 201 m
A = 39.48 m²
per = 22.62 m
Q = 131.4 kcfm = 62.0 m³/s
k = .0111 kg/m³
mean age = 3y = 26,280 yrs.
WF = .02

t_{wbi} = 20.97 °C
t_{dbi} = 35.6 °C

Output
t_{wb} = 20.93 °C
t_{db} = 35.03 °C

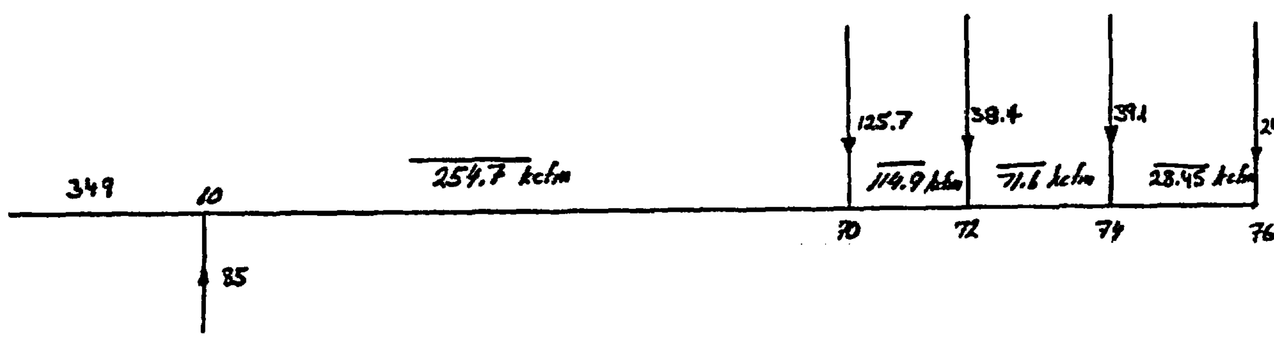
48-70

L = 20 m
Q = 125.7 kcfm

- The conditions of the air will not be significantly affected by this length of drift - neglected.

Conditions at junction 70: t_{wb} = 20.93 °C
t_{db} = 35.03 °C

Taft Main - Return



Conditions:	Junction
20.93/35.03	70
21.83/37.89	72
21.84/37.95	74
21.56/38.10	76

Initial parameters for the prediction of heat and humidity

Physical description of 49-48 WASTE MAIN

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 26280 (hrs), Age at outlet 26280 (hrs)

Ventilation at intake

Quantity = 62 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 20.97 Deg C, Dry bulb temp. = 35.6 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 61.708 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696 A161 Sheet 100 of 150

Job Title Vert. Emp Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 49-48 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	35.60	20.97	10.99	27.68	92.650	1.038	63.01	25.0	925	25.36	24.72
25	35.53	20.97	11.01	27.84	92.650	1.038	62.98	25.0	926	25.30	24.69
50	35.45	20.97	11.02	28.00	92.649	1.038	62.95	25.0	926	25.28	24.66
75	35.38	20.96	11.04	28.16	92.649	1.039	62.92	25.0	927	25.25	24.62
101	35.31	20.96	11.06	28.32	92.649	1.039	62.90	25.0	927	25.23	24.58
126	35.24	20.94	11.08	28.48	92.648	1.039	62.87	25.0	928	25.20	24.54
151	35.17	20.94	11.10	28.64	92.648	1.039	62.84	25.0	928	25.17	24.51
176	35.10	20.93	11.12	28.79	92.648	1.040	62.82	25.0	929	25.14	24.47
201	35.03	20.93	11.14	28.95	92.647	1.040	62.79	25.0	930	25.12	24.43

Subject: Vent. Emp. Cooling Analysis

For this analysis all leakage from the service main will be neglected. These low leakages will bring cooler air due to the low velocities + low VRT. The return air from the waste main drift will dictate the conditions in the return.

Tuff ramp - L = 4,797'
Tuff main - 10,540'
15,337'
= 4,675 m

For simplicity, motor efficiency will not be accounted for. All heat is assumed to be dissipated by friction.
motor every 2400' gives 6 motors for a total of 6·149 kW = 894 kW. At 90% utilization, load = 805 kW / 4,674 = 0.172 kW/m

76-74 Tuff main w/belt

t_{wbi} = 21.56°C
t_{dbi} = 38.10°C
Q = 28.45 kcfm = 13.4 m³/s
L = 660×2 = 1,320' = 402 m
A = 35.30 m²
per. = 26.97 m
k = .0130 kg/m³
Heat load from conveyor = 402 · 0.172 = 69.2 kW
mean age = 8,760 hrs.
WF = .02

Output
t_{wb} = 21.86°C
t_{db} = 37.97°C

Junction 74
Mixture:
28.45 / (28.45 + 39.1) = 0.42

t_{wb} = (21.86 − 21.84) 0.42 + 21.84 = 21.8
t_{db} = (37.97 − 37.85) 0.42 + 37.85 = 37.9

74-72 Tuff Main

t_{wbi} = 21.85°C
t_{dbi} = 37.96°C
$\bar{Q}$ = 71.6 kcfm = 33.8 m³/s
L = 745' + 660' = 1,405' = 428 m
Heat load = 73.6 kW
mean age = 1.6 y = 14,016 hrs.

Output
t_{wb} = 22.02°C
t_{db} = 37.34°C

Junction 72
Mixture:
38.4 / (38.4 + 71.6) = 0.35

t_{wb} = (21.85 − 22.02) .35 + 22.02 = 21.
t_{db} = (37.89 − 37.34) .35 + 37.34 = 37.

Initial parameters for the prediction of heat and humidity

Physical description of 76-74 TUFF MAIN W/BELT

Length = 402 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 26.97 m, Cross-sectional area = 35.3 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 8760 (hrs), Age at outlet 8760 (hrs)

Ventilation at intake

Quantity = 13.4 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.56 Deg C, Dry bulb temp. = 38.1 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 17.469 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 8 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	69.20	402

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Job No. 3696A161   Sheet 103 of 150

Job Title Vert. Emp Cooling Analysis   DESIGNED BY: D.B.   DATE ________

Description: 10 yr Development   CHECKED BY : 6.R.   DATE ________

Predicted Environment: 76-74 TUFF MAIN W/BELT

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	38.10	21.56	10.83	23.82	92.650	1.030	65.16	25.0	503	26.52	26.6
Start linear source no. 1 sensible heat = 69.2 kW For 402 m											
50	38.08	21.58	10.90	23.99	92.650	1.030	65.30	25.0	508	26.22	26.6
101	38.06	21.62	10.97	24.16	92.650	1.030	65.45	25.0	507	26.25	26.6
151	38.04	21.66	11.03	24.33	92.650	1.030	65.60	25.0	505	26.27	26.6
201	38.03	21.70	11.10	24.50	92.650	1.030	65.74	25.0	504	26.29	26.6
251	38.01	21.74	11.17	24.66	92.650	1.030	65.89	25.0	503	26.32	26.6
302	38.00	21.78	11.23	24.82	92.650	1.030	66.04	25.0	502	26.34	26.7
352	37.98	21.82	11.30	24.99	92.650	1.030	66.19	25.0	501	26.37	26.7
402	37.97	21.86	11.37	25.15	92.650	1.030	66.34	25.0	500	26.39	26.7

Initial parameters for the prediction of heat and humidity

Physical description of 74-72 TUFF MAIN

Length = 428 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 26.97 m, Cross-sectional area = 35.3 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 14016 (hrs), Age at outlet 14016 (hrs)

Ventilation at intake

Quantity = 33.8 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.85 Deg C, Dry bulb temp. = 37.96 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 44.064 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 9 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	73.60	428

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Job No. 3696A161 Sheet 105 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 10 yr Development CHECKED BY : GR DATE

Predicted Environment: 74-72 TUFF MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.96	21.85	11.33	25.08	92.650	1.030	66.23	25.0	696	26.68	26.42
Start linear source no. 1 sensible heat = 73.6 kW For 428 m											
48	37.88	21.85	11.39	25.32	92.650	1.030	66.31	25.0	698	26.57	26.39
95	37.81	21.87	11.45	25.55	92.649	1.030	66.39	25.0	698	26.56	26.37
143	37.74	21.89	11.51	25.79	92.649	1.030	66.46	25.0	697	26.56	26.36
190	37.67	21.91	11.57	26.02	92.649	1.031	66.54	25.0	696	26.55	26.34
238	37.60	21.93	11.63	26.25	92.648	1.031	66.62	25.0	696	26.54	26.32
285	37.53	21.95	11.69	26.48	92.648	1.031	66.70	25.0	695	26.54	26.31
333	37.47	21.97	11.75	26.71	92.647	1.031	66.78	25.0	694	26.53	26.29
380	37.41	21.99	11.81	26.93	92.647	1.031	66.86	25.0	694	26.53	26.26
428	37.34	22.02	11.87	27.16	92.647	1.032	66.94	25.0	693	26.53	26.26

72-70 Tuff Main

t_{wbi} = 21.95°C
t_{dbi} = 37.53°C
$\bar{Q}$ = 114.9 kcfm = 54.2 m³/s
L = 660 + 745 = 1,405' = 428 m
Heat load = 73.6 kW
mean age = 2.5y = 21,900 hrs.

Output

t_{wb} = 22.08°C
t_{db} = 36.83°C

Mixture

114.9 / (114.9 + 125.7) = 0.48

t_{wb} = (22.08 − 20.93) 0.48 + 20.93 = 21.48
t_{db} = (36.83 − 35.03) 0.48 + 35.03 = 35.89

(70.7, 96.6 °F)

70-60

L = 6,410' = 1,954 m
t_{wbi} = 21.48°C
t_{dbi} = 35.89°C
$\bar{Q}$ = 254.7 kcfm = 120.2 m³/s
Age in = 3.1y = 27,156 hrs
Age out = 10y = 87,600 hrs
Heat load = 336 kW

Output

t_{wbi} = 21.92°C
t_{db} = 32.92°C

Mixture

Assuming shop exit conditions at 25/37°C with 85 kcfm.

85 / 349 = 0.24

t_{wb} = (25 − 21.92) 0.24 + 21.92 = 22.66°C
t_{db} = (37 − 32.92) 0.24 + 32.92 = 33.90°C

(72.8, 93.0 °F)

L = 490 + 350 + 180 + 590 + 590 + 725 + 640 + 85 + 660 + 745 + 660 + 745 = 6,410'

60-59 - Tuff Ramp

L = 4797' = 1,426 m
Q = 349 m³/s = 165 m³/s
A = 37.16 m²
per. = 26.21 m
k = .0111 kg/m³
Age in = 87,600 hrs
Age out = 96,360 hrs
Heat load = 245 kW

t_{wbi} = 22.66°C
t_{dbi} = 33.90°C

Output

t_{wb} = 21.65°C
t_{db} = 29.65°C

(71.0, 85.4 °F)

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Job No. 3696A16L Sheet 107 of 150

Job Title Vent. Emp Cooling Analysis DESIGNED BY D Brunner DATE 4/17/86

Description: 10 yr. Development CHECKED BY : G Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 72-70 TUFF MAIN

Length = 428 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 26.97 m, Cross-sectional area = 35.3 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 21900 (hrs), Age at outlet 21900 (hrs)

Ventilation at intake

Quantity = 54.2 (m^3/s), Pressure = 92.65 (kPa)
Wet bulb temp. = 21.95 Deg C, Dry bulb temp. = 37.53 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 70.660 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 9 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	73.60	428

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Job No. 3696 A161 Sheet 108 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: TB DATE ________

Description: 10 yr. Development CHECKED BY: GR DATE ________

Predicted Environment: 72-70 TUFF MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	37.53	21.95	11.66	26.41	92.650	1.031	66.61	25.0	861	26.62	26.03
Start linear source no. 1 sensible heat = 73.6 kW For 428 m											
48	37.45	21.95	11.72	26.66	92.649	1.031	66.67	25.0	862	26.56	25.99
95	37.36	21.97	11.78	26.92	92.648	1.032	66.73	25.0	861	26.55	25.96
143	37.28	21.98	11.84	27.17	92.647	1.032	66.80	25.0	861	26.54	25.94
190	37.20	22.00	11.90	27.42	92.646	1.032	66.86	25.0	860	26.53	25.91
238	37.13	22.02	11.95	27.66	92.645	1.032	66.92	25.0	860	26.51	25.88
285	37.05	22.03	12.01	27.91	92.644	1.032	66.99	25.0	859	26.50	25.86
333	36.98	22.05	12.07	28.16	92.643	1.033	67.05	25.0	858	26.49	25.83
380	36.90	22.07	12.13	28.40	92.642	1.033	67.12	25.0	858	26.48	25.81
428	36.83	22.08	12.18	28.64	92.641	1.033	67.18	25.0	857	26.47	25.79

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Job No. 3696A161   Sheet 109 of 150

Job Title Vent. Emp. Cooling Analysis   DESIGNED BY: D. Brunner DATE 4/17/86

Description: 10yr Development   CHECKED BY: GK Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 70-60 TUFF MAIN

Length = 1954 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 26.97 m, Cross-sectional area = 35.3 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 27156 (hrs), Age at outlet 87600 (hrs)

Ventilation at intake

Quantity = 120.2 (m^3/s), Pressure = 92.64 (kPa)
Wet bulb temp. = 21.48 Deg C, Dry bulb temp. = 35.89 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 156.703 kJ/hr/m/Deg C

Distance between temperature outputs = 200 m - 10 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	336.00	1954

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO.

Job No. 3696A161 Sheet 110 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE

Description: 10 yr. Development CHECKED BY : GR DATE

Predicted Environment: 70-60 TUFF MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	35.89	21.48	11.63	28.81	92.640	1.037	64.87	25.0	1337	25.80	24.22
Start linear source no. 1 sensible heat = 336 kW For 1954 m											
195	35.50	21.51	11.85	29.97	92.621	1.037	65.02	25.0	1335	25.71	24.01
391	35.14	21.55	12.07	31.12	92.601	1.038	65.18	25.0	1333	25.63	23.81
586	34.80	21.59	12.28	32.25	92.582	1.039	65.35	25.0	1330	25.56	23.62
782	34.48	21.63	12.48	33.35	92.562	1.040	65.53	25.0	1327	25.49	23.44
977	34.18	21.68	12.68	34.44	92.543	1.041	65.71	25.0	1324	25.43	23.27
1172	33.90	21.73	12.87	35.50	92.523	1.041	65.89	25.0	1321	25.38	23.11
1368	33.63	21.77	13.06	36.53	92.504	1.042	66.08	25.0	1318	25.34	22.96
1563	33.38	21.82	13.25	37.55	92.484	1.042	66.27	25.0	1315	25.29	22.81
1759	33.14	21.87	13.42	38.54	92.465	1.043	66.47	25.0	1311	25.26	22.67
1954	32.92	21.92	13.60	39.52	92.445	1.043	66.67	25.0	1308	25.23	22.54

Initial parameters for the prediction of heat and humidity

Physical description of 60-59 TUFF RAMP

Length = 1426 m, Depth in = 311 m, Depth out = 0 m
Perimeter = 26.21 m, Cross-sectional area = 37.16 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 87600 (hrs), Age at outlet 96360 (hrs)

Ventilation at intake

Quantity = 165 (m^3/s), Pressure = 92.4 (kPa)
Wet bulb temp. = 22.66 Deg C, Dry bulb temp. = 33.9 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 174.476 kJ/hr/m/Deg C

Distance between temperature outputs = 200 m - 7 output stations

Heat Sources

Linear heat sources

No.	Distance from intake end (m)	Sensible Heat Load (kW)	Length of Source (m)
1	0	245.00	1426

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Job No. 3696 A161 Sheet 162 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10yr Development CHECKED BY : GR DATE ________

Predicted Environment: 60-59 TUFF RAMP

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	33.90	22.66	14.34	39.38	92.400	1.039	69.45	25.0	1443	26.03	23.44
Start linear source no. 1 sensible heat = 245 kW for 1426 m											
204	33.28	22.54	14.48	40.94	91.920	1.036	69.17	22.9	1455	25.80	22.98
407	32.67	22.39	14.61	42.54	91.442	1.033	68.88	20.7	1470	25.50	22.48
611	32.06	22.25	14.74	44.18	90.966	1.030	68.58	18.6	1485	25.22	21.98
815	31.45	22.10	14.87	45.85	90.490	1.026	68.27	16.4	1501	24.93	21.46
1019	30.85	21.96	14.98	47.57	90.017	1.023	67.94	14.3	1516	24.64	20.92
1222	30.25	21.80	15.10	49.32	89.545	1.019	67.61	12.1	1532	24.36	20.36
1426	29.65	21.65	15.20	51.12	89.075	1.016	67.26	10.0	1548	24.07	19.79

Waste Emplacement System

WASTE. RAMP 27-28

L = 6,362' = 1,939 m
Q = 163.2 kcfm = 77 m³/s
A = 26.11 m²
per = 19.0 m
k = .0058 kg/m³
twbi = 15.2 °C
tdbi = 30.3 °C
WF = .02
Age = 96,360 hrs. in, 87600 hrs. out
Pi = 88.0 kPa

Output
twb = 16.04 °C (60.9, 85.2 °F)
tdb = 29.55 °C

28-29 Waste Main

L = 530' = 161.5 m
A = 39.48 m²
per. = 22.62 m
k = .0111 kg/m³ Pi = 91.07
twbi = 16.04 °C
tdbi = 29.55 °C
WF = .02
Age = 87,600 in, 85,848 hrs. out
Q = 157 kcfm = 74.1 m³/s

Output
twb = 16.04 °C
tdb = 29.24 °C

29-31 Waste Main

L = 120' + 95' = 65.5 m
twbi = 16.04 °C
tdbi = 29.24 °C
WF = .02
Age = 85848 hrs, 80,592 hrs.
Q = 93.6 kcfm = 44.2 m³/s

Output
twb = 16.04 °C (60.9, 84.4 °F)
tdb = 29.10 °C

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Job No. 3696 A161 Sheet 114 of 150

Job Title Vert Emp Cooling Analysis DESIGNED BY: D Brunner DATE 4/17/86

Description: 10 yr Development CHECKED BY : CR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of WASTE RAMP 27-28

Length = 1939 m, Depth in = 0 m, Depth out = 311 m
Perimeter = 19 m, Cross-sectional area = 26.11 m^2
Wetness factor = .02 , Airway friction coefficient = .0056 kg/m^3
Age at inlet 96360 (hrs), Age at outlet 87600 (hrs)

Ventilation at intake

Quantity = 77 (m^3/s), Pressure = 88 (kPa)
Wet bulb temp. = 15.2 Deg C, Dry bulb temp. = 30.3 Deg C

Thermal Parameters

V.R.T. at inlet = 10 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 58.462 kJ/hr/m/Deg C

Distance between temperature outputs = 200 m - 10 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161   Sheet 115 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yr. Development   CHECKED BY : GR   DATE ________

Predicted Environment: WASTE RAMP 27-28

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.30	15.20	6.22	20.18	88.000	1.006	45.95	10.0	1651	19.73	18.98
194	30.12	15.23	6.31	20.78	88.302	1.009	46.01	11.5	1650	19.62	18.86
388	29.97	15.29	6.41	21.35	88.604	1.013	46.09	13.0	1645	19.62	18.76
582	29.83	15.36	6.51	21.91	88.908	1.017	46.19	14.5	1641	19.63	18.68
776	29.73	15.45	6.60	22.43	89.213	1.021	46.32	16.0	1635	19.67	18.63
969	29.64	15.53	6.69	22.93	89.519	1.024	46.46	17.5	1629	19.71	18.58
1163	29.58	15.61	6.78	23.41	89.827	1.028	46.62	19.0	1624	19.75	18.56
1357	29.54	15.71	6.88	23.85	90.135	1.032	46.81	20.5	1617	19.82	18.55
1551	29.53	15.81	6.97	24.27	90.444	1.035	47.01	22.0	1611	19.89	18.56
1745	29.53	15.93	7.06	24.66	90.755	1.039	47.23	23.5	1603	19.98	18.59
1939	29.55	16.04	7.14	25.02	91.067	1.042	47.48	25.0	1596	20.07	18.63

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Job No. 3696A161 Sheet 116 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY F. J. Brunner DATE 4/10/86

Description: 16 yr Development CHECKED BY : GR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 28-29 WASTE MAIN

Length = 161 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 87600 (hrs), Age at outlet 85848 (hrs)

Ventilation at intake

Quantity = 74.1 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.04 Deg C, Dry bulb temp. = 29.55 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 73.751 kJ/hr/m/Deg C

Distance between temperature outputs = 30 m - 5 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696 A16 1 Sheet 117 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 28-29 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.55	16.04	7.11	24.91	91.070	1.043	47.39	25.0	1271	20.09	19.43
32	29.49	16.04	7.13	25.08	91.069	1.043	47.39	25.0	1271	20.08	19.39
64	29.42	16.04	7.16	25.25	91.069	1.043	47.38	25.0	1271	20.06	19.35
97	29.36	16.04	7.18	25.42	91.068	1.044	47.37	25.0	1271	20.04	19.31
129	29.30	16.04	7.20	25.58	91.067	1.044	47.36	25.0	1271	20.02	19.27
161	29.24	16.04	7.22	25.75	91.067	1.044	47.35	25.0	1271	20.00	19.23

MVS, Inc. CLIMSIM VERSION 1.1

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Job No. 3696A161 Sheet 118 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/13/86

Description: 10 yr Development CHECKED BY : G R Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 29-31 WASTE MAIN

Length = 65.5 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 85848 (hrs), Age at outlet 80592 (hrs)

Ventilation at intake

Quantity = 44.2 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.04 Deg C, Dry bulb temp. = 29.24 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 43.992 kJ/hr/m/Deg C

Distance between temperature outputs = 10 m - 7 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ___

Job No. 3696 A11c1 Sheet 119 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.R. DATE ________

Description: 10 yr Development CHECKED BY : G.R. DATE ________

Predicted Environment: 29-31 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.24	16.04	7.24	25.81	91.070	1.044	47.40	25.0	1004	20.00	19.9
9	29.22	16.04	7.25	25.86	91.070	1.044	47.39	25.0	1004	19.97	19.9
19	29.20	16.04	7.25	25.91	91.070	1.044	47.39	25.0	1004	19.97	19.8
28	29.18	16.04	7.26	25.96	91.070	1.044	47.38	25.0	1004	19.96	19.8
37	29.16	16.04	7.26	26.02	91.070	1.044	47.38	25.0	1004	19.96	19.8
47	29.14	16.04	7.27	26.07	91.070	1.045	47.37	25.0	1004	19.95	19.8
56	29.12	16.04	7.28	26.12	91.070	1.045	47.37	25.0	1004	19.95	19.8
66	29.10	16.04	7.28	26.17	91.070	1.045	47.37	25.0	1004	19.94	19.8

31 - 35 Waste Main

$L = 85 + 190 + 170 + 150 = 545' = 166.1\,m$
$\bar{Q} = 76.3\ kcfm = 36\ m^3/s$
$t_{wbi} = 16.09°C$
$t_{dbi} = 29.10°C$
Age = 80,592 hrs in − 74,460 hrs out

Output
$t_{wb} = 16.03°C$
$t_{db} = 28.75°C$

Junction 35

21.7 kcfm mixes with the waste intake air at 35. This air is from the ES I shaft. The airflows down ES I + II, 100.6 m³/s, 19.9 m³/s in the vertical case, are similar to those for the horizontal situation, those being 98.3 m³/s and 19.9 m³/s. The conditions at the base of these shafts will be taken from the Horizontal Analysis.

ES I
$Q = 100.6\ m^3/s$ @ 16.48/33.04 °C

ES II
$Q = 19.9\ m^3/s$ @ 16.32/32.49 °C

Mixture at 35

$21.7 / (74.3 + 21.7) = 0.226$
$t_{wb} = (16.48 - 16.03)\,0.226 + 16.03 = 16.13\ °C$
$t_{db} = (33.04 - 28.75)\,0.226 + 28.75 = 29.72°C$

35-36 Waste Main

$L = 310' = 94.5\,m$
$Q = 96\ kcfm = 45.3\ m^3/s$
$t_{wbi} = 16.13°C$
$t_{dbi} = 29.72°C$
Age = 74,460 hrs. in − 73,584 hrs. out

Output
$t_{wb} = 16.13°C$
$t_{db} = 29.51°C$

Mixture at 36

$75.6 / 171.6 = 0.441$

$t_{wb} = (16.48 - 16.13)\,0.441 + 16.13 = 16.28\ °C$
$t_{db} = (33.04 - 29.51)\,0.441 + 29.51 = 31.07\ °C$

Job No. 3696A761 Sheet 121 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Bonner DATE 4/17/86

Description: 10 yr. Development CHECKED BY : R ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 31-35 WASTE MAIN

Length = 166 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 80592 (hrs), Age at outlet 74460 (hrs)

Ventilation at intake

Quantity = 36 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.04 Deg C, Dry bulb temp. = 29.1 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 35.830 kJ/hr/m/Deg C

Distance between temperature outputs = 40 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161   Sheet 122 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yr Development   CHECKED BY : GR   DATE ________

Predicted Environment: 31-35 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.10	16.04	7.30	26.22	91.070	1.045	47.40	25.0	922	19.96	20.0
42	29.01	16.04	7.32	26.46	91.070	1.045	47.37	25.0	922	19.93	19.9
83	28.92	16.04	7.35	26.70	91.070	1.045	47.35	25.0	922	19.90	19.9
125	28.83	16.04	7.38	26.93	91.069	1.045	47.33	25.0	922	19.87	19.8
166	28.75	16.03	7.41	27.17	91.069	1.046	47.31	25.0	923	19.84	19.8

Initial parameters for the prediction of heat and humidity

Physical description of 35-36 WASTE MAIN

Length = 94.5 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 74460 (hrs), Age at outlet 73584 (hrs)

Ventilation at intake

Quantity = 45.3 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.13 Deg C, Dry bulb temp. = 29.72 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 45.087 kJ/hr/m/Deg C

Distance between temperature outputs = 20 m - 5 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1

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Job No. 3696A161 Sheet 124 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 35-36 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.72	16.13	7.15	24.81	91.070	1.043	47.67	25.0	1010	20.21	20.19
19	29.68	16.13	7.17	24.91	91.070	1.043	47.66	25.0	1010	20.18	20.17
38	29.64	16.13	7.18	25.02	91.070	1.043	47.65	25.0	1010	20.17	20.14
57	29.60	16.13	7.19	25.12	91.070	1.043	47.64	25.0	1010	20.15	20.12
76	29.55	16.13	7.21	25.23	91.069	1.043	47.63	25.0	1010	20.14	20.09
95	29.51	16.13	7.22	25.33	91.069	1.043	47.62	25.0	1011	20.13	20.07

Subject Vert. Eng. Cooling Analysis

36-37 Waste Main

L = 250' = 76.2 m
Q = 171.6 kcfm = 80.9 m³/s
twbi = 16.28°C
tdbi = 31.07°C
Age = 73,584 hrs. in - 70,956 hrs.

Output
twb = 16.28°C
tdb = 30.90°C

Mixture at 37

(42.1) @ 16.32/32.49 °C
(101.3 - 42.1) @ 16.48/33.04 °C

twb = (16.32 - 16.48) 0.42 + 16.48 = 16.41
tdb = (32.49 - 33.04) .42 + 33.04 = 32.8 °C

101.3 / 272.8 = 0.37

twb = (16.41 - 16.28) 0.37 + 16.28 = 16.33 °C (61.4, 88.9 °F)
tdb = (32.8 - 30.90) 0.37 + 30.9 = 31.6 °C

37-42 - Waste Main

L = 160 + 85 + 640 + 640 + 85 = 1,610' = 491 m
Q̄ = 266.0 kcfm = 125.6 m³/s
twbi = 16.33°C
tdbi = 31.6°C
Age in = 70,956 hrs. in - 52,560 hrs.

Output
twb = 16.31°C
tdb = 30.58°C
(61.4, 87.0 °F)

42-166 Panel Access w/o belt

A = 22.02 m²
per. = 18.26 m k = .013 kg/m³
twbi = 16.31°C
tdbi = 30.58°C
Age in = 52,560 (mean)
Q = 133.8 + 124.2 + 117.8 + 110.7 / 4 = 121.6 kcfm = 57.4 m³/s
L = 340 + 430 + 430 + 430 = 1,630' = 497 m

Output
twb = 16.26°C
tdb = 28.97°C

Initial parameters for the prediction of heat and humidity

Physical description of 36-37 WASTE MAIN

Length = 76.2 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 73584 (hrs), Age at outlet 70956 (hrs)

Ventilation at intake

Quantity = 80.9 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.28 Deg C, Dry bulb temp. = 31.07 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 80.519 kJ/hr/m/Deg C

Distance between temperature outputs = 20 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc.   CLIMSIM VERSION 1.1   FINAL FILING PAGE NO. ____

Job No. 3696 A16 1   Sheet 127 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yR. Development   CHECKED BY : GR   DATE ________

Predicted Environment: 36-37 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	31.07	16.28	6.78	21.80	91.070	1.038	48.12	25.0	1312	20.72	20.33
19	31.03	16.28	6.80	21.89	91.070	1.038	48.11	25.0	1312	20.70	20.30
38	30.99	16.28	6.81	21.99	91.069	1.038	48.11	25.0	1312	20.68	20.28
57	30.94	16.28	6.83	22.09	91.069	1.039	48.10	25.0	1312	20.67	20.25
76	30.90	16.28	6.84	22.19	91.068	1.039	48.09	25.0	1313	20.66	20.22

Job Title Vert. Evap. Cooling Analysis DESIGNED BY: D Brunner DATE 4/17/86

Description: 10 yr. Development CHECKED BY: GR Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 37-42 WASTE

Length = 491 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 70956 (hrs), Age at outlet 52560 (hrs)

Ventilation at intake

Quantity = 125.6 (m^3/s), Pressure = 91.07 (kPa)
Wet bulb temp. = 16.33 Deg C, Dry bulb temp. = 31.6 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 125.008 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 10 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ___

Job No. 3696 A161 Sheet 129 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: 37-42 WASTE

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	31.60	16.33	6.63	20.67	91.070	1.037	48.27	25.0	1639	20.91	20.00
49	31.49	16.33	6.67	20.91	91.067	1.037	48.26	25.0	1639	20.90	19.93
98	31.39	16.33	6.71	21.16	91.065	1.037	48.25	25.0	1639	20.86	19.86
147	31.28	16.33	6.74	21.40	91.062	1.037	48.23	25.0	1640	20.83	19.79
196	31.18	16.33	6.78	21.65	91.059	1.037	48.22	25.0	1640	20.80	19.72
246	31.08	16.33	6.82	21.89	91.056	1.038	48.21	25.0	1640	20.77	19.64
295	30.98	16.33	6.86	22.13	91.054	1.038	48.20	25.0	1640	20.74	19.57
344	30.88	16.32	6.89	22.38	91.051	1.038	48.19	25.0	1641	20.70	19.50
393	30.78	16.32	6.93	22.62	91.048	1.039	48.18	25.0	1641	20.67	19.43
442	30.68	16.32	6.97	22.87	91.045	1.039	48.17	25.0	1641	20.64	19.36
491	30.58	16.31	7.00	23.11	91.043	1.039	48.16	25.0	1642	20.61	19.29

Initial parameters for the prediction of heat and humidity

Physical description of 42-166 PANEL ACCESS

Length = 497 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 52560 (hrs), Age at outlet 52560 (hrs)

Ventilation at intake

Quantity = 57.4 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.31 Deg C, Dry bulb temp. = 30.58 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 119.961 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 10 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1

FINAL FILING PAGE NO. ---

Job No. 3696A161 Sheet 131 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 42-166 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.58	16.31	7.03	23.20	91.040	1.039	48.22	25.0	1481	20.59	19.65
50	30.41	16.31	7.09	23.63	91.037	1.039	48.20	25.0	1480	20.58	19.53
99	30.24	16.31	7.15	24.06	91.034	1.040	48.18	25.0	1481	20.52	19.42
149	30.07	16.31	7.21	24.49	91.031	1.040	48.16	25.0	1481	20.47	19.30
199	29.91	16.30	7.27	24.92	91.027	1.041	48.14	25.0	1482	20.41	19.18
249	29.74	16.30	7.33	25.36	91.024	1.041	48.12	25.0	1482	20.37	19.07
298	29.58	16.28	7.38	25.79	91.021	1.042	48.10	25.0	1483	20.31	18.95
348	29.42	16.28	7.44	26.23	91.018	1.042	48.08	25.0	1483	20.26	18.84
398	29.27	16.27	7.50	26.66	91.015	1.043	48.06	25.0	1484	20.21	18.73
447	29.12	16.27	7.55	27.09	91.012	1.043	48.04	25.0	1485	20.16	18.61
497	28.97	16.26	7.61	27.53	91.008	1.044	48.03	25.0	1486	20.10	18.50

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Engineers • Architects • Planners

COMPUTATION SHEET

Job No. 3696 A.16.1
Made by Brammer
Date 4/17/86
Checked by R. Rogers
Date 5/7/86

Subject Vert. Emp. Cooling Analysis

166 – 189 Panel Access w/o belt

A = 22.02 m²
per. = 18.26 m
twbi = 16.26°C
tdbi = 28.97°C
Age (mean) = 52,560 hrs.
Q = 103.2 + 98.7 + 95/3 = 98.9 kcfm = 46.7 m³/s
L = 490' + 590' + 360' = 1440' = 439 m

Output
twb = 16.24°C
tdb = 27.71°C

Conditions at 189

twb = 16.24°C
tdb = 27.71°C

189 – 192 Panel Access w/o belt

Q = 48.5 kcfm = 22.9 m³/s
twbi = 16.29°C
tdbi = 27.71°C
Age (mean) = 52,560 hrs.
L = 140' = 42.7 m

Output (192)
twb = 16.24°C (61.2, 81.6 °F)
tdb = 27.58°C

42 – 44 Waste Main

Q̄ = 129.3 + 128.3/2 = 128.8 kcfm = 60.8 m³/s
A = 39.98 m²
per. = 22.62 m
k = .0111 kg/m³
twbi = 16.31°C
tdbi = 30.58°C
Age = 43,800 hrs. (mean)
L = 660 · 2 = 1,320' = 402 m

Output
twb = 16.27°C (61.3, 85.4°F)
tdb = 29.69°C

Initial parameters for the prediction of heat and humidity

Physical description of 166-189 PANEL ACCESS

Length = 439 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 52560 (hrs), Age at outlet 52560 (hrs)

Ventilation at intake

Quantity = 46.7 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.26 Deg C, Dry bulb temp. = 28.97 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 97.599 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 9 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO.

Job No. 3696A161 Sheet 134 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE

Description: 16yr. Development CHECKED BY : GR DATE

Predicted Environment: 166-189 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	28.97	16.26	7.62	27.59	91.040	1.045	48.07	25.0	1340	20.07	18.90
49	28.82	16.26	7.68	28.02	91.038	1.045	48.05	25.0	1340	20.06	18.80
98	28.67	16.26	7.73	28.45	91.036	1.045	48.03	25.0	1340	20.01	18.69
146	28.53	16.26	7.78	28.88	91.034	1.045	48.02	25.0	1340	19.97	18.59
195	28.39	16.26	7.84	29.31	91.032	1.046	48.00	25.0	1341	19.93	18.49
244	28.25	16.25	7.89	29.74	91.030	1.046	47.98	25.0	1341	19.88	18.38
293	28.11	16.25	7.94	30.17	91.028	1.047	47.97	25.0	1342	19.84	18.28
341	27.97	16.24	7.99	30.59	91.026	1.047	47.95	25.0	1343	19.79	18.18
390	27.84	16.24	8.04	31.02	91.024	1.048	47.94	25.0	1343	19.75	18.08
439	27.71	16.24	8.09	31.45	91.021	1.048	47.93	25.0	1343	19.71	17.98

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO.

Job No. 3696A161 Sheet 135 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Dcunner DATE 4/17/66

Description: 10 yr. Development CHECKED BY: ER ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 189-192 PANEL ACCESS

Length = 43 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 52560 (hrs), Age at outlet 52560 (hrs)

Ventilation at intake

Quantity = 22.9 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.24 Deg C, Dry bulb temp. = 27.71 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.859 kJ/hr/m/Deg C

Distance between temperature outputs = 10 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

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Job No. 3696A161   Sheet 136 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 16yr. Development   CHECKED BY : GR   DATE ________

Predicted Environment: 189-192 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	27.71	16.24	8.12	31.57	91.040	1.049	48.01	25.0	970	19.68	19.13
11	27.68	16.24	8.13	31.67	91.040	1.049	48.01	25.0	970	19.66	19.11
22	27.65	16.24	8.14	31.77	91.040	1.049	48.00	25.0	970	19.65	19.09
32	27.62	16.24	8.15	31.87	91.040	1.049	47.99	25.0	970	19.64	19.07
43	27.58	16.24	8.16	31.97	91.040	1.049	47.99	25.0	970	19.63	19.05

Initial parameters for the prediction of heat and humidity

Physical description of 42-44 WASTE MAIN

Length = 402 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 22.62 m, Cross-sectional area = 39.48 m^2
Wetness factor = .02 , Airway friction coefficient = .0111 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 60.8 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.31 Deg C, Dry bulb temp. = 30.58 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 60.514 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 8 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc.   CLIMSIM VERSION 1.1   FINAL FILING PAGE NO. ___

Job No. 3696A161   Sheet 138 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yr Development   CHECKED BY : GR   DATE ________

Predicted Environment: 42-44 WASTE MAIN

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	30.58	16.31	7.03	23.20	91.040	1.039	48.22	25.0	1143	20.59	20.41
50	30.46	16.31	7.06	23.47	91.039	1.039	48.20	25.0	1144	20.56	20.34
101	30.35	16.31	7.10	23.74	91.039	1.040	48.17	25.0	1144	20.53	20.28
151	30.24	16.31	7.14	24.02	91.038	1.040	48.15	25.0	1144	20.49	20.21
201	30.13	16.30	7.17	24.29	91.037	1.040	48.12	25.0	1145	20.45	20.14
251	30.02	16.30	7.21	24.57	91.037	1.041	48.10	25.0	1145	20.42	20.07
302	29.91	16.28	7.24	24.84	91.036	1.041	48.08	25.0	1146	20.38	20.00
352	29.80	16.27	7.28	25.11	91.035	1.042	48.05	25.0	1147	20.34	19.94
402	29.69	16.27	7.31	25.39	91.035	1.042	48.03	25.0	1147	20.30	19.87

44 - 168 Panel Access w/o belt

$\bar{Q}$ = 117.5 kcfm = 55.45 m³/s
L = 497m
Age = 43,800 hrs. mean
twbi = 16.27 °C
tdbi = 29.69 °C
A = 22.02 m²
per. = 18.26 m
k = .013 kg/m³

Output

twb = 16.23 °C
tdb = 28.19 °C

168 - 191 Panel Access w/o belt

L = 439m
Q = 100.6 + 97.1 + 94.6 / 3 = 97.4 kcfm = 45.9 m³/s
Age = 43,800 hrs. mean.
twbi = 16.23 °C
tdbi = 28.19 °C

Output

twb = 16.21 °C
tdb = 27.02 °C

191 - 194 Panel Access w/o belt.

L = 42.7 m
Age (mean) = 43,800 hrs.
twbi = 16.21 °C
tdbi = 27.02 °C
Q = 47.8 kcfm = 22.6 m³/s

Output (194)

twb = 16.21 °C (61.2, 80.4 °F)
tdb = 26.91 °C

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ___

Job No. 3696A161 Sheet 140 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D Bauer DATE 4/17/86

Description: 10 yr Development CHECKED BY : CR Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 44-168 PANEL ACCESS

Length = 497 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 55.45 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.27 Deg C, Dry bulb temp. = 29.69 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 115.886 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 10 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING
PAGE NO. ----

Job No. 3696A161 Sheet 141 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D.B. DATE

Description: 16 yr Development CHECKED BY : GR DATE

Predicted Environment: 44-168 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	.vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	29.69	16.27	7.34	25.49	91.040	1.042	48.10	25.0	1458	20.30	19.09
50	29.53	16.27	7.40	25.93	91.037	1.042	48.08	25.0	1458	20.28	18.98
99	29.37	16.27	7.46	26.36	91.034	1.043	48.06	25.0	1458	20.23	18.87
149	29.22	16.27	7.51	26.80	91.031	1.043	48.04	25.0	1459	20.19	18.75
199	29.06	16.27	7.57	27.23	91.028	1.044	48.02	25.0	1459	20.14	18.64
249	28.91	16.26	7.62	27.67	91.025	1.044	48.01	25.0	1460	20.09	18.53
298	28.76	16.26	7.68	28.10	91.022	1.045	47.99	25.0	1460	20.04	18.42
348	28.62	16.24	7.73	28.54	91.019	1.045	47.98	25.0	1461	19.99	18.31
398	28.47	16.24	7.78	28.97	91.016	1.045	47.96	25.0	1461	19.94	18.20
447	28.33	16.23	7.84	29.41	91.013	1.046	47.95	25.0	1462	19.89	18.09
497	28.19	16.23	7.89	29.84	91.010	1.046	47.93	25.0	1463	19.85	17.98

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ----

Job No. 3696A161 Sheet 142 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Bonner DATE 4/17/86

Description: 10 yr Development CHECKED BY : GK Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 168-191 PANEL ACCESS

Length = 439 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 45.9 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.23 Deg C, Dry bulb temp. = 28.19 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 95.927 kJ/hr/m/Deg C

Distance between temperature outputs = 50 m - 9 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING

PAGE NO. ____

Job No. 3696A161 Sheet 143 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 168-191 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	28.19	16.23	7.91	29.92	91.040	1.047	47.98	25.0	1331	19.82	18.37
49	28.05	16.23	7.96	30.35	91.038	1.047	47.97	25.0	1331	19.81	18.27
98	27.92	16.23	8.01	30.78	91.036	1.048	47.95	25.0	1332	19.77	18.17
146	27.78	16.23	8.06	31.21	91.034	1.048	47.94	25.0	1332	19.73	18.08
195	27.65	16.23	8.11	31.63	91.032	1.048	47.92	25.0	1332	19.69	17.98
244	27.52	16.23	8.15	32.06	91.030	1.049	47.91	25.0	1332	19.65	17.88
293	27.39	16.22	8.20	32.48	91.028	1.049	47.90	25.0	1333	19.60	17.78
341	27.27	16.22	8.25	32.91	91.026	1.050	47.89	25.0	1333	19.56	17.69
390	27.15	16.22	8.29	33.33	91.024	1.050	47.88	25.0	1334	19.52	17.59
439	27.02	16.21	8.34	33.75	91.022	1.050	47.87	25.0	1335	19.48	17.49

MVS, Inc. CLIMSIM VERSION 1.1 FINAL FILING PAGE NO. ---

Job No. 3696A161 Sheet 144 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/17/86

Description: 10 yr Development CHECKED BY : GR ROGERS DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of 191-194 PANEL ACCESS

Length = 42.7 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 18.26 m, Cross-sectional area = 22.02 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 22.6 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.21 Deg C, Dry bulb temp. = 27.02 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 47.232 kJ/hr/m/Deg C

Distance between temperature outputs = 10 m - 4 output stations

Heat Sources

Virgin rock temperature is the only heat source for this simulation

:-300

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Job No. 3696A161 Sheet 145 of 150

Job Title Vert Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr Development CHECKED BY : GR DATE ________

Predicted Environment: 191-194 PANEL ACCESS

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	27.02	16.21	8.36	33.86	91.040	1.051	47.92	25.0	968	19.45	18.70
11	26.99	16.21	8.37	33.96	91.040	1.051	47.92	25.0	968	19.44	18.68
21	26.96	16.21	8.38	34.05	91.040	1.051	47.91	25.0	968	19.43	18.66
32	26.93	16.21	8.39	34.15	91.040	1.051	47.91	25.0	968	19.42	18.64
43	26.91	16.21	8.40	34.25	91.040	1.051	47.90	25.0	968	19.41	18.63

Emplacement Room 189-190

t_{wbi} = 16.24°C
t_{dbi} = 27.71°C
Q = 45kcfm = 21.24 m³/s
L = 660' = 201.2m
k = .013 kg/m³
A = 28.34m²
per. = 20.63m
NF = .02
Age (mean) = 43,800 hrs.

Equipment

Emplacement:
Diesel Transporter at 100m.
Rated at 360 hp = 268.4 kW
Power utilization @ 40%

Conditions at end of drift.

t_{wb} = 20.26°C
t_{db} = 37.22°C (68.5, 99.0°F)

Emplacement Room 191-190

t_{wbi} = 16.21°C
t_{dbi} = 27.02°C
Q = 21.24m³/s
L = 201.2m
Age (mean) = 43,800 hrs.

Equipment

Transporter at 100m, 268.4 kW
@ 40%

Conditions at end of drift

t_{wb} = 20.24°C
t_{db} = 36.57°C

Initial parameters for the prediction of heat and humidity

Physical description of EMPLACEMENT ROOM 189-190

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 21.24 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.24 Deg C, Dry bulb temp. = 27.71 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 34.491 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	100	268.40	40.0	Diesel

Amount of water emitted by diesel = 3 liters water/liter fuel

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Job No. 3696A161 Sheet 148 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: DB DATE ________

Description: 10 yr. Development CHECKED BY : GR DATE ________

Predicted Environment: EMPLACEMENT ROOM 189-190

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	27.71	16.24	8.12	31.57	91.040	1.049	48.01	25.0	852	19.68	19.47
25	27.64	16.24	8.14	31.79	91.040	1.049	48.00	25.0	852	19.66	19.43
50	27.57	16.24	8.16	32.00	91.040	1.049	47.98	25.0	852	19.64	19.39
75	27.50	16.24	8.18	32.21	91.040	1.049	47.96	25.0	852	19.62	19.35
After spot source no. 1 sensible heat = 237.99 kW, latent heat = 65.84 kW											
101	37.87	20.32	9.42	20.66	91.040	1.049	61.47	25.0	738	22.45	25.81
126	37.70	20.32	9.45	20.92	91.039	1.014	61.38	25.0	689	25.46	25.75
151	37.54	20.30	9.49	21.17	91.039	1.014	61.30	25.0	690	25.40	25.68
176	37.38	20.29	9.52	21.43	91.039	1.015	61.22	25.0	691	25.34	25.61
201	37.22	20.26	9.55	21.69	91.039	1.015	61.14	25.0	692	25.28	25.54

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Job No. 3696 A161 Sheet 149 of 150

Job Title Vert. Emp. Cooling Analysis DESIGNED BY: D. Brunner DATE 4/17/86

Description: 10 yr. Development CHECKED BY: C.R. Rogers DATE 5/7/86

Initial parameters for the prediction of heat and humidity

Physical description of EMPLACEMENT ROOM 191-190

Length = 201 m, Depth in = 311 m, Depth out = 311 m
Perimeter = 20.63 m, Cross-sectional area = 28.34 m^2
Wetness factor = .02 , Airway friction coefficient = .013 kg/m^3
Age at inlet 43800 (hrs), Age at outlet 43800 (hrs)

Ventilation at intake

Quantity = 21.24 (m^3/s), Pressure = 91.04 (kPa)
Wet bulb temp. = 16.21 Deg C, Dry bulb temp. = 27.02 Deg C

Thermal Parameters

V.R.T. at inlet = 25 Deg C, Geothermal step = 20.7 m/Deg C
Conductivity = 2.070 W/m/Deg C, Diffusivity = 0.003300 m^2/hr
Heat transfer coefficient = 34.491 kJ/hr/m/Deg C

Distance between temperature outputs = 25 m - 8 output stations

Heat Sources

Equipment spot heat sources

No.	Distance from intake (m)	Full load power output (kW)	Percent utilization at equiv. full load	Diesel or Electric
1	100	268.40	40.0	Diesel

Amount of water emitted by diesel = 3 liters water/liter fuel

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Job No. 3696 A161   Sheet 150 of 150

Job Title Vert. Emp. Cooling Analysis   DESIGNED BY: DB   DATE ________

Description: 10 yr. Development   CHECKED BY : BR   DATE ________

Predicted Environment: EMPLACEMENT ROOM 191-190

dist (m)	dry blb (C)	wet blb (C)	moist cont (g/kg)	rel hum (%)	pres (kPa)	den (kg/m3)	sigma heat (kJ/kg)	vrt (C)	acp (W/m2)	wbgt (C)	eff tmp (C)
0	27.02	16.21	8.36	33.86	91.040	1.051	47.92	25.0	855	19.45	19.05
25	26.96	16.21	8.39	34.07	91.040	1.051	47.91	25.0	855	19.43	19.01
50	26.90	16.21	8.41	34.27	91.040	1.051	47.90	25.0	855	19.42	18.97
75	26.84	16.21	8.43	34.48	91.040	1.051	47.89	25.0	855	19.40	18.93
After spot source no. 1 sensible heat = 237.99 kW, latent heat = 65.84 kW											
101	37.18	20.29	9.66	21.98	91.040	1.051	61.36	25.0	740	22.24	25.54
126	37.02	20.29	9.69	22.24	91.039	1.016	61.28	25.0	692	25.24	25.48
151	36.87	20.28	9.72	22.50	91.039	1.016	61.20	25.0	693	25.19	25.41
176	36.72	20.26	9.75	22.76	91.039	1.017	61.13	25.0	694	25.13	25.34
201	36.57	20.24	9.78	23.02	91.039	1.017	61.05	25.0	695	25.07	25.27

REFERENCES FOR APPENDIX C

American Conference of Governmental Industrial Hygienists, Industrial Ventilation, A Manual of Recommended Practice, Edwards Brothers, Inc., Ann Arbor, MI, 1980, 16th ed.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE Handbook of Fundamentals, Atlanta, GA, 1981.

Bish, D. L., D. T. Vaniman, F. M. Byers, Jr., and D. E. Broxton, "Summary of the Mineralogy-Petrology of Tuffs of Yucca Mountain and Secondary-Phase Thermal Stability in Tuffs," LA-9321-MS, Los Alamos National Laboratory, Los Alamos, NM, November 1982.

DOL (U.S. Department of Labor, Mine Safety and Health Administration), "Safety and Health Standards--Underground Metal and Nonmetal Mines," Code of Federal Regulations, Mineral Resources, Title 30, Part 57, Washington, D.C., July 1985.

Eglinton, T. W., and R. J. Dreicer, "Meteorological Design Parameters for the Candidate Site of a Radioactive Waste Repository at Yucca Mountain, Nevada," SAND84-0440/2, Sandia National Laboratories, Albuquerque, NM, December 1984.

Grenia, J. D., Parsons Brinckerhoff Quade & Douglas, Inc., personal communication with M. Robb, Sandia National Laboratories, March 25, 1985.

Grenia, J. D., and R. R. Harig, Parsons Brinckerhoff Quade & Douglas, personal communication with K. G. Wallace, Jr., Mine Ventilation Services, Inc., April 18, 1985.

Hartman, H. L., Mine Ventilation and Air Conditioning, John Wiley & Sons, New York, NY, 1982.

McElroy, G. E., "Engineering Factors in the Ventilation of Metal Mines," U.S. Bureau of Mines, Bulletin No. 385, 1935.

McPherson, M. J., and D. J. Brunner, "An Investigation into the Ventilation Characteristics of a Longwall District in a Coal Mine," report to the U.S. Department of Energy, Contract DC AC03-768 F00098 A 75 15 20, p. 152, September 1983.

McPherson, M. J., "The Metrication and Rationalization of Mine Ventilation Calculations," The Mining Engineer, Vol. 130, No. 131, Institution of Mining Engineers, London, August 1971.

McPherson, M. J., "Ventilation Network Analysis," Environmental Engineering in South African Mines, Cape and Transvaal Printers (Pty.) Ltd., Cape Town, p. 211, 1982.

Mine Ventilation Services, Inc., CLIMSIM Users Manual, Lafayette, CA, 1986.

Mine Ventilation Services, Inc., VNT-PC Users Manual, Lafayette, CA, 1986.

REFERENCES FOR APPENDIX C
(concluded)

Mitchell, D., and A. Whillier, "Cooling Power of Underground Environments," Journal of the Mine Ventilation Society of South Africa, Vol. 25, No. 8, pp. 140-151, August 1972.

National Materials Advisory Board, Commission on Sociotechnical Systems, "Measurement and Control of Respirable Dust in Mines," NMAB-363, National Academy of Sciences, Washington, D.C., 1980.

NRC (U.S. Nuclear Regulatory Commission), "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Code of Federal Regulations, Energy, Title 10, Part 60, Washington, D.C., January 1986.

Spengler, R. W., D. C. Mullen, and R. B. Livermore, "Preliminary Report on the Geology and Geophysics of Drill Hole UE25a-1, Yucca Mountain, Nevada Test Site," USGS-OFR-79-1244, Denver, CO, 1979.

Wallace, K. G., and M. J. McPherson, "Mine Ventilation Economics," report to the U.S. Department of Energy, Contract DC AC03-768 F00098, p. 150, September 1982.

APPENDIX D

EQUIPMENT FOR SURFACE SUPPORT AND WASTE HANDLING, UNDERGROUND DEVELOPMENT, AND WASTE TRANSPORTATION, EMPLACEMENT, AND RETRIEVAL

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1.0 INTRODUCTION

This appendix describes work done during conceptual design on equipment needed for the Yucca Mountain Repository and provides equipment descriptions and lists. Section 2 comprises a long, briefly descriptive list of equipment needed in the surface facilities. For the most part, support equipment on the surface such as pumps, blowers, etc., is commercially available. The waste handling equipment listed, especially the fuel consolidation equipment, is still in very early stages of design development, and work done to date is documented in "NNWSI Project: Spent Fuel Consolidation System," (Townes et al., 1987a) and "NNWSI Project: Conceptual Design of Facilities for Unloading Radioactive Waste from Shipping Casks," (Townes et al., 1987b). That work (conceptual design of waste handling equipment) was not repeated here.

Section 3 describes the underground development operations and equipment. Drift excavation will be done with equipment that is commercially available, or available with modification, so most of the discussion here regards its use in operations. More detail is provided for the equipment and systems for drilling vertical and horizontal boreholes. The equipment for these systems, though not commercially available, is based on modified versions of available equipment. The horizontal borehole drilling system and its components are described here and in more detail in Robbins (1987).

The length of Section 4 reflects the substantial amount of work done on equipment and operations for underground waste transportation and emplacement. For both vertical and horizontal configurations, the section presents detailed descriptions of the waste emplacement borehole, the hardware required to prepare the borehole for waste emplacement, the hardware necessary to close the borehole after waste emplacement, and the major equipment needed to support the emplacement operations. The equipment and operations described here are still in the conceptual stage but are based on adaptations of commercially available equipment components and technology. Further discussion of emplacement operations and equipment is available in Stinebaugh and Frostenson (1987) and Stinebaugh et al. (1987).

This appendix also provides a very brief description of the operations and equipment needed for waste retrieval (Section 5) and an outline of the program for continuing equipment development, which includes eventual detailed design of emplacement and retrieval systems, proof-of-principle demonstrations, and prototype equipment development (Section 6).

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2.0 SURFACE EQUIPMENT LIST

A list of equipment required for the surface facilities is given in Table D-1. The equipment is identified as to whether it is commercially available (CA), or whether it needs development (ND). The equipment that is characterized as commercially available is essentially available as "off-the-shelf" equipment today. It may or may not require minor modifications for installation or use at the repository. An example of this type of equipment is the 125-ton bridge crane, equipment No. 211-H-027, which is operated in a personnel accessible area. This will be contact-maintained in the area where it operates (no need for a special shielded maintenance bay) and has a capacity and space and operating requirements that are normal for today's industrial cranes. This type of crane can be purchased from a number of manufacturers such as Whiting, HECO Pacific, and Erderer. The cranes are built to the Crane Manufacturers Association of America (CMAA) Specification No. 70 and should require relatively few custom features for installation and use at the tuff repository.

The "needs development" designation applies to two categories of equipment. One category is prototype equipment, which includes items such as the shield valve with drive, equipment No. 211-N-014, or the 10-ton bridge crane with E/M manipulator, equipment No. 211-H-012. The prototype equipment requires little new technology. Similar equipment has been designed by Bechtel and built by companies such as Westmont Industries and is currently in the process of final testing in the field at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico. However, the special requirements that will be specified for this equipment in the area of controls, maintenance, durability for the production operation at the tuff repository, and safety will make the equipment unique to an extent that warrants a "needs development" classification.

The other "needs development" category of equipment is the special equipment associated with fuel consolidation. The consolidation equipment specified in the equipment list is based on a concept proposed by BE, Inc., as reported in their fuel consolidation equipment report (Townes et al., 1987a). Dry consolidation of fuel has not been attempted, nor has large-volume consolidation at a rate of 3,000 MTU per year been undertaken by anyone, either wet or dry. The production rate disassembly of fuel assemblies, the collection of large numbers of individual fuel rods, and consolidation of the rods into compact arrays all require remote-handling equipment that has not been developed yet in this country or, to the best of our knowledge, anywhere else in the world. This equipment will have to be conceptually designed, and new concepts, components, and subsystems tested. Full-sized prototype hardware must then be designed, fabricated, acceptance tested, installed, cold tested, and hot tested. Experience indicates that in each step of the process, modifications will be required. Finally, the equipment will be put into use on the production line, and at that time it is reasonable to assume that additional modifications will be required before the equipment will function smoothly under the rigors of a full production schedule. Examples of this equipment, most of which will be located in the consolidation hot cell, are the multicollet gripper C/W support carriage assembly, equipment No. 212-S-071, fuel rod collector assembly, equipment No. 212-S-074, and the container sector collecting device, equipment No. 212-S-075.

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	A	001	A-B	SUPPLY AIR HANDLING UNIT	35,000 CFM	60 HP 20 KW		CA	2	ROOF - WHB 1				05	CA = COMMERCIALLY AVAILABLE	
211	A	002		AIR HANDLING UNIT	10,000 CFM	20 HP 20 KW		CA	1	ANNEX OFFICE BLDG				05		
211	A	003	A-B	AIR HANDLING UNIT	10,000 CFM	20 HP 15 KW		CA	2	ANNEX OFFICE BLDG.				05		
211	A	004	A-B	AIR HANDLING UNIT	20,000 CFM	20 HP		CA	2					05	TORNADO DAMPER AT INLET	
211	A	005		HUMIDIFIER		3 KW		CA	1	ANNEX CONTROL ROOM				05		
211	C	001	A-B	RETURN/EXHAUST FAN	26,500 CFM	20 HP		CA	2	ROOF - WHB 1				05	RECV'G SHPP'G BAYS	
211	C	002	A-B	EXHAUST FAN	13,600 CFM	20 HP		CA	2	ROOF - WHB 1				05	FROM CASK UNLOADING CELL	
211	C	003	A-B	EXHAUST FAN	3,700 CFM	10 HP		CA	2	ROOF - WHB 1				05	HEPA FILTER GALLERY	
211	C	004	A-B	EXHAUST FAN	20,300 CFM	15 HP		CA	2	VAULT ROOF				05	SURFACE STORAGE AREA	
211	C	005	A-B	EXHAUST FAN	10,150 CFM	15 HP		CA	2	ROOF -WHB 1				05	EMERGENCY EXHAUST	
211	C	006		RETURN/EXHAUST FAN	8,500 CFM	15 HP		CA	1	ANNEX OFFICE BLDG.				05	OFF, LAB, CH. AREA	
211	C	007		EXHAUST FAN	1,500 CFM	3 HP		CA	1	ANNEX OFFICE BLDG.				05	LOCKERS, TOILETS	
211	D	001		TORNADO DAMPER	53,500 CFM			CA	1	SUPPLY-REC'G & SHIPPING AREA				05	REC'G BAY ENTRY	
211	D	002		TORNADO DAMPER	53,500 CFM			CA	1	RET-RECEIVING & SHIPPING AREA				05	EXIT DUCT	
211	D	003		TORNADO DAMPER	10,000 CFM			CA	1	ANNEX BLDG.				05	SUPPLY - OFFICE & LAB ENTRY DUCT	

DATE 02/13/87
REVISION 3
JOB 16039

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	D	004		TORNADO DAMPER	8,500 CFM			CA	1	ANNEX BLDG.				05	RETURN- OFFICE & LAB EXIT DUCT	
211	D	005		TORNADO DAMPER	1,500 CFM			CA	1					05	EXHAUST - LOCKER & CHANGE ROOM EXIT DUCT	
211	D	006	A	TORNADO DAMPER	10,000 CFM			CA	1	CONTROL ROOM				05	SUPPLY	
211	D	006	B	TORNADO DAMPER	10,000 CFM			CA	1	CONTROL ROOM				05	EXHAUST	
211	D	008		TORNADO DAMPER	37,600 CFM			CA	1	MAIN STACK EXHAUST - WHB 1				05		
211	D	011		DUCT SILENCER	10,000 CFM 40 DB			CA	1					05	ENTRY DUCT	
211	D	012		DUCT SILENCER	8,500 CFM 40 DB			CA	1					05	EXHAUST DUCT	
211	D	013		DUCT SILENCER	10,000 CFM 40 DB			CA	1					05	SUPPLY DUCT	
211	D	014		DUCT SILENCER	10,000 CFM 40 DB			CA	1					05	EXHAUST DUCT	
211	E	001	A-C	WATER CHILLER /COND PACKAGE FAN @ 10 HP EACH	100 TONS	110 KW		CA	3					05		
211	F	001	A-B	EXHAUST HEPA FILTER UNIT	13,600 CFM			CA	2	HEPA FILTER GALLERY				05		
211	F	002	A-B	EXHAUST HEPA FILTER UNIT	3,700 CFM			CA	2	HEPA FILTER GALLERY				05		
211	F	003	A-B	EXHAUST HEPA FILTER UNIT	10,150 CFM			CA	2	VAULT BLDG ROOF				05		
211	F	004		SUPPLY HEPA FILTER UNIT	13,000 CFM			CA	1	VAULT BLDG ROOF				05		
211	F	005		HIGH HEPA PREFILTER UNIT	11,500 CFM			CA	1	CASK UNLOADING CELL				05		

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	M	002		FUEL HANDLING GRAPPLE	2000 LBS	1 HP		ND	8	UNLOADING HOT CELL		SK-211-M-301		06	ND = NEEDS DEVELOPMENT	
211	M	008		BRIDGE CRANE WITH E/M MANIP.	5 TONS			ND	1	REMOTE EQPT MAINT. CELL				06		
211	M	009		JIB CRANE	10 TONS			CA	1	CASK PREP AREA/ DECON STATION	SK-211-P-301	SK-211-M-301		06		
211	M	010		SHIPPING CASK LIFTING STRONGBACK - TRUCK	40 TONS			ND	1	CASK RECEIVING & SHIPPING AREA		SK-211-M-301		07		
211	M	012		BRIDGE CRANE WITH E/M MANIP.	20 TONS			ND	1	UNLOADING HOT CELL		SK-211-M-301		06		
211	M	013		CONTAINER TRANSFER MACHINE		50 HP		ND	1	SURFACE STORAGE VAULT		SK-211-M-301		06		
211	M	017		SHIPPING CASK LIFTING STRONGBACK - RAIL	125 TONS			ND	1	CASK RECEIVING & SHIPPING AREA		SK-211-M-301		07		
211	M	018		CONTAINER GRAPPLE	5000 LBS	1 HP		ND	2	UNLOADING HOT CELL				06		
211	M	022		UNDER HUNG CRANE	1/2 TON	3 HP		CA	1	EQPT MAINT. DECON ROOM				06		
211	M	027		BRIDGE CRANE	125/25 TON			CA	1	CASK RECEIVING & SHIPPING BAY		SK-211-M-301		07		
211	M	028		ROTATING LOAD BLOCK	125 TONS			CA	1	CASK RECEIVING & SHIPPING BAY		SK-211-M-301		07		
211	M	030		ROTATING LOAD BLOCK	20 TONS			ND	2	UNLOADING HOT CELL		SK-211-M-301		06		
211	M	031		FACILITY GRAPPLE	20 TONS			ND	8	UNLOADING HOT CELL		SK-211-M-301		06		
211	M	032		PLUG REMOVAL FIXTURE	20 TONS			ND	4	UNLOADING HOT CELL				06		
211	M	042		CONTAINER TRANSFER MONORAIL				CA	1	OPERATING GALLERY				06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	M	043		MONORAIL SYSTEM WITH HOIST				CA	1	EMPTY CONTAINER STORAGE				06		
211	M	002		MAINTENANCE HATCH		10 HP		ND	1	UNLOADING HOT CELL	SK-211-P-301			03		
211	M	003		CELL WINDOW	3' x 3'			CA	11	UNLOADING HOT CELL	SK-211-P-301			03		
211	M	003		CELL WINDOW	3' x 3'			CA	1	REMOTE EQPT MAINT. CELL	SK-211-P-301			03		
211	M	003		CELL WINDOW	3' x 3'			CA	2	EQPT MAINT DECON ROOM	SK-211-P-301			03		
211	M	007		VENT BARRIER DOOR W/ DRIVE		7.5 HP		ND	4	CASK PREP/ TRANSFER TUNNEL	SK-211-P-301	SK-211-H-501		03		
211	M	008		CASK SEAL ADAPTER				ND	4	CASK PREP/ TRANSFER TUNNEL				03	MATES CASK TO PORT	
211	M	009	A	SHIELDING DOOR-SLIDING				ND	1	REMOTE EQPT MAINT. CELL	SK-211-P-301			03		
211	M	009	B	SHIELDING DOOR - SLIDING				ND	1	EQPT MAINT DECON ROOM	SK-211-P-301			03		
211	M	010		CASK UNLOADING PORT PLUG				ND	4	UNLOADING HOT CELL		SK-211-H-501		03		
211	M	014		SHIELD VALVE WITH DRIVE				ND	4	SURFACE STORAGE VAULT	SK-211-P-301			03		
211	M	021		VENT BARRIER ROLL UP DOOR				CA	2	OUT TRANSFER BAY	SK-211-P-301	SK-211-H-501		07		
211	M	024		CRANE MAINT. SHIELD DOOR				ND	1	UNLOADING HOT CELL	SK-211-P-301	SK-211-H-501		03		
211	M	028		TRANSFER DRAWER				ND	3	UNLOADING HOT CELL	SK-211-P-301			03		
211	M	031		TRANSFER DRAWER				ND	1	EQPT DECON GLOVE BOX	SK-211-P-301			03		

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	M	032		TRANSFER DRAWER				ND	1	REMOTE EQPT MAINT. CELL	SK-211-P-301			03		
211	M	033		VENTILATION BARRIER DOOR				CA	4	CASK RECEIVING & SHIPPING BAY		SK-211-M-501		07		
211	M	035		ROLL-UP DOOR				CA	4	CASK RECEIVING/ SHIPP'G AIRLOCK	SK-212-P-301	SK-211-M-501		07		
211	M	039		CASK SHROUD SHIELD PANEL				ND	4	CASK PREP AREA/ TRANSFER TUNNEL		SK-211-M-501		03		
211	M	042		VENT BARRIER DOOR				ND	2	CONTAINER TRANSFER TUNNEL		SK-211-M-501		03		
211	M	043		SLIDING SHIELD DOOR				ND	2	UNLOADING HOT CELL				03		
211	M	045		SHIELD VALVE				ND	2	CONTAINER TRANSFER LOCK				03		
211	P	001		CHILLED WATER PUMP	180 GPM	25 HP		CA	1					05		
211	P	003		HYDRO-LASER SPRAY PUMP UNIT				ND	2	PORTABLE OPER'TG GALLERY				06		
211	Q	002		TANK, PUMP & FILTER CASK DECON EQPT				CA	1	CASK PREP AREA/ DECON SUPP EQPT	SK-211-P-301			06		
211	Q	003		CASK GAS SAMPLING AND VENTING SYSTEM				ND	1	CASK PREP AREA				06		
211	Q	005		CONTAINER DECON. VESSEL				ND	1	UNLOADING HOT CELL	SK-211-P-301			06		
211	Q	007		AIR FILTER FRAME SEPARATOR/ FILTER COMPACTOR				ND	1	UNLOADING HOT CELL	SK-211-P-301			06		
211	Q	008		AIR FILTER FRAME SHREDDER				CA	1	UNLOADING HOT CELL				06		
211	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	3	UNLOADING HOT CELL				06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	1	REMOTE EQPT MAINT. CELL				06		
211	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	2	EQPT MAINT. DECON ROOM				06		
211	R	005		TRU-MOTION MINI MANIPULATOR				CA	1	EQPT DECON GLOVE BOX				06		
211	R	006		PEDESTAL-MOUNTED ROBOT				CA	1	UNLOADING HOT CELL				06		
211	S	014		RAIL CAR TRAILER/PULLER				CA	2	CASK RECEIVING & SHIPPING BAY				07		
211	S	015		SHIPPING CASK TRANSFER CART W/ DRIVE	125 TONS			ND	4	CASK PREP/ TRANSFER TUNNEL		SK-211-M-501		06		
211	S	018		FUEL INSPECTION STATION				ND	1	UNLOADING HOT CELL				06		
211	S	020		PLATFORM	3600 SQ FT			CA	1	CASK RECEIVING & SHIPPING BAY				07		
211	S	021		DECON STATION PLATFORM	800 SQ FT			CA	1	CASK PREP/ DECON STATION				06		
211	S	023		MASTER SLAVE MAINIP. REMOVAL EQPT PORTABLE				CA	1	M.S.M. STORE RM & REP SHOP				06		
211	S	028		WELD INSPECTION STATION				ND	1	UNLOADING HOT CELL		SK-211-M-501		06		
211	S	031		CONTAINER TRANSFER/STORAGE CAR				ND	2	CONTAINER TRANSFER TUNNEL	SK-211-P-301	SK-211-M-501		06		
211	S	033		EQUIPMENT TRANSFER CART	20 TONS	3 HP		ND	1	REMOTE EQPT MAINT. CELL				06		
211	S	035		FUEL ASS'Y BASKET				ND	40	UNLOADING HOT CELL				06		
211	S	039		LEAK TEST STATION				ND	1	UNLOADING HOT CELL				06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-1 EQUIPMENT LIST

EQUIPMENT NO. N B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
211	S	044		DRUM TRANSFER STORAGE CAGE	500 LBS	3 HP		ND	1	REMOTE EQPT MAINT. CELL				06		
211	S	045		TRANSFER CART TURNTABLE		2 HP		ND	1	EQPT MAINT. DECON ROOM				06		
211	S	053		ULTRASONIC CLEANER				CA	1	EQPT MAINT. DECON ROOM	SK-211-P-301			06		
211	S	054		ELECTRO-POLISHER		2 HP		CA	1	EQPT MAINT. DECON ROOM	SK-211-P-301			06		
211	S	086		STORAGE RACK				ND	1	SURFACE STORAGE VAULT		SK-211-M-501		06	72 POSITIONS	
211	S	088		CONTAINER WELDING STATION				ND	1	UNLOADING HOT CELL		SK-211-M-501		06		
211	S	090		CONTAINER TRANSFER CAR				ND	2	UNLOADING HOT CELL				06		
211	S	096		CONTAINER STORAGE RACK				ND	1	UNLOADING HOT CELL				06		
211	S	098		GLOVE BOX UNIT				CA	1	EQPT MAINT. DECON ROOM	SK-212-P-301			06		
211	T	001		DECON TANK ASSEMBLY				ND	1	UNLOADING HOT CELL		SK-211-M-501		06		
211	V	004		REMOTE VIEWING SYSTEM				CA	1	CASK PREP/CASK TRANSFER TUNNEL				06		
211	V	005		REMOTE VIEWING SYSTEM				CA	3	UNLOADING HOT CELL				06		
211	V	006		REMOTE VIEWING SYSTEM				CA	2	EQPT MAINT. DECON ROOM				06		
211	V	008		REMOTE VIEWING SYSTEM				CA	1	REMOTE EQPT MAINT CELL				06		
211	X	001		RADIATION MONITORING SYSTEM				CA	1	CASK RECEIVING & SHIPPING BAY				07		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	A	001	A-B	AIR HANDLING UNIT	43,000 CFM	40 HP		CA	2	RECV'G BAYS WHB HVAC ROOM				05		
212	A	002		SUPPLY AIR HANDLING UNIT	30,000 CFM			CA	1	ANNEX OFFICE BLDG				05		
212	A	003	A	SUPPLY AIR HANDLING UNIT	25,000 CFM			CA	1	WHB HVAC ROOM		SK-212-M-206		05	TORNADO DAMPER AT INLET	
212	A	003	B	SUPPLY AIR HANDLING UNIT	25,000 CFM			CA	1	WHB HVAC ROOM		SK-212-M-206		05	TORNADO DAMPER AT INLET	
212	A	004	A-C	AIR HANDLING UNIT	14,000 CFM			CA	3	VAULT STORAGE MECHANICAL RM		SK-212-M-207		05	TORNADO DAMPER AT INLET	
212	A	005	A-B	SUPPLY AIR HANDLING UNIT	13,100 CFM			CA	2	ANNEX OFFICE BLDG				05	WITH AIR COOLED CONDENSER	
212	A	006	A-B	SUPPLY AIR HANDLING UNIT	29,000 CFM			CA	2	WHB HVAC ROOM				05		
212	A	007		HUMIDIFIER		3 KW		CA	1	WHB 2 - CONTROL ROOM				05		
212	C	001	A-B	RETURN/EXHAUST FAN	41,000 CFM			CA	2	WHB HVAC ROOM				05		
212	C	002		RETURN/EXHAUST FAN	28,500 CFM			CA	1	ROOF -ANNEX OFFICE BLDG				05		
212	C	003	A-F	EXHAUST FAN	5,000 CFM			CA	6	CONSOLIDATION HOT CELL		SK-212-M-206		05	WHB EXHAUST ROOM	
212	C	004	A-C	EXHAUST FAN	6,250 CFM			CA	3			SK-212-M-205		05	WHB EXHAUST ROOM WASTE PKG	
212	C	005	A-C	EXHAUST FAN	9,800 CFM			CA	3			SK-212-M-205		05	WHB EXH. ROOM CASK UNLOADING	
212	C	006	A-C	EXHAUST FAN	14,100 CFM			CA	3			SK-212-M-207		05	VAULT STORAGE MECHANICAL ROOM	
212	C	007	A-B	EXHAUST FAN	14,100 CFM			CA	2			SK-212-M-207		05	VAULT STORAGE MECHANICAL ROOM	

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	C	008	A-B	RETURN/EXHAUST FAN	16,000 CFM			CA	2	ROOF – ANNEX OFFICE BLDG				05		
212	C	009	A-B	EXHAUST FAN	42,300 CFM			CA	2	ROOF – ANNEX OFFICE BUILDING				05		
212	C	010		EXHAUST FAN	1,500 CFM			CA	1	ROOF -ANNEX OFFICE BLDG				05	LOCKERS & TOILETS	
212	D	001		TORNADO DAMPER	86,000 CFM			CA	1	RECEIVING & SHIPPING BAY				05	SUPPLY	
212	D	002		TORNADO DAMPER	84,000 CFM			CA	1	RECV'G & SHIP'G BAY WALL				05	EXHAUST	
212	D	003		TORNADO DAMPER	30,000 CFM			CA	1	OFFICE & LAB ANNEX BLDG				05	SUPPLY	
212	D	004		TORNADO DAMPER	28,500 CFM			CA	1	OFFICE & LAB				05	EXHAUST	
212	D	005		TORNADO DAMPER	1,500 CFM			CA	1	LAB & CHANGE RM				05	EXHAUST	
212	D	006	A	TORNADO DAMPER	13,100 CFM			CA	1	CONTROL ROOM				05	SUPPLY	
212	D	006	B	TORNADO DAMPER	13,100 CFM			CA	1	CONTROL ROOM				05	EXHAUST	
212	D	008		TORNADO DAMPER	12,300 CFM			CA	1			SK-212-M-207		05	EXHAUST AIR HEADER	
212	D	009	A-B	TORNADO DAMPER	15,000 CFM			CA	2	ROOF-ANNEX BLDG				05		
212	D	010	A-B	TORNADO DAMPER	2,000 CFM			CA	2	ROOF-ANNEX BLDG				05		
212	D	011		DUCT SILENCER	30,000 CFM			CA	1	ANNEX OFFICE M.P. LOCKER RM				05	SUPPLY	
212	D	012		DUCT SILENCER	28,500 CFM			CA	1	ANNEX OFFICE M.P. LOCKER RM				05	EXHAUST	

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	D	013		DUCT SILENCER	13,100 CFM			CA	1	ROOF-ANNEX CONTROL BLDG				05	SUPPLY	
212	D	014		DUCT SILENCER	13,100 CFM			CA	1	ROOF-ANNEX CONTROL BLDG				05	EXHAUST	
212	D	015		DUCT SILENCER	42,000 CFM			CA	1	ANNEX OFFICE-LAB N. GAC				05	REMOTE MAINTENANCE	
212	D	016		DUCT SILENCER	42,300 CFM			CA	1	ANNEX OFFICE-LAB, N. GAC				05	REMOTE MAINTENANCE	
212	E	001	A-B	AIR COOLED CHILLER PACKAGE	150 TONS			CA	2					05	160 KW COMPRESSOR	
212	E	LST		HOT CELL EQUIPMENT FOR 2 HOT CELLS - FROM BEI 1983 COST				CA	1					06	REPORT - ADD 30% FOR DESIGN GROWTH	
212	F	001	A-D	HEPA FILTER UNIT	5000 CFM			CA	4	HVAC ROOM		SK-212-M-206		05	SUPPLY	
212	F	002	A-D	FILTER UNIT	5000 CFM			CA	4	CONSOLIDATION HOT CELL	SK-212-P-315	SK-212-M-206		05		
212	F	003	A-F	HEPA FILTER UNIT	5000 CFM			CA	6	EXHAUST HEPA FILTER ROOM		SK-212-M-206		05	EXHAUST	
212	F	004	A-C	HEPA FILTER UNIT	6250 CFM			CA	3	EXHAUST HEPA FILTER ROOM		SK-212-M-205		05	EXHAUST	
212	F	005		HEPA FILTER UNIT	17,500 CFM			CA	1	HVAC ROOM		SK-212-M-205		05	SUPPLY	
212	F	007		HIGH HEPA PREFILTER UNIT	17,500 CFM			CA	1	CASK UNLOADING HOT CELL		SK-212-M-205		05		
212	F	007	A	HIGH HEPA PREFILTER UNIT	17,500 CFM			CA	1	CASK UNLOADING HOT CELL		SK-212-M-205		05		
212	F	008	A-C	HEPA FILTER UNIT	9800 CFM			CA	3	EXHAUST HEPA FILTER ROOM		SK-212-M-205		05	EXHAUST	
212	F	009	A-B	HEPA FILTER UNIT	14,100 CFM			CA	2	VAULT STORAGE MECHANICAL ROOM		SK-212-M-207		05	EMERGENCY EXHAUST	

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYPE	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	F	010	A-B	HEPA FILTER UNIT	42,300 CFM			CA	2	ROOF-ANNEX BLDG				05		
212	M	002		FUEL HANDLING GRAPPLE	2000 LBS	1 HP		ND	16	UNLOADING HOT CELL		SK-212-M-501		06		
212	M	008		BRIDGE CRANE WITH E/M MANIP.	5 TONS			ND	4	REMOTE EQPT MAINT. CELL	SK-212-P-317			06		
212	M	009		JIB CRANE	10 TONS	20 HP		CA	2	CASK PREP AREA/ DECON STATION	SK-212-P-317	SK-212-M-501		06		
212	M	010		SHIPPING CASK LIFTING STRONGBACK - TRUCK	40 TONS			ND	1	CASK RECEIVING & SHIPPING BAY		SK-212-M-501		07		
212	M	012		BRIDGE CRANE WITH E/M MANIP.	20 TONS	33 HP		ND	2	UNLOADING HOT CELL	SK-212-P-317	SK-212-M-501		06		
212	M	013		CONTAINER TRANSFER MACHINE		50 HP		ND	1	SURFACE STORAGE VAULT	SK-212-P-317	SK-212-M-504		06		
212	M	017		SHIPPING CASK LIFTING STRONGBACK - RAIL	125 TONS			ND	1	CASK RECEIVING & SHIPPING BAY		SK-212-M-501		07		
212	M	018		CONTAINER GRAPPLE	5000 LBS	1 HP		ND	2	UNLOADING HOT CELL				06		
212	M	022		UNDER HUNG CRANE	1/2 TON	3 HP		CA	4	EQPT MAINT. DECON ROOM				06		
212	M	027		BRIDGE CRANE	125/25 TON			CA	1	CASK RECEIVING & SHIPPING BAY	SK-212-P-317	SK-212-M-501		07		
212	M	028		ROTATING LOAD BLOCK	125 TONS			CA	1	CASK RECEIVING & SHIPPING BAY		SK-212-M-501		07		
212	M	030		ROTATING LOAD BLOCK	20 TONS			ND	2	UNLOADING HOT CELL		SK-212-M-501		06		
212	M	031		FACILITY GRAPPLE	20 TONS			ND	16	UNLOADING HOT CELL		SK-212-M-501		06		
212	M	032		PLUG REMOVAL FIXTURE	20 TONS			ND	8	UNLOADING HOT CELL				06		

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	H	033		BRIDGE CRANE	10 TONS	25 HP		ND	4	CONSOLIDATION HOT CELL	SK-212-P-317	SK-212-H-502		06		
212	H	034		ROTATING LOAD BLOCK	10 TONS			ND	4	CONSOLIDATION HOT CELL		SK-212-H-502		06		
212	H	035		FACILITY GRAPPLE	10 TONS			ND	8	CONSOLIDATION HOT CELL		SK-212-H-502		06		
212	H	037		BRIDGE CRANE WITH E/M MANIP	10 TONS			ND	2	PACKAGING HOT CELL	SK-212-P-317	SK-212-H-503		06		
212	H	038		ROTATING LOAD BLOCK	10 TONS			ND	2	PACKAGING HOT CELL		SK-212-H-503		06		
212	H	039		FACILITY GRAPPLE	10 TONS			ND	2	PACKAGING HOT CELL		SK-212-H-503		06		
212	H	040		FUEL CONTAINER HANDLING TOOL	2 TONS			ND	2	PACKAGING HOT CELL		SK-212-H-503		06		
212	H	041		BRIDGE CRANE	5 TONS			CA	2	DECON CONTAINER TRANSFER ROOM	SK-212-P-317			06		
212	H	042		CONTAINER TRANSFER MONORAIL W/ HOIST	2 TONS			CA	1	OPERATING GALLERY				06		
212	H	043		MONORAIL SYSTEM W/ HOIST	2 TONS			CA	1	EMPTY CONTAINER STORAGE AREA				06		
212	H	046		FUEL HANDLING TOOLS	2000 LBS	1 HP		ND	48	CONSOLIDATION HOT CELL				06		
212	M	001		SHIELD VALVE W/ DRIVE		5 HP		ND	8	CONSOLIDATION HOT CELL		SK-212-H-502		03		
212	M	002		MAINTENANCE HATCH		10 HP		ND	4	CONSOLIDATION HOT CELL	SK-212-P-315			03		
212	M	003		CELL WINDOW	3' x 3'			CA	15	UNLOADING HOT CELL	SK-212-P-315			03		
212	M	003		CELL WINDOW	3' x 3'			CA	20	CONSOLIDATION HOT CELL	SK-212-P-315			03		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. NBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	N	003		CELL WINDOW	3' x 3'			CA	20	PACKAGING HOT CELL	SK-212-P-315			06		
212	N	003		CELL WINDOW	3' x 3'			CA	4	REMOTE EQPT MAINT. CELL				03		
212	N	003		CELL WINDOW	3' x 3'			CA	8	EQPT MAINT. DECON ROOM				03		
212	N	004		CRANE MAINT. SHIELD DOOR		10 HP		ND	4	CONSOLIDATION HOT CELL	SK-212-P-315	SK-212-M-502		03		
212	N	005		INTERCELL SEAL VALVE W/ DRIVE		5 HP		ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		03		
212	N	007		VENT. BARRIER ROLL-UP DOOR WITH DRIVE		7.5 HP		ND	8	CASK PREP AREA/ TRANSFER TUNNEL		SK-212-M-501		03		
212	N	008		CASK SEAL ADAPTER				ND	8	CASK PREP AREA/ TRANSFER TUNNEL				03	MATES CASK TO PORT	
212	N	009	A-D	SHIELDING DOOR-SLIDING		7.5 HP		ND	4	REMOTE EQPT MAINT. CELL				03		
212	N	009	E-G	SHIELDING DOOR - SLIDING				ND	4	EQPT MAINT DECON ROOM				03		
212	N	010		CASK UNLOADING PORT PLUG				ND	8	UNLOADING HOT CELL		SK-212-M-501		03	8' DIA	
212	N	012		MAINTENANCE HATCH				ND	2	PACKAGING HOT CELL	SK-212-P-315			03		
212	N	013		SHIELD DOOR				ND	2	CRANE MAINT. ROOM	SK-212-P-315	SK-212-M-503		03		
212	N	014		SHIELD VALVE W/ DRIVE		5 HP		ND	6	SURFACE STORAGE VAULT		SK-212-M-504		03		
212	N	015		MAINTENANCE HATCH		10 HP		ND	2	UNLOADING HOT CELL	SK-212-P-315			03		
212	N	018		MAINTENANCE HATCH		10 HP		ND	8	CRANE MAINT. ROOM	SK-212-P-315			03		

DATE [illegible]/13/8[illegible]
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JOB 16039

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	N	021		VENT BARRIER ROLL UP DOOR W/ DRIVE		5 HP		CA	2	CUT TRANSFER BAY		SK-212-N-504		07		
212	N	022		VENTILATION BARRIER DOOR				ND	2	WASTE TRANSFER TUNNEL				03		
212	N	024		CRANE MAINT. SHIELD DOOR				ND	2	CRANE MAINT. ROOM	SK-212-P-315	SK-212-N-501		03		
212	N	025	A-D	TRANSFER DRAWER		2 HP		ND	4	PACKAGING HOT CELL	SK-212-P-315			03		
212	N	025	E-F	TRANSFER DRAWER		2 HP		ND	2	DECON ROOM/ PACK'G HOT CELL				03		
212	N	028		TRANSFER DRAWER		2 HP		ND	4	UNLOADING HOT CELL	SK-212-P-315			03		
212	N	031		TRANSFER DRAWER		2 HP		ND	4	EQPT DECON GLOVE BOX				03		
212	N	032		TRANSFER DRAWER		2 HP		ND	4	REMOTE EQPT MAINT. CELL				03		
212	N	033		VENTILATION BARRIER DOOR		5 HP		CA	8	CASK RECEIVING & SHIPPING BAY	SK-212-P-317	SK-212-N-501		07		
212	N	035		ROLL-UP DOOR				CA	8	CASK RECEIVING/ SHIPP'G AIRLOCK	SK-212-P-315			07		
212	N	039		CASK SHADOW SHIELD PANEL				ND	8	CASK PREP AREA/ TRANSFER TUNNEL	SK-212-P-317	SK-212-N-501		03		
212	N	040		AIR LOCK SHIELD VALVE W/ DRIVE				ND	4	PACK'G HOT CELL /DECON CELL	SK-212-P-315	SK-212-N-503		03		
212	N	041		AIR LOCK SHIELD VALVE W/ DRIVE				ND	4	PACK'G HOT CELL TRANSFER TUNNEL	SK-212-P-315	SK-212-N-503		03		
212	N	042		VENT BARRIER DOOR				ND	2	UNLOADING HOT CELL				03		
212	N	043		SLIDING SHIELD DOOR				ND	2	UNLOADING HOT CELL				03		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	N	045		SHIELD VALVE				ND	4	CONTAINER TRANSFER LOCK	SK-212-P-315			03		
212	N	049		SHIELD VALVE W/ DRIVE				ND	1	OUT TRANSFER STATION		SK-212-M-504		03		
212	P	001	A-C	CHILLED WATER PUMP	180 GPM	25 HP		CA	3	OUTSIDE				05		
212	P	002	A-C	CONDENSER WATER PUMP	160 GPM	40 HP		CA	3	OUTSIDE				05		
212	P	003		HYDRO-LASER SPRAY PUMP UNIT				ND	4	PORTABLE - OPER'TG GALLERY				06		
212	Q	002		TANK,PUMP & FILTER CASK DECON EQPT				CA	2	CASK PREP AREA/ DECON SUPP EQPT				06		
212	Q	003		CASK GAS SAMPLING AND VENTING SYSTEM				ND	2	CASK PREP AREA				06		
212	Q	005		CONTAINER DECON. STATION				ND	1	UNLOADING HOT CELL	SK-212-P-315			06		
212	Q	006		CASK DECON. STATION				ND	2	CASK PREP AREA	SK-212-P-315			06		
212	Q	007	A	AIR FILTER FRAME SEPARATOR/ FILTER COMPACTOR				ND	1	UNLOADING HOT CELL	SK-212-P-315			06		
212	Q	007	B-C	AIR FILTER FRAME SEPARATOR/ FILTER COMPACTOR				ND	2	CONSOLIDATION HOT CELL	SK-212-P-315			06		
212	Q	008	A	AIR FILTER FRAME SHREDDER				CA	1	UNLOADING HOT CELL				06		
212	Q	008	B-C	AIR FILTER FRAME SHREDDER				CA	2	CONSOLIDATION HOT CELL				06		
212	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	4	UNLOADING HOT CELL		SK-212-M-501		06		
212	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	6	CONSOLIDATION HOT CELL				06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	4	PACKAGING HOT CELL				06		
212	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	4	REMOTE EQPT MAINT. CELL				06		
212	R	002		MASTER SLAVE MANIPULATOR SET OF 2				CA	8	EQPT MAINT. DECON ROOM				06		
212	R	004		BRIDGE MOUNTED E/M MANIPULATOR	10 TONS			ND	4	CONSOLIDATION HOT CELL	SK-212-P-317	SK-212-M-502		06		
212	R	005		TRU-MOTION MINI MANIPULATOR				CA	4	EQPT DECON GLOVE BOX				06		
212	R	006		PEDESTAL MOUNTED ROBOT				CA	4	PACKAGING HOT CELL				06		
212	R	006	A-B	PEDESTAL MOUNTED ROBOT				CA	2	UNLOADING HOT CELL				06		
212	R	006	C-F	PEDESTAL MOUNTED ROBOT				CA	4	PACKAGING HOT CELL				06		
212	R	006	G-H	PEDESTAL MOUNTED ROBOT				CA	2	DECON ROOM/ PACK'G HOT CELL				06		
212	S	014		RAIL CAR TRAILER / PULLER				ND	4	CASK RECEIVING & SHIPPING BAY				07		
212	S	015		SHIPPING CASK TRANSFER CAR W/ DRIVE	125 TONS			ND	8	CASK PREP AREA/ TRANSFER TUNNEL		SK-212-M-501		06		
212	S	016		TRANSFER STORAGE CAR				ND	8	UNLOADING HOT CELL	SK-212-P-315			06		
212	S	018		FUEL INSPECTION STATION				ND	2	UNLOADING HOT CELL	SK-212-P-315			06		
212	S	020		PLATFORM	7200 SQ FT			CA	1	CASK RECEIVING & SHIPPING BAY				07		
212	S	021		DECON STATION PLATFORM	800 SQ FT			CA	2	CASK PREP AREA/ DECON STATION				06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYPE	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	S	023		MASTER SLAVE MANIP PORTABLE REMOVAL EQPT				CA	4	M.S.M. STORE RM & REP SHOP				06		
212	S	028		WELD INSPECTION STATION				ND	2	UNLOADING HOT CELL		SK-212-M-501		06		
212	S	031	A-B	CONTAINER TRANSFER/STORAGE CAR				ND	2	WASTE TRANSFER TUNNEL		SK-212-M-501		06		
212	S	031	C-D	CONTAINER TRANSFER/STORAGE CAR				ND	2	CONTAINER TRANSFER TUNNEL				06		
212	S	033		EQUIPMENT TRANSFER CART	20 TONS	3 HP		ND	4	REMOTE EQPT MAINT. CELL				06		
212	S	034		TRANSFER CART TURNTABLE		2 HP		ND	4	REMOTE EQPT MAINT. CELL				06		
212	S	035		FUEL ASS'Y BASKET				ND	60	UNLOADING HOT CELL		SK-212-M-501		06		
212	S	039		LEAK TEST STATION				ND	2	UNLOADING HOT CELL				06		
212	S	044		DRUM TRANSFER STORAGE CAGE	500 LBS	3 HP		ND	4	REMOTE EQPT MAINT. CELL				06		
212	S	045		TRANSFER STORAGE CART TURNTABLE		2 HP		ND	4	EQPT MAINT. DECON ROOM				06		
212	S	053		ULTRASONIC CLEANER				CA	4	EQPT MAINT. DECON ROOM				06		
212	S	054		ELECTRO-POLISHER		2 HP		CA	4	EQPT MAINT. DECON ROOM				06		
212	S	070		CONTAINER LID STORAGE				CA	4	PACKAGING HOT CELL				06		
212	S	071		MULTI COLLET GRIPPER C/W SUPPORT CARRIAGE ASSEMBLY				ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	072		NUT REMOVAL TOOL (BWR)				ND	4	CONSOLIDATION HOT CELL				06	COST INCLUDED IN 212-E-LST	

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	S	073		GUIDE TUBE INTERNAL CUTTER (PWR)				ND	4	CONSOLIDATION HOT CELL				06	COST INCLUDED IN 212-E-LST	
212	S	074		FUEL ROD COLLECTOR ASSEMBLY				ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	075		CONTAINER SECTOR COLLECT DEVICE				ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	076		TELESCOPING CYLINDER				ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	077		CRITICALITY & RADIATION MONITORING SYSTEM				CA	4	CONSOLIDATION HOT CELL				06		
212	S	078		LEAK TEST STATION				ND	2	PACKAGING HOT CELL				06		
212	S	079		CONSOLIDATED MOUNT & ROTATING CONTAINER DEVICE				ND	2	PACKAGING HOT CELL		SK-212-M-503		06	COST INCLUDED IN 212-E-LST	
212	S	080	A-D	FUEL CONTAINER WELDER STATION				ND	4	PACKAGING HOT CELL		SK-212-M-503		06		1
212	S	081	A-D	WELD INSPECTION STATION				ND	4	PACKAGING HOT CELL		SK-212-M-503		06		1
212	S	082		SHEARER				ND	2	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	083		FUEL ASSEMBLY FRAME COMPACTOR				ND	2	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	084		CONTAINER TRANSFER CAR				ND	2	PACKAGING HOT CELL		SK-212-M-503		06		
212	S	085		TRAVERSING CARRIAGE				ND	2	CONSOLIDATION HOT CELL		SK-212-M-502		06		
212	S	086		STORAGE RACK				ND	1	SURFACE STORAGE VAULT	SK-212-P-315	SK-212-M-504		06	112 POSITIONS	
212	S	088		CONTAINER WELDING STATION				ND	2	UNLOADING HOT CELL	SK-212-P-315	SK-212-M-501		06		

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF WHB-2 EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
212	S	091		FULL & EMPTY CONTAINER STORAGE RACK				ND	4	PACKAGING HOT CELL				06		
212	S	093		IN-CELL TOOL STORAGE RACK				ND	4	CONSOLIDATION HOT CELL				06		
212	S	097		CONSOLIDATION FRAME ASSEMBLY				ND	4	CONSOLIDATION HOT CELL		SK-212-M-502		06	COST INCLUDED IN 212-E-LST	
212	S	098		GLOVE BOX UNIT				CA	4	EQPT MAINT. DECON ROOM				06		
212	S	103		WASTE COLLECTION BIN				CA	4	CONSOLIDATION HOT CELL				06	COST INCLUDED IN 212-E-LST	
212	T	001		DECON TANK ASSEMBLY				ND	1	UNLOADING HOT CELL		SK-212-M-501		06		
212	T	002		DECON TANK SYSTEM				ND	2	DECON ROOM/ PACK'G HOT CELL		SK-212-M-503		06		
212	V	001		REMOTE VIEWING SYSTEM				CA	4	CONSOLIDATION HOT CELL				06		
212	V	002		REMOTE VIEWING SYSTEM				CA	1	PACKAGING HOT CELL				06		
212	V	004		REMOTE VIEWING SYSTEM				CA	1	CASK PREP AREA/ TRANSFER TUNNEL				06		
212	V	005		REMOTE VIEWING SYSTEM				CA	1	UNLOADING HOT CELL				06		
212	V	006		REMOTE VIEWING SYSTEM				CA	8	EQPT MAINT. DECON ROOM				06		
212	V	008		REMOTE VIEWING SYSTEM				CA	4	REMOTE EQPT MAINT CELL				06		
212	X	001		RADIATION MONITORING SYSTEM				CA	1	CASK RECEIVING & SHIPPING BAY				07		

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF BOP EQUIPMENT LIST

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
215	W	001		CEMENT FEED SCREW CONVEYOR				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		
215	W	002		BRIDGE CRANE W/ REMOTE CONTROL PANEL	7.5 TONS			CA	1	WASTE TREATMENT BLDG	SK-215-K-167			01	60 FT. SPAN BY 120 FT. RUN	
215	P	001	A-B	WASTE RECIRCULATION PUMP	75 GPM 100 FT TDH	5 HP		CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	CENTRIFUGAL, S.S. CONSTRUCTION	
215	P	002		CHEMICAL ADDITION PUMP	5 GPM 100 FT TDH	1 HP		CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	CENTRIFUGAL, S.S. CONSTRUCTION	
215	P	003		WASTE FEED PUMP	15 GPM 100 FT TDH	1 HP		CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	CENTRIFUGAL, S.S. CONSTRUCTION	
215	P	004	A-B	WASTE COLLECTION TANK PUMP	50 GPM 100 FT TDH			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	CENTRIFUGAL, S.S. CONSTRUCTION	
215	P	005	A-B	RECYCLE MONITOR TANK PUMP	75 GPM 100 FT TDH			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	CENTRIFUGAL, S.S. CONSTRUCTION	
215	P	006		RESIN MIXING PUMP	15 GPM 100 FT TDH			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	SCREW PUMP, S.S. CONSTRUCTION	
215	P	007		SPENT RESIN SLURRY PUMP	75 GPM 100 FT TDH			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	SCREW PUMP, S.S. CONSTRUCTION	
215	Q	003		WASTE COMPACTOR	100 CU FT			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-166		01	HIGH PRESSURE BOX COMPACTOR USES 4'X4'X6' STEEL BOXES	
215	Q	004		CEMENT FILL STATION				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		
215	Q	005		SAMPLE STATION				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		
215	Q	006		WASTE FILL AND DRUMMING STATION				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	(INCL. SHIELDING, VALVING, INSTR&CONTROLS) INCL 215-Q-009	
215	Q	007	A-B	CARTRIDGE FILTER	50 GPM			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	S.S. FILTER HOUSING(1'DIAx4'Lx.5"THK)CLOTH FILTER ELEM.CARTR	
215	Q	008		SPENT CARTRIDGE FILTER PACKAGING STATION				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	DRUM CAPPER, SHIELD WINDOW, REMOTE OPERATION W/ CCTV	

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SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF BOP EQUIPMENT LIST

EQUIPMENT NO. W B S	T Y P	N U M	P C E	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
215	Q	009		INSPECTION STATION				CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	INCLUDED IN 215-Q-006	
215	Q	010	A-B	ION EXCHANGER	50 GPM			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	MIXED BED(ANION & CATION), RESINS, 33CF BED,S.S. HOUSING	
215	S	001		SHIELDED FORKLIFT ELECTRIC BATTERY POWERED				CA	1	WASTE TREATMENT BLDG		SK-215-K-166		01	1/4 IN. STEEL-PLATED PERSONNEL SHIELDING	
215	S	002		SHIELDED VAN				CA	1			SK-215-K-166		01	ENCLOSED 24 FT. SHIELDED VAN	
215	S	003		FILTER TRANSFER CASK				CA	1	WASTE TREATMENT BLDG		SK-215-K-165		01		
215	S	004		DRUMMED FILTER TRANSPORT CASK				CA	1	WASTE TREATMENT BLDG		SK-215-K-166		01	CONTAINS ONE 55 GALLON FILTER DRUM	
215	S	005		FLATBED TRUCK	15 TONS			CA	1			SK-215-K-166		01	ON-SITE TRANSPORT VEHICLE	
215	T	001		CEMENT STORAGE SILO	600 CU FT			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		
215	T	002		CEMENT DAY TANK	15 CU FT			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		
215	T	003	A-B	WASTE STORAGE TANK	5000 GAL			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	S.S. CONSTR,VERT S.S.TANK W/CONICAL BOTTOM W/MIXER	
215	T	004	A-B	WASTE COLLECTION TANK	10,000 GAL			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	S.S. VERTICAL TANK W/ CONICAL BOTTOM	
215	T	005	A-B	RECYCLE MONITOR TANK	10,000 GAL			CA	2	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	S.S. VERTICAL TANK W/ CONICAL BOTTOM	
215	T	006		RESIN MIXING TANK	50 CU FT			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01	S.S. VERTICAL TANK W/ MIXER	
215	W	001		FORKLIFT BATTERY RECHARGING STATION				CA	1	WASTE TREATMENT BLDG				01		
215	Z	001		SCALE	5000 LBS			CA	1	WASTE TREATMENT BLDG	SK-215-K-167	SK-215-K-165		01		

DATE 02/13/87
REVISION 3
JOB 16039

TABLE D-1

SURFACE FACILITIES EQUIPMENT

JOB 16039 – REPOSITORY IN TUFF

EQUIPMENT NO. WBS	TYP	NUM	PCE	EQUIPMENT DESCRIPTION	CAPACITY	ELECTRICAL RATING	DESIGN CLASS	DEVEL. STATUS	QUANTITY	LOCATION	REFERENCE DRAWING	P&ID / FLOW DIAG.	SPEC NO.	COST ACCT	REMARKS	REV
230	C	001	A-E	EXHAUST AXIAL FAN #1,2,3,4 & 5	235000 CFM 18.8" WG	1000 HP		CA	5		SK-230-P-301			83		
230	C	002		EXHAUST FAN	8,000 CFM			CA	1					83	(CLEANING BLDG)	
230	C	003	A-E	AXIAL FLOW AIR SUPPLY FAN	140000 CFM 11" W.G.	250 HP		CA	5		SK-230-P-302			13		
230	D	001		INTAKE AIR TORNADO DAMPER FOR OUTSIDE AIR	939000 CFM			CA	1		SK-230-P-301			83		
230	D	002		TORNADO DAMPER FOR EXHAUST AIR	939000 CFM			CA	1					83		
230	D	003	A-E	SILENCER	40,000 CFM			CA	5		SK-230-P-302			13		
230	D	004	A-E	SILENCER	235000 CFM			CA	5		SK-230-P-301			83		
230	D	005	A-J	ISOLATION DAMPER	40,000 CFM			CA	5		SK-230-P-302			13		
230	D	006	A-L	ISOLATION DAMPER	939000 CFM			CA	12					83	(1700 CFM/SF = 550SF) 12 @ 46 SF/EA	
230	F	001	A-F	HEPA FILTER #1, 2, 3,4,5 & 6	80,000 CFM			CA	6		SK-230-P-301			83	18'-6"W X 23'H X 34' L	
230	F	002		HEPA FILTER	8,000 CFM			CA	1					83	(CLEANING BLDG)	

3.0 UNDERGROUND DEVELOPMENT EQUIPMENT DESCRIPTION

This section describes major equipment used for the excavation and operation of the subsurface facilities. The equipment is discussed under three categories: drift excavation equipment, borehole drilling equipment, and equipment used for general support underground.

3.1 Drift Excavation Equipment

Conventional drill-and-blast equipment and full-face mechanized boring machines are used for drift excavation.

Drill Jumbo

Two-boom, electric-hydraulic drill jumbos will be used for blasthole drilling in the conventional drill-and-blast headings. This machine uses a diesel motor for tramming and electric motors to drive the hydraulic system for the percussion drills. A trailing cable supplies power to the machine, which is otherwise self-contained. Multiboom drill jumbos are commercially available from several vendors.

Load/Haul/Dump (LHD) Machine

Diesel powered LHD machines will be used to move blasted rock (muck) from the various conventional headings to the belt conveyor system. The LHD is a front-end loader that has rubber tires and a transmission designed for equal speed in forward and reverse gears. Its 5-8-yd^3 bucket is suitable for the longer hauls expected. LHD machines are commercially available from several vendors.

Rock-Bolting Jumbo

The rock-bolting jumbo is a three-boom, electric-hydraulic rig designed to install welded-wire mesh with rock bolts or dowels in a single operation. The outer-articulated arms hold the mesh against the drift crown and walls while the inner boom installs the necessary bolts in the prescribed pattern. A diesel tramming motor powers movement from one heading to another. Rock-bolting jumbos are commercially available from several vendors.

Scaling Machine

A scaling machine consists of a hydraulically activated impact pick mounted to an articulated boom on a rubber-tired, diesel-powered carrier. This rig allows a single operator to safely scale loose rock from the perimeter of repository drifts. Scaling machines are commercially available from several vendors.

Tunnel-Boring Machine (TBM)

The TBM is an electrically powered, full-face excavating machine that cuts a circular opening in rock. The size of the machine determines the diameter of the opening. An adjustment of 1-2 ft in the bored diameter is possible in specially manufactured machines. Cutting is done by hardened steel disks mounted to the rotating face of the machine. Hydraulic cylinders provide forward thrust on the rotating face; hydraulic gripper pads that extend outward to the tunnel walls supply the necessary reaction thrust and torque.

Cuttings from the face are gathered and transferred behind the machine by a belt conveyor. TBMs are available from several manufacturers but typically require 6 mo to 1 yr lead time, as they are usually built for a specific job.

Underground Support Equipment

A variety of diesel-powered vehicles is required for support and maintenance of the mining equipment and for miscellaneous underground tasks. Typically, this machinery is mounted on a two- or four-wheel-driven, articulated chassis with rollover protection for the operator. All diesel exhausts are scrubbed by liquid or catalytic exhaust purifiers. Commercially available support equipment includes

- shotcrete batch truck,
- concrete mixer/transporter,
- bulk explosive loading truck,
- lube truck,
- fuel truck,
- crane truck,
- personnel carrier,
- flat-bed carrier,
- flat-bed truck,
- scissor lift, elevated bed truck,
- single-boom basket truck, and
- rough terrain forklift.

3.2 Borehole Drilling Equipment

This section describes major components of the emplacement borehole drilling systems proposed for the vertical and horizontal emplacement configurations.

3.2.1 Vertical Drilling Equipment

The vertical drilling operation is a two-step process requiring two major pieces of equipment, a small-diameter pilot drill followed by a larger reaming drill. Both the pilot-hole drilling system and the hole-opening system have crawler-mounted machines that move readily from one hole to the next. The crawlers are equipped with roof jacks for positioning and reaction of drilling forces and with leveling devices for alignment. Both the pilot drill and the reamer drill are modified versions of commercially available equipment. A detailed description of the equipment is provided by Robbins (1984).

Pilot Drill

The first step consists of drilling an 11-in.-diameter pilot hole 27 ft deep. The equipment required for this is a standard raise drill, modified to accept a 10-in.-diameter drill pipe. Mounted on the crawler is an electrically powered hydraulic power package, which supplies power to the rotary drive motor, hydraulic thrust cylinders, and pipe loader. Space remains on the crawler for drill string component storage and an operator's control console. This system also requires electrical power to drive the hydraulic pump motors, compressed air for muck removal, and water for heat exchange and dust suppression. All system elements are either standard or similar to existing equipment. Figure D-1 is a schematic of the two drills operating in a typical emplacement drift.

Reamer Drill

The second step in the vertical borehole drilling operation consists of opening the 11-in.-diameter pilot hole to a 29-in.-diameter hole 25 ft deep. (The pilot of the reamer bit follows the pilot hole, which is drilled 2 ft deeper than the depth of the final reamed hole.) Reaming is also performed by a crawler-mounted machine that can move readily from one hole to the next. One additional system element, a vacuum system, is required for muck removal. This unit is self-contained, mounted on a trailer, and towed by the crawler. The unit is connected to the drill system by a flexible hose attached to the muck discharge on top of the movable portion of the raise drill derrick. The reaming machine itself is modified to accommodate an offset drive to provide adequate muck passage through its center. Also, this machine employs circular guide columns to enhance stability. The blower drive motor, which is part of the vacuum system, increases the electrical power required by this system.

3.2.2 Horizontal Drilling Equipment

A horizontal boring system is being developed. Detailed descriptions of the most recent equipment are presented by Robbins (1987).

A schematic of the prototype development hardware under consideration is shown in Figure D-2. This system consists of the following components.

Inhole Drill

The drill motor is located inside the borehole and drives a drill head fitted with carbide-insert roller cutters. The drill is connected to the borehole liner through a ball joint assembly that allows the drill head to be steered to maintain proper trajectory. Steering is accomplished by hydraulically actuating wedges that push against the liner and force the drill head into alignment with the desired trajectory. A laser guidance system is used by the operator to determine the current position of the drill head so that corrective steering action can be taken.

Borehole Liner

The borehole is lined as it is drilled. Thrust to the inhole drill is transmitted from the mobile derrick through the liner and ball joint

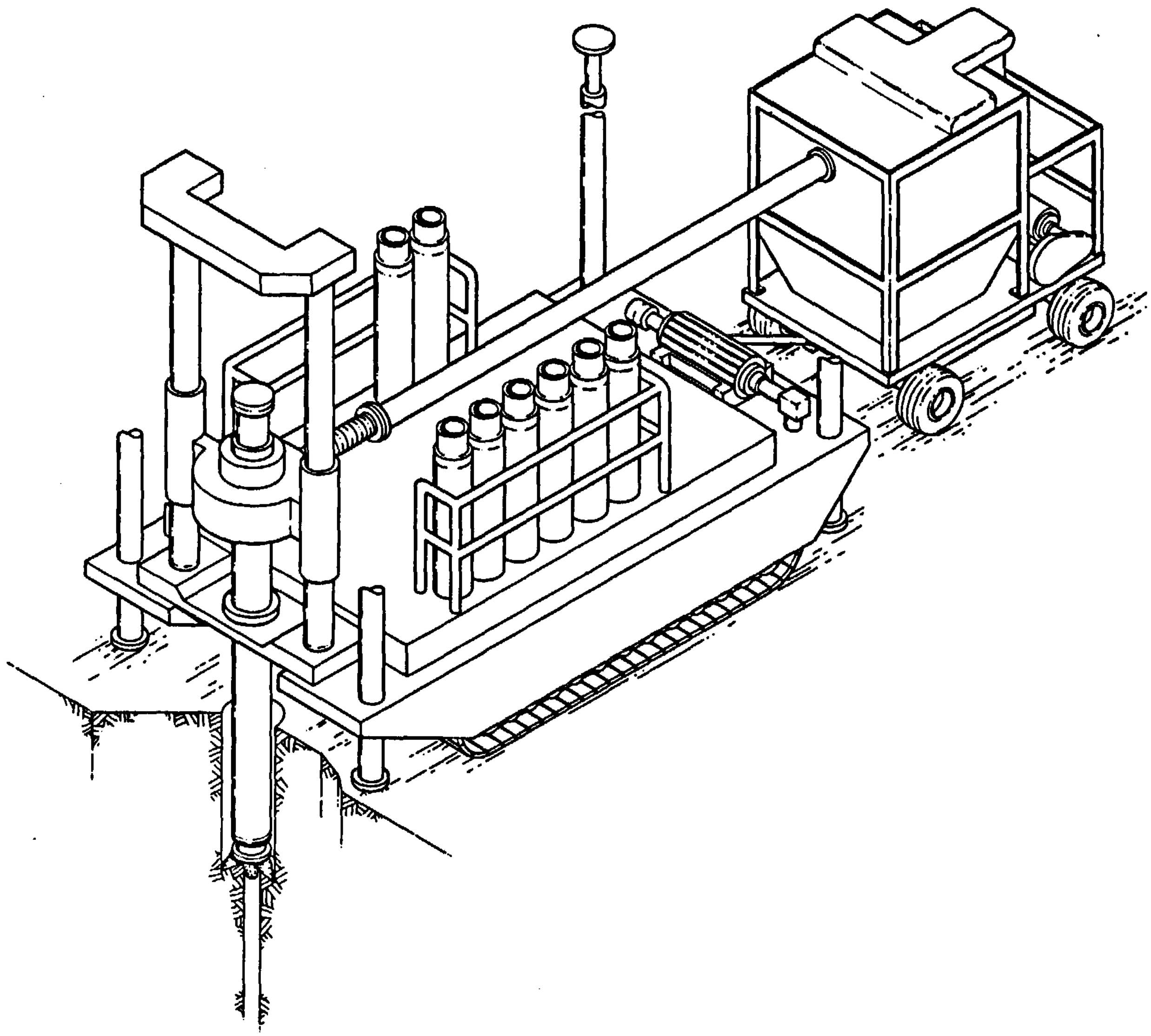


Figure D-1. Vertical Repository Drill System (Pilot Drill and Reaming Machine)

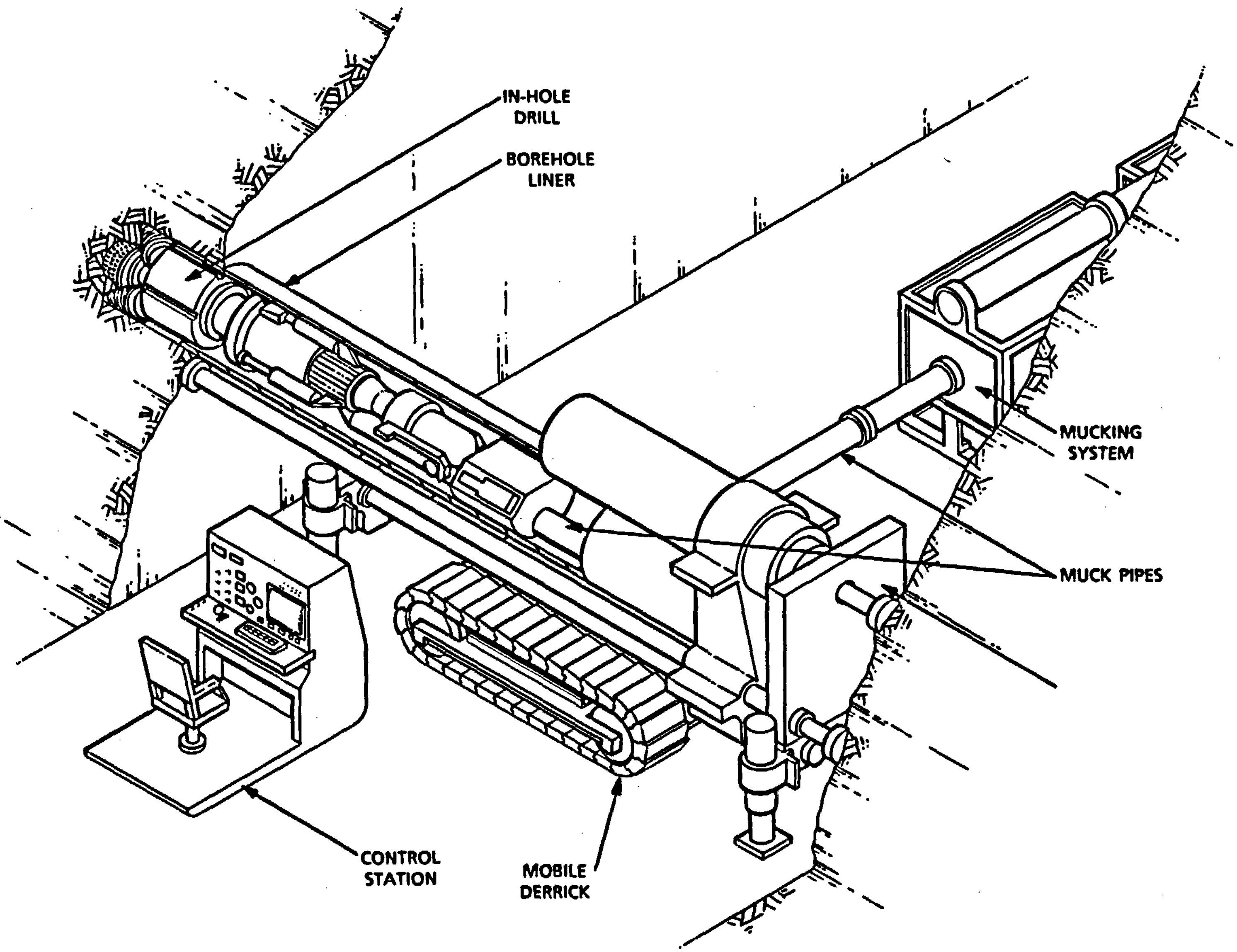


Figure D-2. Horizontal Borehole Drilling and Lining Machine assembly. The inhole drill can be removed for maintenance and upon completion of the hole by remotely uncoupling the ball joint assembly from the liner and pulling the drill assembly through the inside of the liner. This operation is possible because the drill head's diameter is smaller than the liner's inside diameter. By mounting the drill head eccentrically on the rotary shaft, a hole larger than the liner's outside diameter can be drilled with the shaft centered; by moving the shaft to an eccentric position, the drill head is centered and can be withdrawn.

Mobile Derrick

The derrick is anchored to the walls and roof of the drift and provides thrust to the liner through a traversing head powered by large hydraulic cylinders. The traversing head also provides passage for the muck pipes that carry rock chips from the drill head to the mucking system.

Mucking System

Because of the self-imposed design goal that little or no water be introduced into the borehole for chip removal, a vacuum mucking system is employed. The system consists of vacuum pumps, muck pipes, and filter boxes. Clean air is drawn by vacuum down the inside of the liner, across the drill head where it picks up rock chips, through the muck pipes, and into the filter boxes. Primary and secondary filtering removes rock chips and fugitive dust particles before discharge of the air back into the drift.

Although this system design is newly developed, it is based on existing technology. The inhole drill represents a reduction in scale of current tunnel boring machines (TBM). Drill head and cutter design, as well as thrust requirements, are based on extensive blind-hole drilling experience. The derrick assembly design draws heavily on extensive experience with raise drills in operation worldwide. The vacuum mucking system design is based on pneumatic transport of rock cutting in tunnel-boring, backfilling, and drilling operations.

4.0 UNDERGROUND WASTE TRANSPORTATION AND EMPLACEMENT EQUIPMENT

The waste emplacement concepts for both the vertical and horizontal waste emplacement options are presented in this section. The systems for normal waste emplacement and retrieval are described in additional detail in Stinebaugh, et al. (1987) and Stinebaugh and Frostenson (1987).

The equipment concepts presented represent the current, documented configurations; these concepts are subject to change as additional work is completed. These concepts are based on adaptation of commercial equipment components and technology to ensure feasibility.

4.1 Vertical Configuration

This section describes the (1) vertical emplacement borehole, (2) the hardware required to prepare the borehole for waste emplacement, (3) the hardware necessary to close the borehole after waste emplacement, and (4) the equipment needed to support operations. A cross section of the vertical emplacement borehole is shown on Figure D-3 of this appendix.

4.1.1 Vertical Emplacement Borehole and Borehole Hardware

4.1.1.1 Vertical Emplacement Borehole

The borehole, as shown in Figure D-4, has a 29-in. diameter and is drilled to a depth of 25 ft. The upper 6-ft section of the borehole is counterbored to a diameter of 34 in. to accommodate the beveled ring on the partial borehole liner.

4.1.1.2 Vertical Borehole Hardware

Liner

The borehole liner (Figure D-5) provides structural stability for the upper borehole, protection for the mouth of the borehole, assistance in positioning emplacement and retrieval equipment, attenuation of radiation from the borehole, and a means for securing the borehole cover.

The tubular-steel borehole liner extends approximately 12 ft into the 25-ft borehole to encompass the pintle and upper portion of the waste container. The liner supports the plug and centers the upper part of the waste container in the borehole. The heavy beveled ring that encircles the liner at a depth of 6 ft transfers the loads imposed on the liner by the plug and the emplacement and retrieval equipment to the surrounding rock. The presence of the beveled ring creates a 2.5-in. annulus between the borehole and the liner that extends from the drift floor to the top of the ring. This annulus is manually filled with grout or aggregate to within 12 in. of the drift floor to provide additional shielding and steady the borehole liner. The beveled ring also serves to attenuate any radiation that may pass through the annulus to the drift. An additional interior liner is built into the lower 23 in. of the borehole liner. The plug rests on this section of the liner. Together with the main liner, the interior liner extends into the borehole far enough to encompass the pintle and center the upper portion of the waste container.

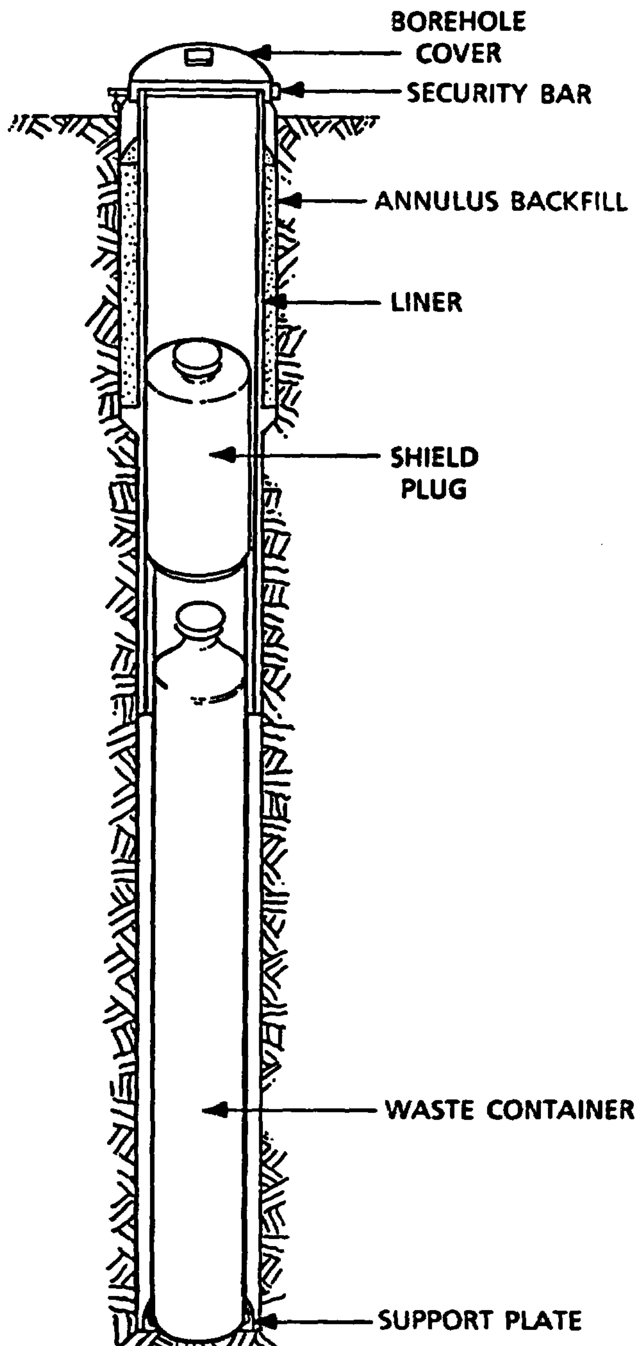


Figure D-3. Design Configuration for Vertical Emplacement

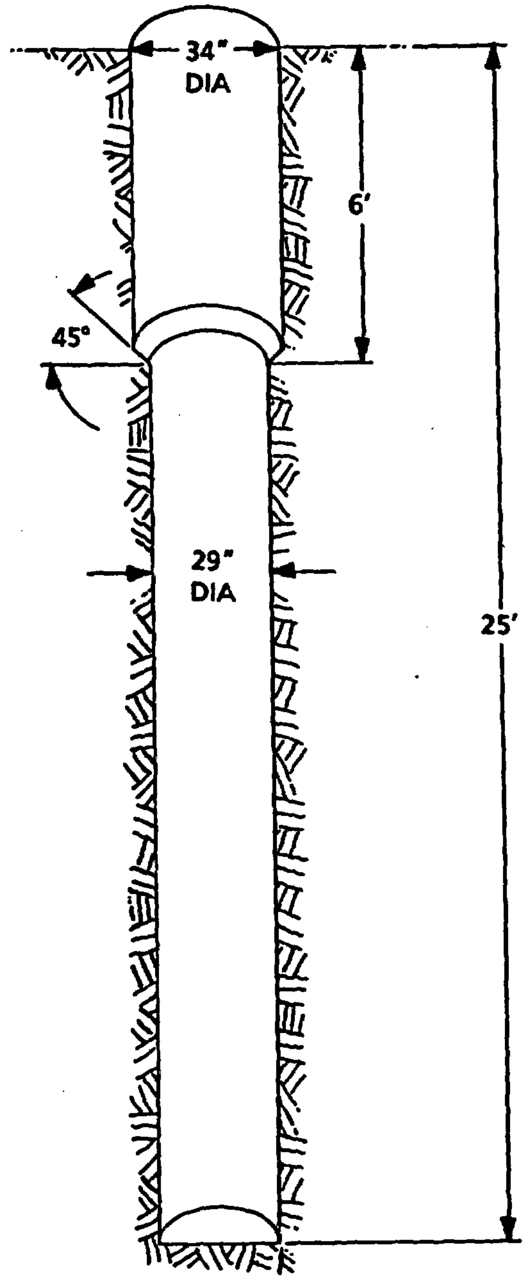


Figure D-4. Vertical Emplacement Borehole Dimensions

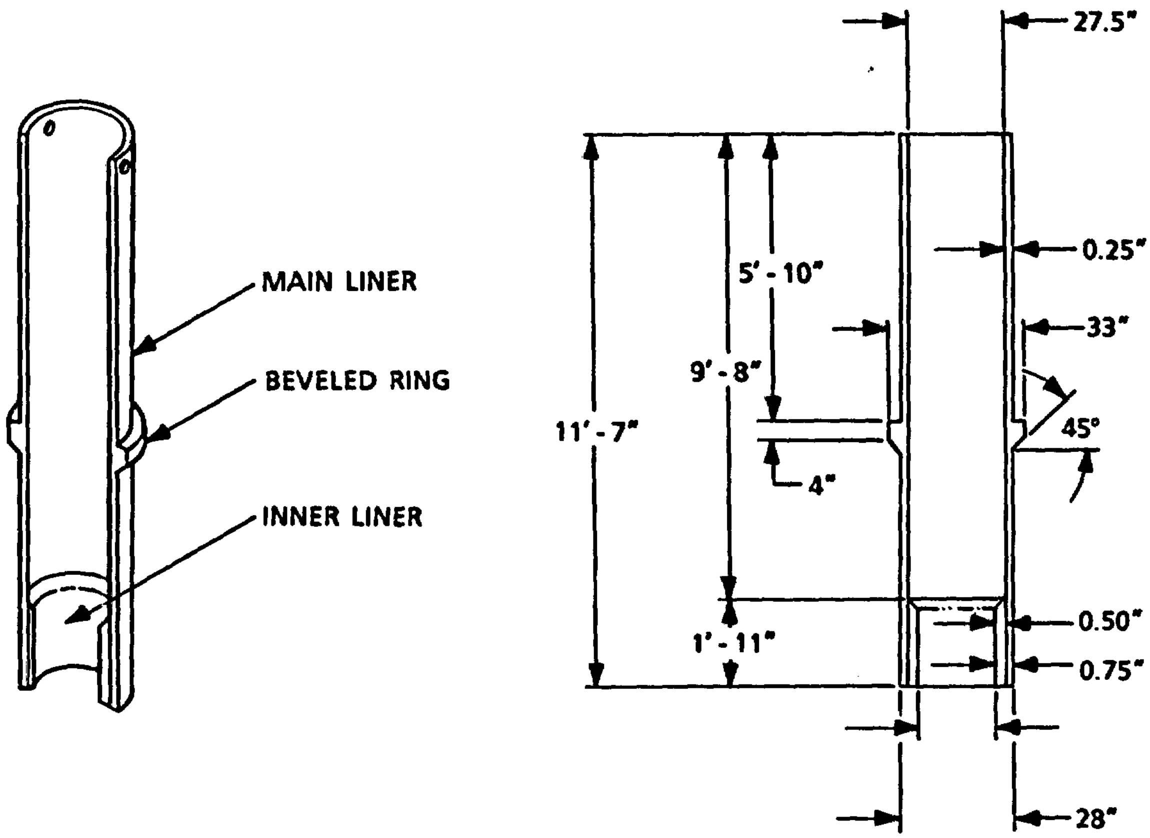


Figure D-5. Vertical Borehole Liner

Support Plate

The support plate (Figure D-6) is placed at the bottom of the borehole. The support plate centers the bottom of the waste container in the borehole, isolates the base of the waste container from the bottom of the borehole, and eliminates points of high stress by supporting the weight of the waste container evenly. The triangular holes in the support plate permit drainage of any moisture that might accumulate. The plate is lowered into the borehole before installation of the borehole shielding closure.

4.1.1.3 Vertical Borehole Closure Hardware

The borehole closure hardware consists of a shield plug and cover. These items are used to secure the borehole after waste emplacement.

Shield Plug

The plug, as shown in Figure D-6, is made of cast iron, steel, or other dense material. A pintle, dimensionally identical to the pintle on the waste container, is located on the top of the plug so that a common grapple design can be used for both the waste package and plug.

Cover

The borehole cover (Figure D-6) provides final closure and identifies the location of the borehole. The cover bears the borehole identification number and an identification plate that describes the type of waste contained in the waste container. The cover also serves to prevent debris from falling into the space above the plug so that, if retrieval becomes necessary, access to the pintle will be unobstructed. The cover also provides some radiation shielding and prevents tampering. A bar secures the cover to the borehole liner and provides a place for installation of a security seal.

4.1.2 Vertical Waste Transportation and Emplacement Equipment

Only the major equipment required for vertical waste emplacement is described in this section; this includes the container transporter, the modified forklift, the borehole shielding closure, and the shield plug installer/remover.

4.1.2.1 Waste Container Transporter

The transporter, illustrated in Figures D-7 and D-8 is approximately 25 ft long, 10 ft wide, and 8 ft high and weighs approximately 120,000 lb. The transporter will have sufficient ground clearance to be able to move over previously emplaced waste containers in covered boreholes. Either diesel or electrical power will be used to drive the transporter. The transporter has four main parts: (1) the transporter cab, (2) the running gear, (3) the hydraulic system, and (4) the cask.

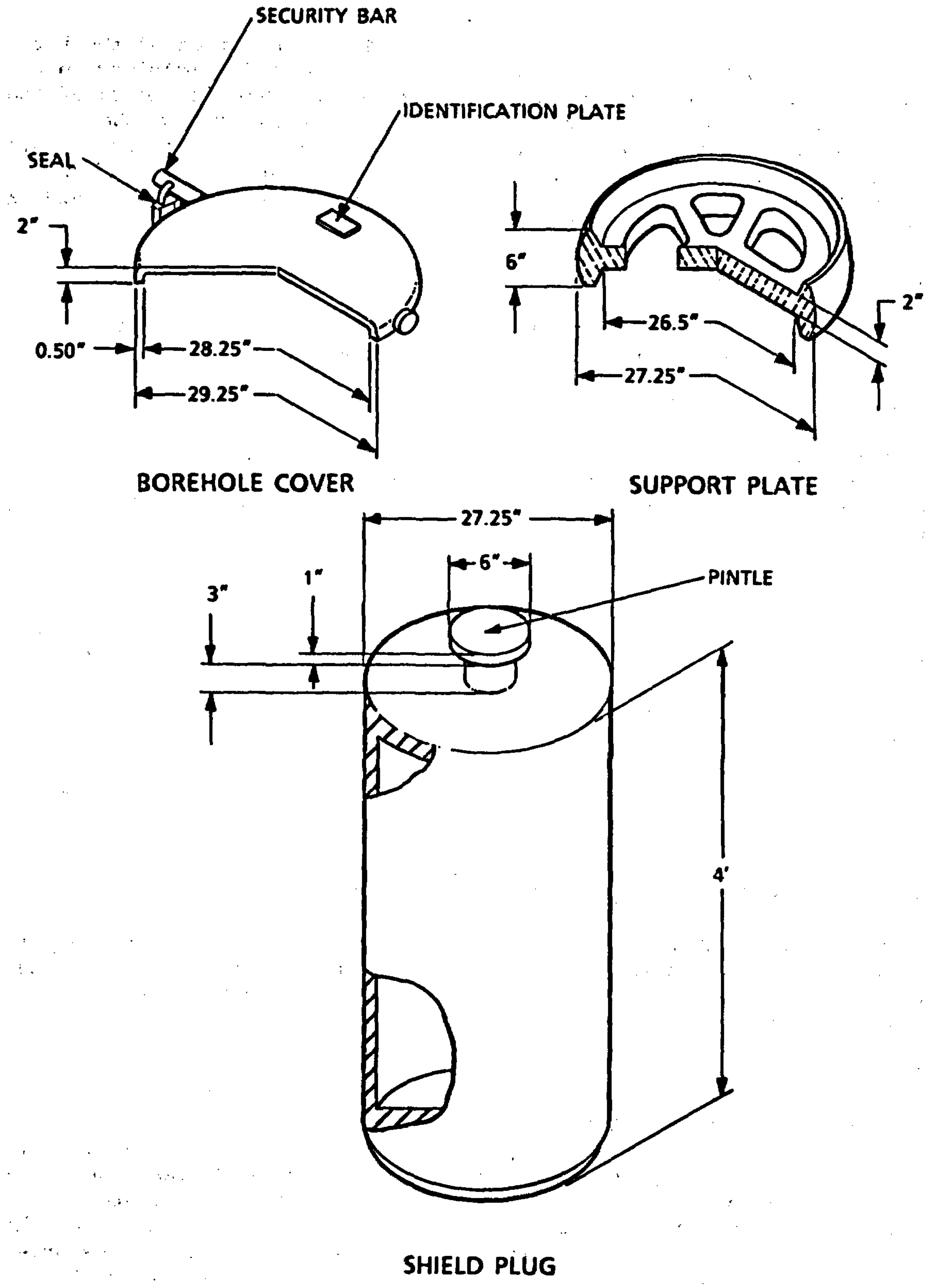


Figure D-6. Vertical Borehole Support Plate, Shield Plug, and Cover

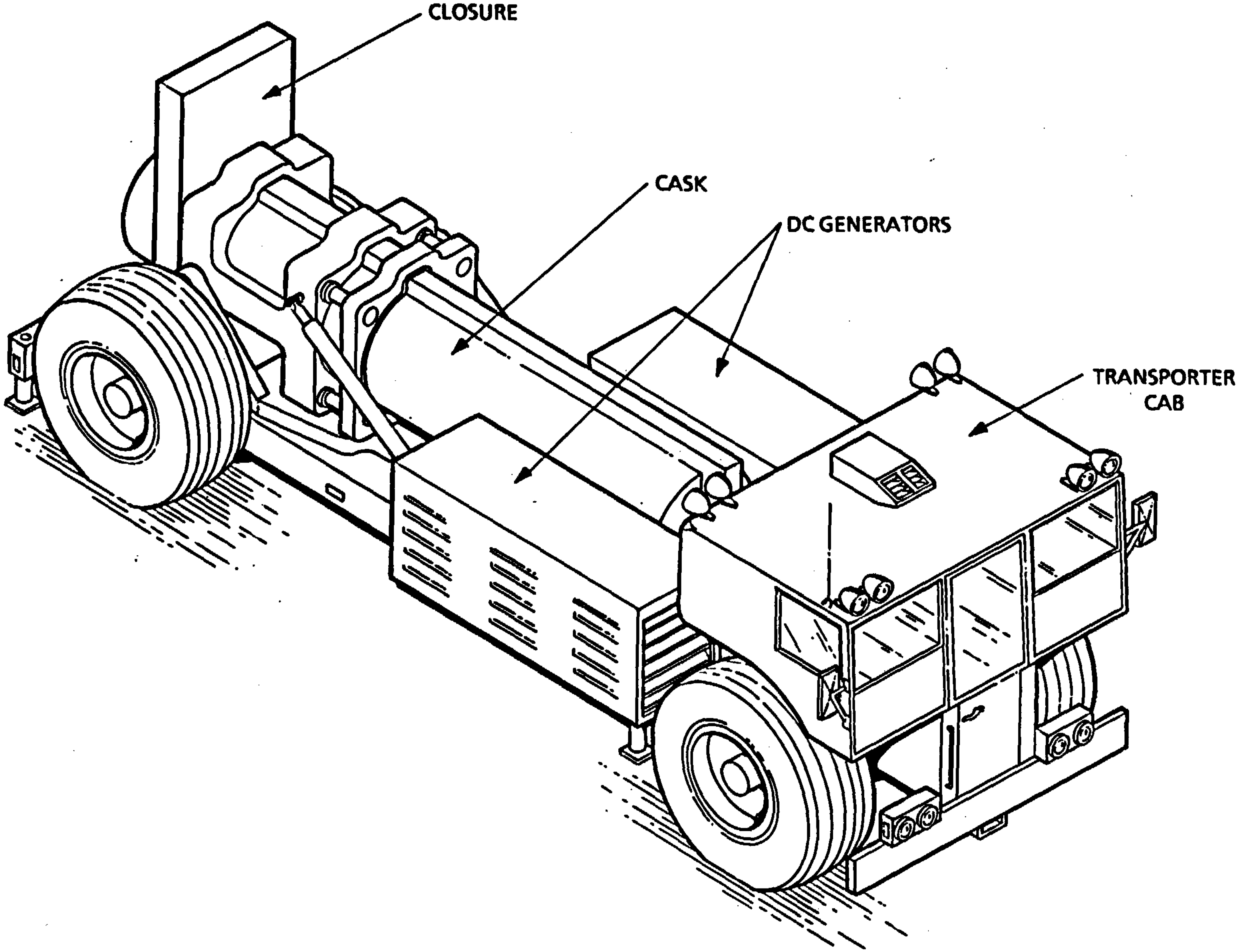


Figure D-7. Waste Container Transporter in Transport Mode (Vertical Configuration)

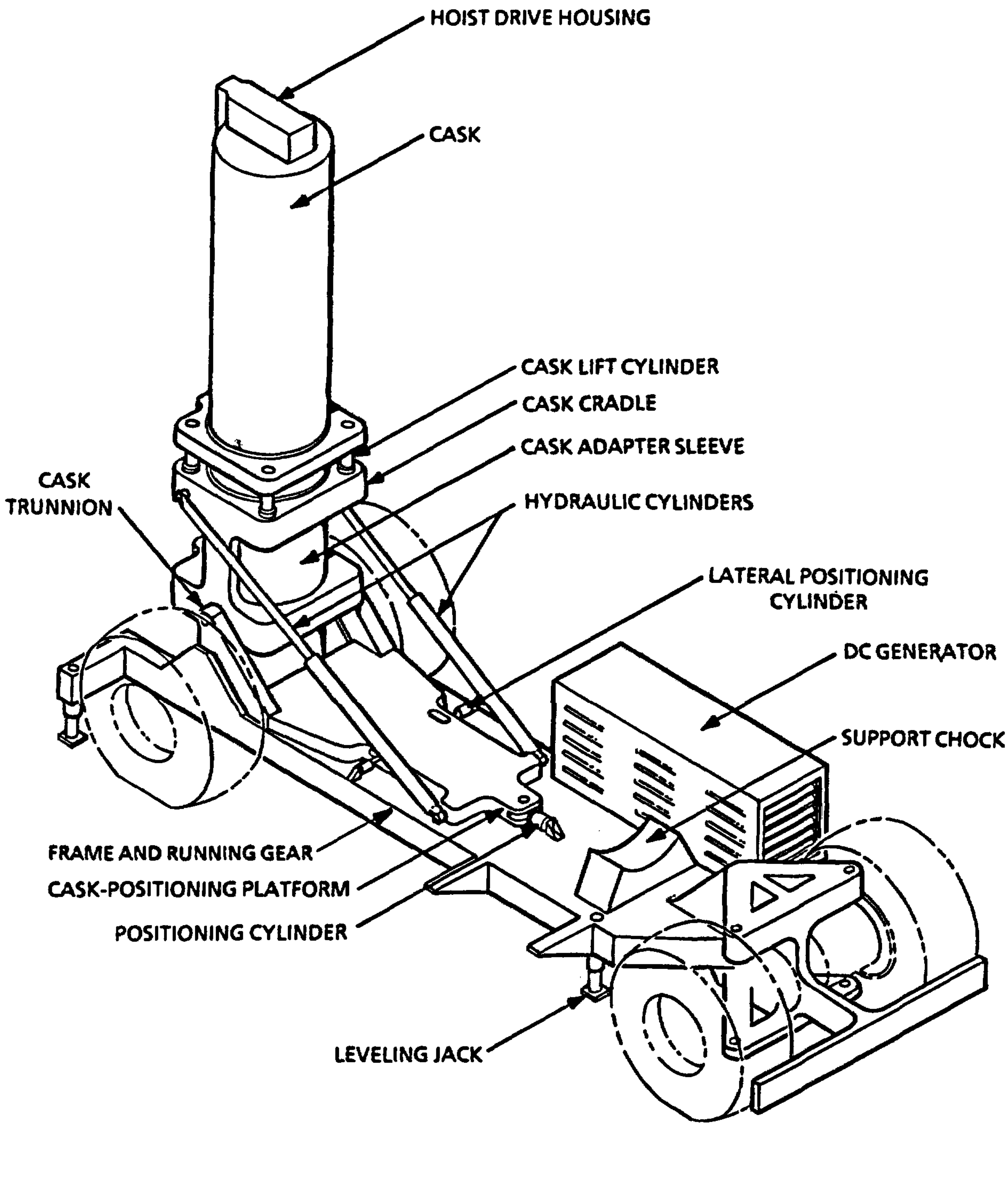


Figure D-8. Waste Container Transporter in Emplacement Mode (Vertical Configuration)

Transporter Cab

The cab will be partially sealed so that the pressure inside the cab is always greater than the pressure outside the cab. The inlet air will be temperature-conditioned, filtered, and monitored by a continuous air monitor. The operator will be able to select one of two filtration modes: (1) a mode that removes normal dust and (2) a high-efficiency mode in which inlet air is filtered through HEPA filters. The transporter cab will be shielded to reduce the radiation dose to the occupants. The small rear windows (facing the cask) will be made of leaded glass and will provide adequate visibility. All windows will meet the necessary safety requirements. The cab will be designed to limit the operator dose to less than 1/5 the allowable dose of 5 rem/yr (DOE, 1986b).

The transporter cab (Figure D-7) is designed to accommodate two occupants. The cab contains the driving controls and separate controls for the emplacement equipment: cask-positioning system, cask hoist, cask closure, and borehole shielding closure. The cab will also be equipped with a radio communications system that enables the operator to maintain contact with other vehicles and various control stations in the repository.

Running Gear

The running gear, as shown in Figure D-8, will be a rigid-framed, four-wheeled design with electric hub-mounted DC motors, powered by two 150-kW diesel generators. The vehicle will use the front wheels for driving and steering and will be designed with a minimum 25-ft turning radius.

Hydraulic Systems

The cask-leveling circuit will control four hydraulic cylinders (jacks) located at the four corners of the transporter frame. These cylinders will operate simultaneously or individually to vertically position and level the transporter. The forward pair of cylinders will be connected so that the load is shared by all cylinders, making the lift system analogous to a three-point lift system. The cask-rotation circuit will control two cylinders that are hydraulically linked to permit load sharing.

The cask-positioning platform and chock shown in Figure D-8 support the cask in transit from the surface facility to the borehole. The platform is equipped to rotate the cask from the horizontal transport position to the vertical emplacement position. This platform also provides adjustments to align and connect the cask with the shielding collar or shielding closure on the borehole. An optical guidance system will help the operator position the transporter.

Transporter Cask

The cask will be designed to accommodate the current 10,000-lb, 15-ft long, and 26-in. diameter waste packages. The cask will be approximately 18 ft long and 4 ft wide (O.D.). The cask design, construction, and shielding materials will limit the radiation level, at a distance of 2 m (6.6 ft) from the surface of the cask, to less than 10 mrem/hr.

The cask (Figures D-8 and D-9) consists of a shell and shielding cylinder, a waste container hoist, a waste package grapple, and a shielding closure at the end of the shielding cylinder.

Cask Hoist

The cask hoist will develop a pulling force of 25,000 lb. The load and extension of the hoist will be monitored and displayed in the transporter cab.

The cask hoist, which consists of lift chains, a lead screw, worm gear set, drive motor and block guide bearings, is shown in Figure D-9. The hoist is located on the exterior of the cask and attaches to the waste container through an opening in the top of the cask by means of a grapple.

Cask Closure

The cask closure housing must be designed so that shielding for operations is maintained regardless of whether the closure gate is open or closed. Instrumentation will indicate the fully open and fully closed positions and will be displayed in the transporter cab.

The cask closure design (Figure D-9) incorporates a rotating lock. By counterrotating the drive motors after the gate has been closed, the lock on the gate key is aligned perpendicular to the key slot in the housing, which prevents the gate from opening if an accident occurs.

Cask Grapple

The design requirements for this device are (1) it must safely handle a load that is four times the maximum anticipated load, (2) it must provide both mechanical indicators of latching visible from the transporter cab and electrical indicators of latching in the transporter cab, (3) it must be incapable of automatic release when loaded, (4) its normal mode will be "latched," and (5) it must have a backup, independent release method.

The grapple will be used to connect the cask hoist to a waste container. The grapple is shown in Figure D-10.

4.1.2.2 Modified Forklift

The modified forklift is used to transport, install, and tow various equipment used for waste emplacement and retrieval. The modified forklift, as illustrated in Figure D-11, will consist of a commercially available, extending-boom forklift adapted for use in the repository. The dimensions of the forklift are given in Table D-2.

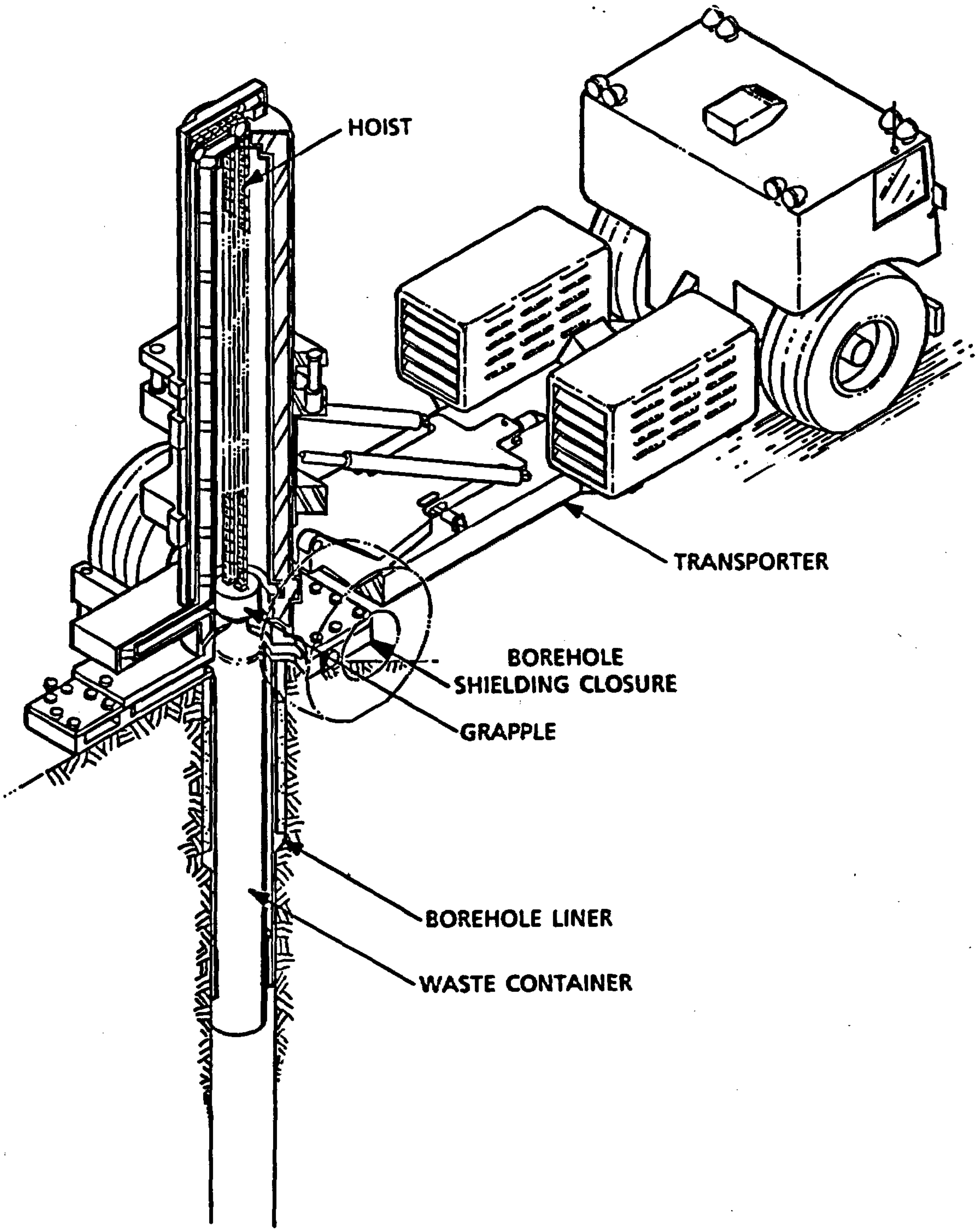


Figure D-9. Transporter Cask (Vertical Configuration)

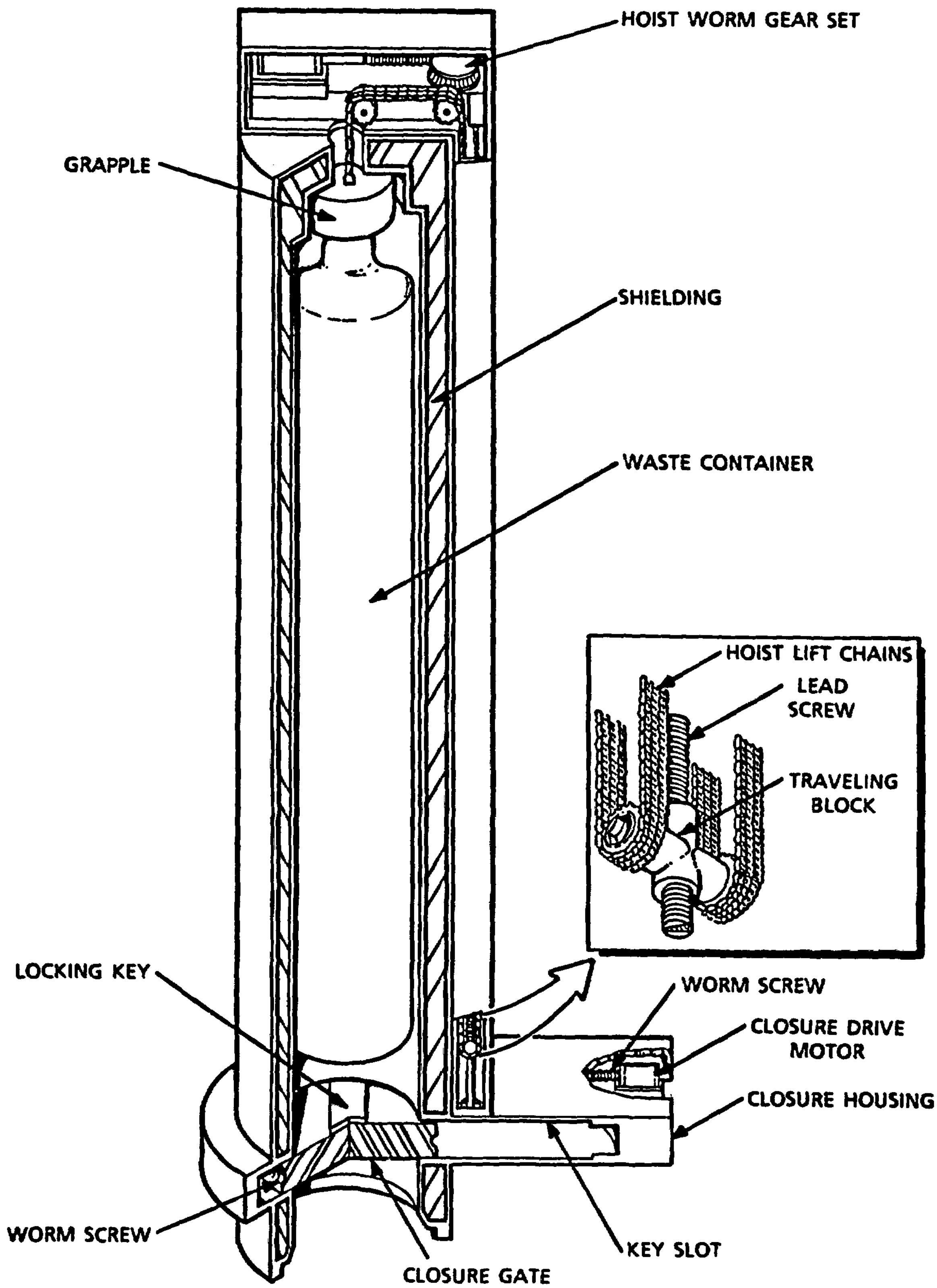


Figure D-9. Transporter Cask (Vertical Configuration) (continued)

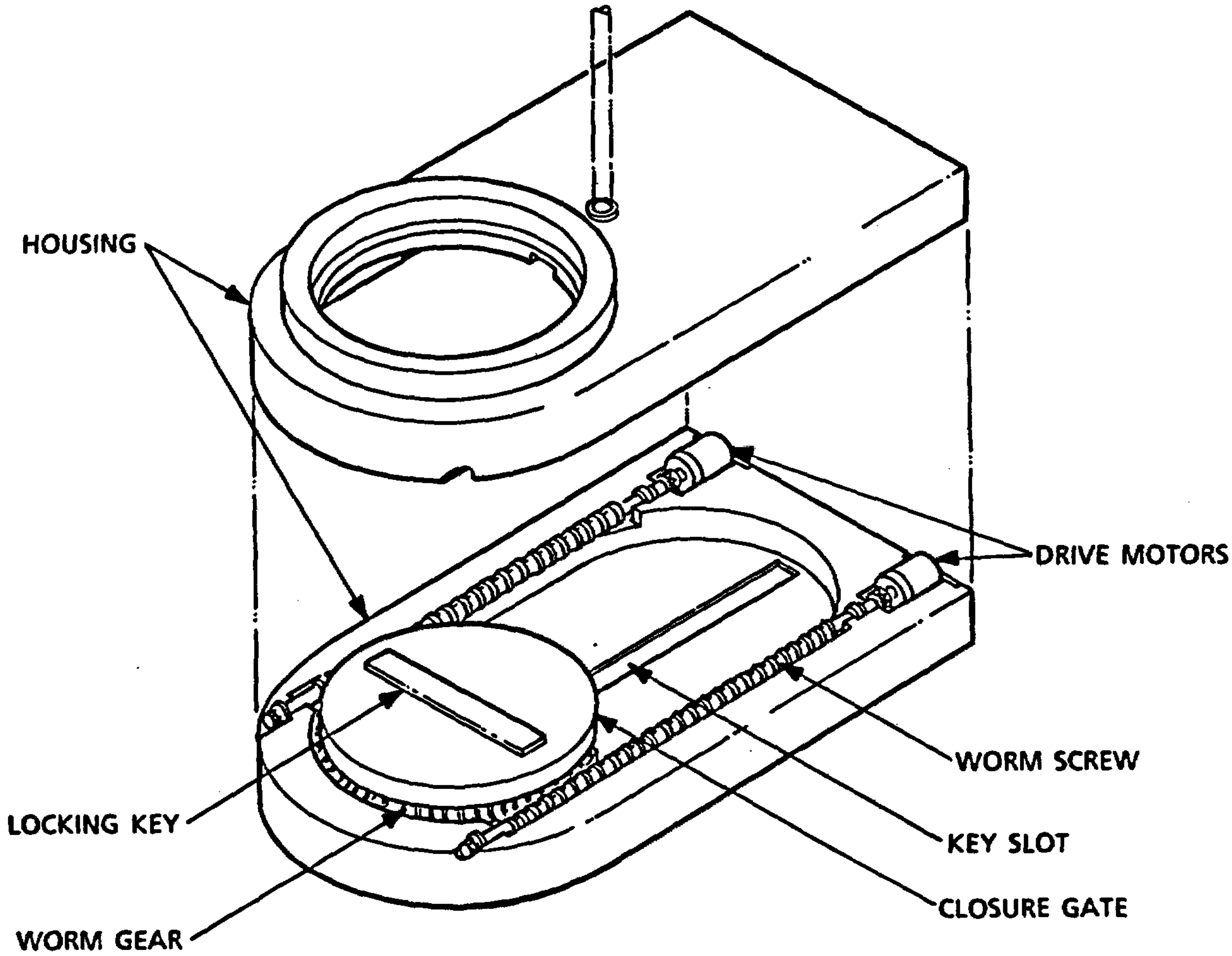


Figure D-9. Transporter Cask (Vertical Configuration) (concluded)

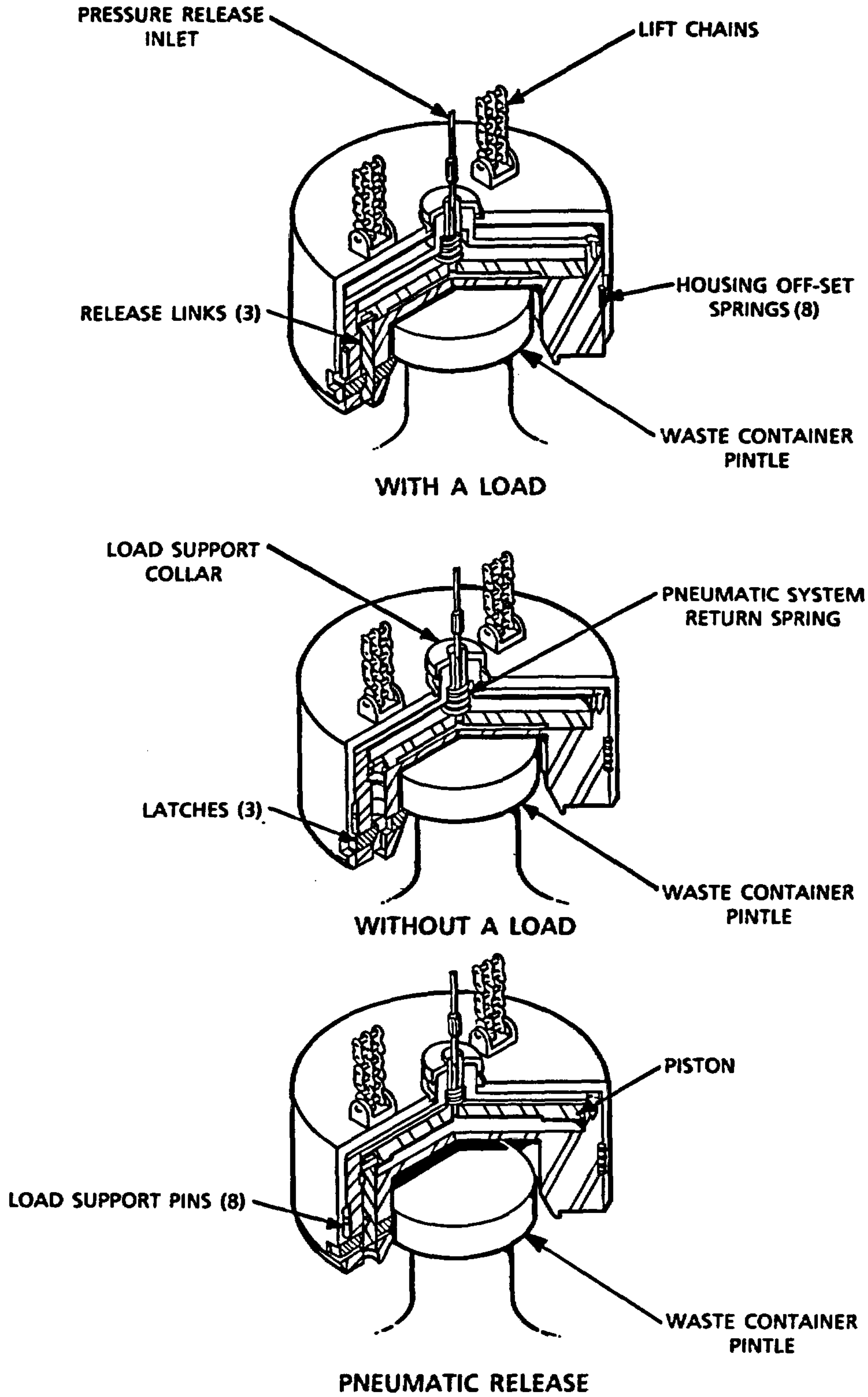


Figure D-10. Vertical Cask Grapple

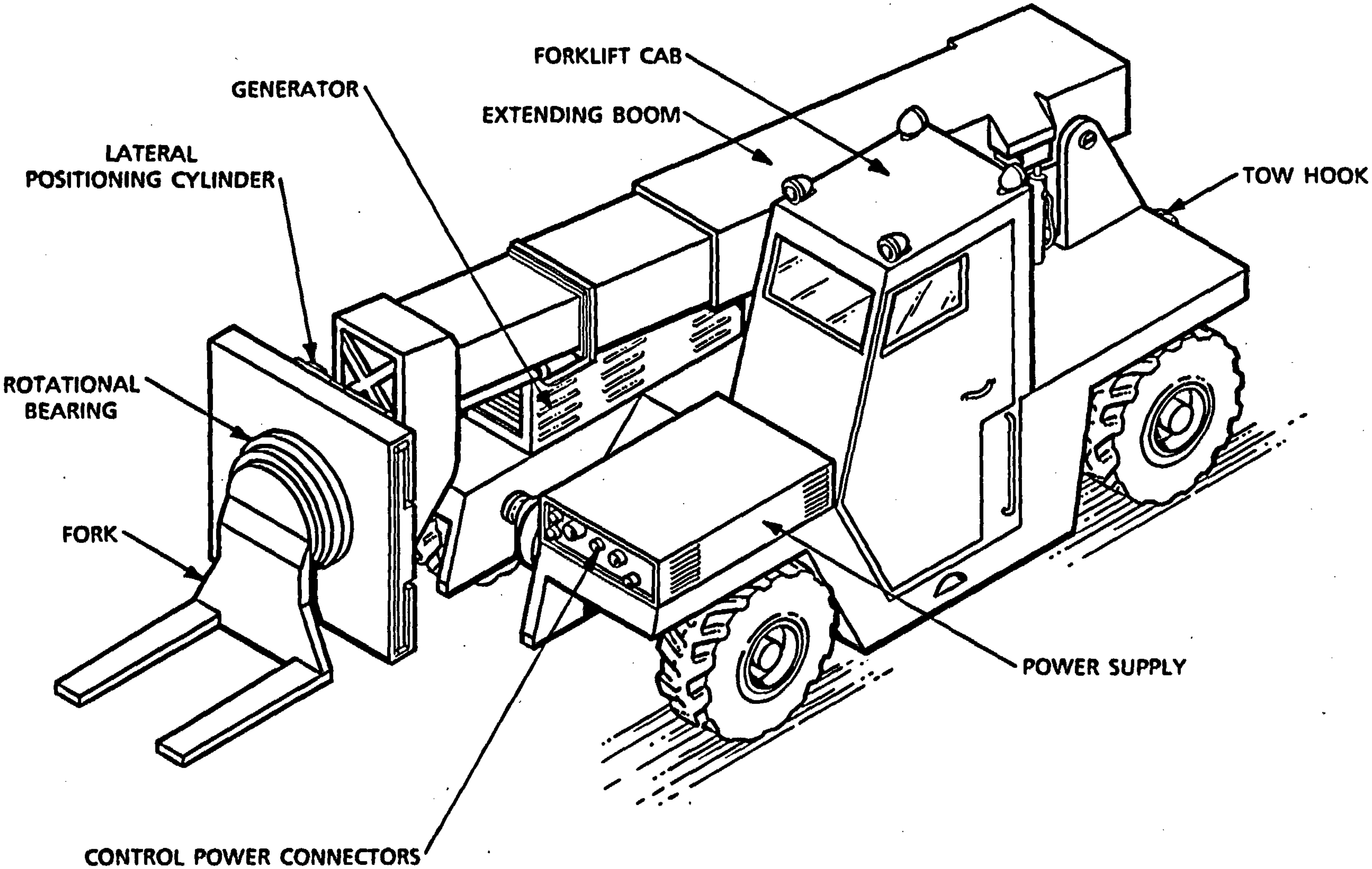


Figure D-11. Modified Forklift and Special Fork (Vertical Configuration)

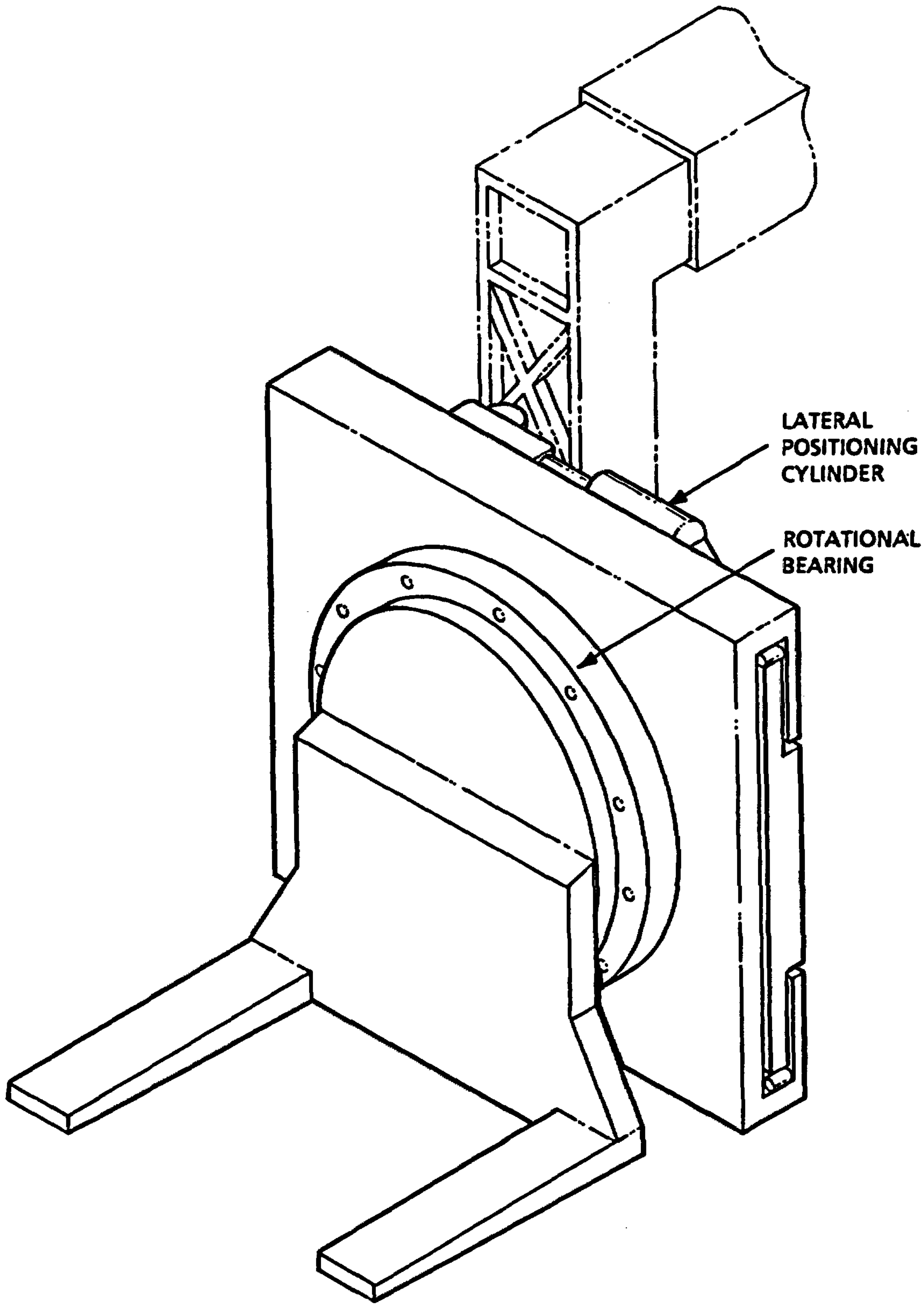


Figure D-11. Modified Forklift and Special Fork (Vertical Configuration) (concluded)

TABLE D-2

DIMENSIONS OF MODIFIED FORKLIFT (VERTICAL CONFIGURATION)

	Weight	Length	Width	Height
Boom Retracted (with ballast)	20 000 lb	19 ft	8 ft	8 ft
Boom Extended (with ballast)	20.000 lb	39 ft	8 ft	8 ft

Forklift Cab

The cab will be equipped with radiation shielding to minimize the amount of radiation exposure to the operator. The windows will be small and made of leaded glass; the cab will be partially sealed so that the interior environment can be controlled. Air entering the cab will be filtered, and the operator will be able to select normal or HEPA filtration. The forklift cab will be equipped with a communications system to enable the operator to communicate with emplacement operations control personnel. The cab accommodates a single operator.

Running Gear

The forklift will be rear-wheel steered, and each wheel of this four-wheeled vehicle will be independently driven by the hydraulic motor.

Extending Boom

The load-handling boom will extend up to 20 ft from the retracted position. When the boom is extended 2 ft, the forklift will be able to pick up and haul 8,000 lb. With the boom extended 18 ft, the forklift will be able to lift and transport 2,350 lb.

Special Fork

The standard fork tines on the commercial vehicle will be replaced by a special fork (Figure D-11) that can be shifted laterally or rotated to align the temporary shielding equipment.

4.1.2.3 Borehole Shielding Closure

The borehole shielding closure (Figure D-12) is designed to reduce radiation from a waste package to levels safe for personnel during emplacement and retrieval operations. A cylindrical sleeve on the housing of the closure fits over the borehole liner to ensure alignment and to provide shielding. The shielding closure is operated by an electric drive motor, but a mechanical backup is provided to open or close the shielding closure in case the motor fails. Mechanical jacks

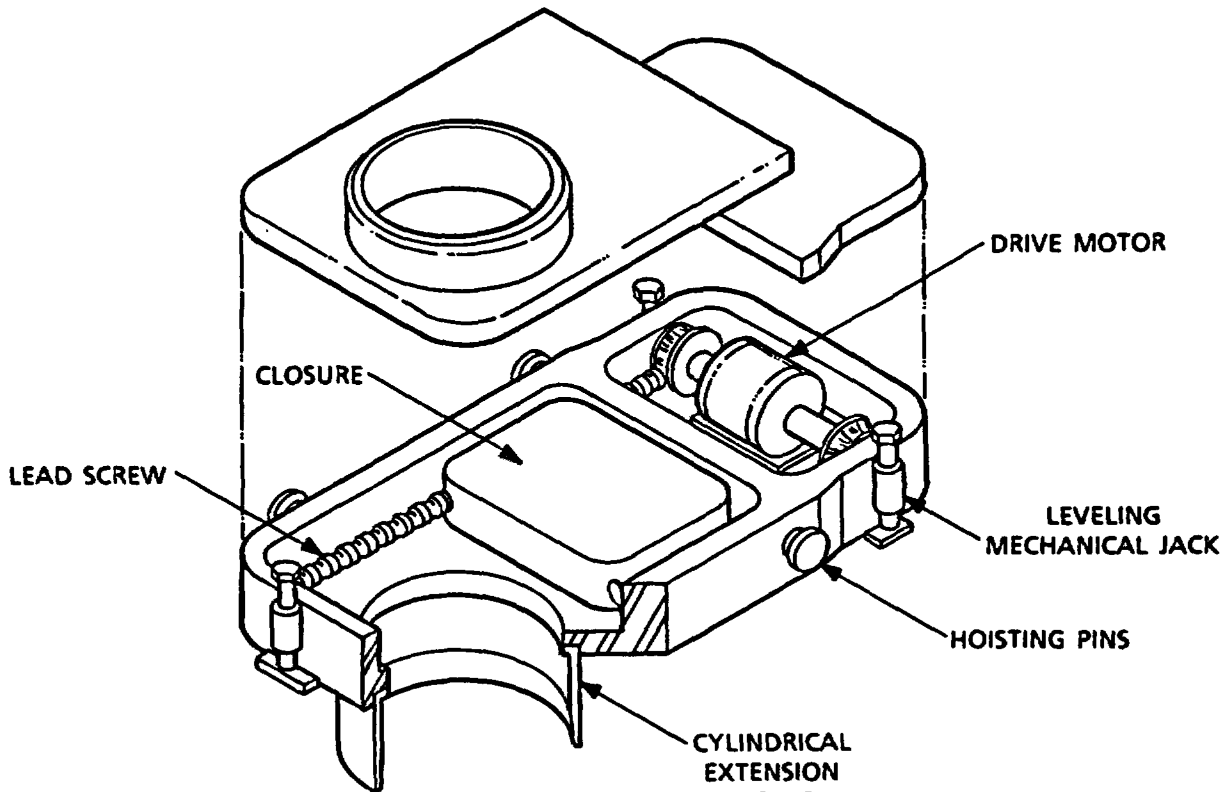


Figure D-12. Vertical Borehole Shielding Closure

are installed on each corner of the closure housing to level the closure and to provide support for the closure. The dimensions of the shielding closure are shown in Table D-3.

TABLE D-3

DIMENSIONS OF BOREHOLE SHIELDING CLOSURE

Item of Equipment	Weight	Length	Width	Height*
Shielding Closure	7,500 lb	74 in.	38 in.	12 in.

* The height does not include the extension sleeve.

4.1.2.4 Shield Plug Installer/Remover

The plug installer attaches to the modified forklift and consists of three major elements: the housing, a hoist, and a grapple. The plug installer/remover is illustrated in Figure D-13.

Housing

The housing surrounds the plug to maintain shielding during installation and removal.

Hoist

The plug hoist must raise and lower a 2,500-lb plug. The hoist is an electrically driven, roller chain hoist. An indicator in the cab of the forklift will display hoist extension and retraction.

Grapple

The grapple must be capable of holding a 2,500-lb shield plug. The grapple is similar to that used by the waste transporter except that it does not provide a visual indication of latching.

4.2 Horizontal Configuration

This subsection describes the (1) horizontal waste emplacement borehole, (2) the hardware required to prepare the borehole for waste emplacement, (3) the hardware necessary to close the borehole after emplacement, and (4) the equipment needed to support operations. A cross section of the horizontal emplacement borehole is shown in Figure D-14. The equipment presented here and the operational procedures for horizontal emplacement are described fully in Stinebaugh et al., 1987.

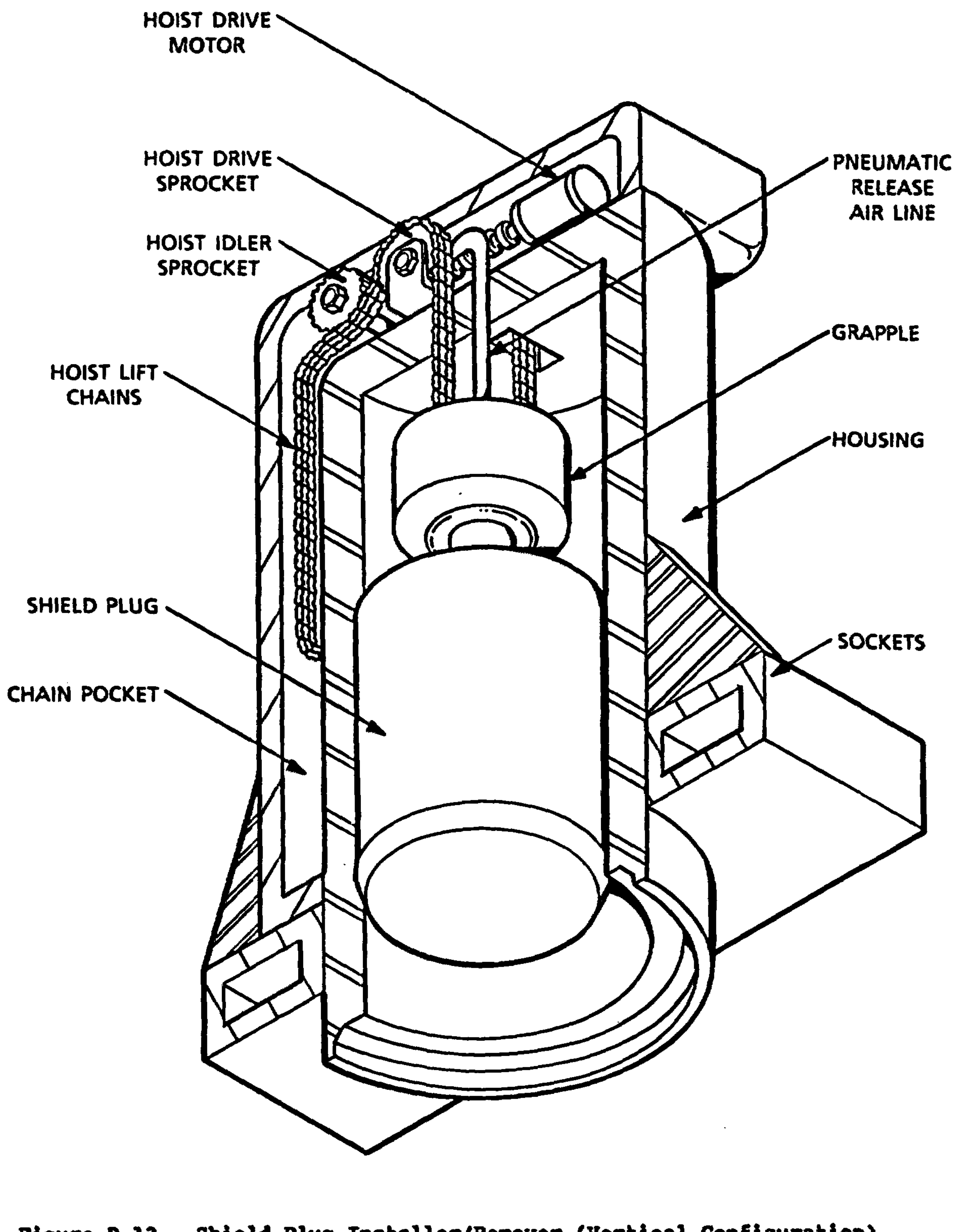


Figure D-13. Shield Plug Installer/Remover (Vertical Configuration)

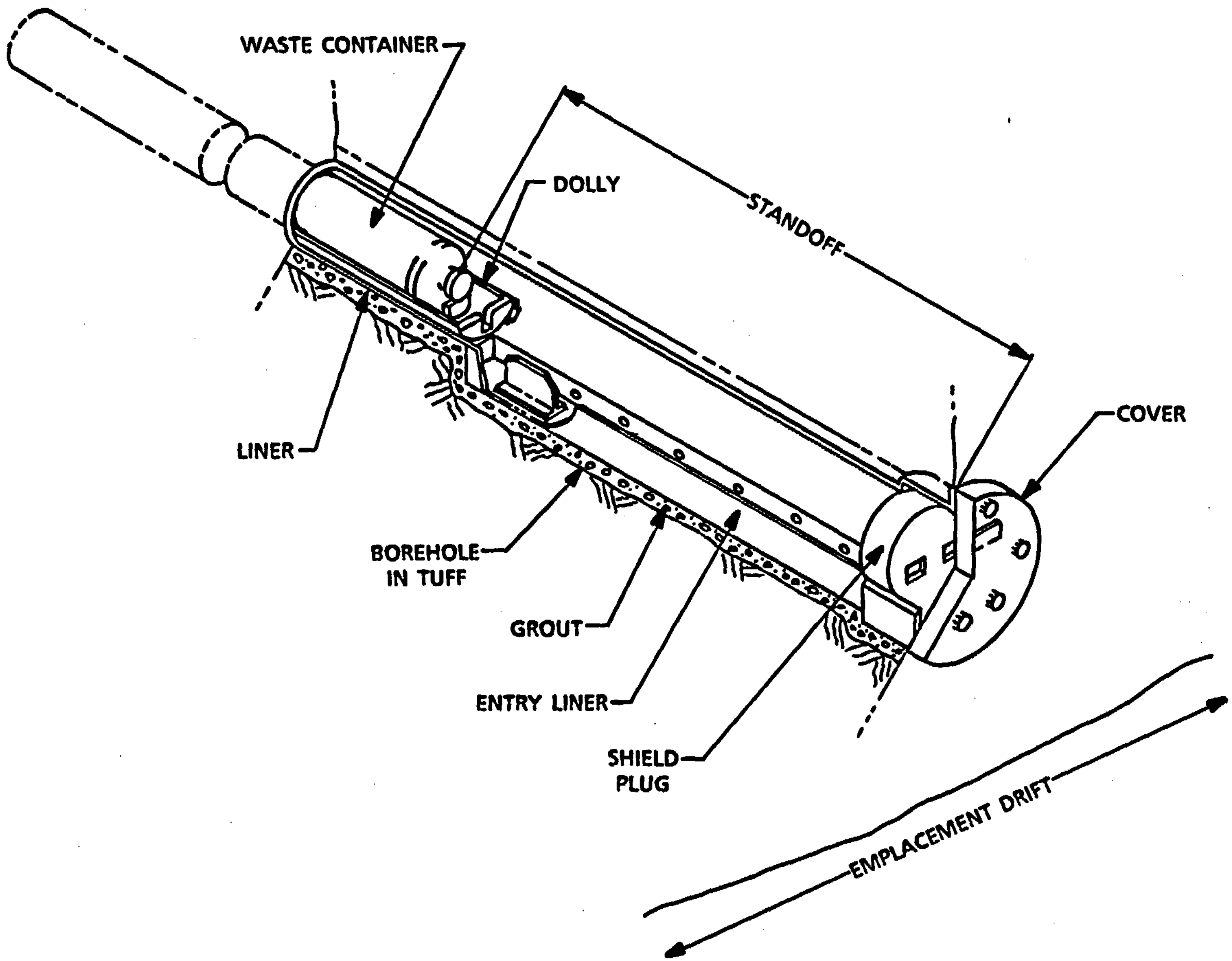


Figure D-14. Design Configuration for Horizontal Emplacement

4.2.1 Horizontal Emplacement Borehole and Borehole Hardware

4.2.1.1 Horizontal Emplacement Borehole

The horizontal borehole is illustrated in Figure D-15. The borehole will be drilled horizontally with a constant diameter, then counterbored to accommodate the larger-diameter entry liner. Techniques for drilling the portion of the borehole containing the entry liner are under investigation.

4.2.1.2 Horizontal Borehole Hardware

The only hardware necessary to prepare a horizontal borehole for emplacement is the borehole liner. The borehole liner covers the entire length of borehole and provides structural stability for the borehole and support and guidance for the waste container and dolly. The borehole liner is illustrated in Figure D-16. The 350-ft liner will accommodate 15 waste containers and dollies with a stand-off distance from the drift of 102 ft.

4.2.1.3 Horizontal Borehole Closure Hardware

Shield Plug

The shield plug (Figure D-17) is made of steel or other dense material, designed as a radiation shield. It has attachment holes located on the front for installation and removal, and is sized and keyhole-shaped to fit in the front of the entry liner.

Cover

After the shield plug is in place, a steel cover plate (Figure D-17) is bolted to the flange on the front of the entry liner to seal, secure, and identify the filled borehole. The cover bears the borehole identification number and an identification plate describing the type of waste contained in the emplaced waste containers. The cover provides additional radiation shielding and prevents tampering.

4.2.2 Horizontal Waste Transportation and Emplacement Equipment

Only the major equipment required for horizontal waste emplacement is described in this subsection. These items are the waste container dolly, waste container transporter, modified forklift, borehole shielding closure, and shield plug installer/remover.

4.2.2.1 Waste Container Dolly

The 15.5-ft waste container is mounted on a dolly in the surface storage facility; the dolly provides waste container mobility without loading or stressing the waste container. The waste container remains on the dolly throughout emplacement and retrieval operations. The dolly consists of a curved steel plate, cast iron or steel rollers attached to each side of the plate, a rear dolly hook, and a front steel plate that

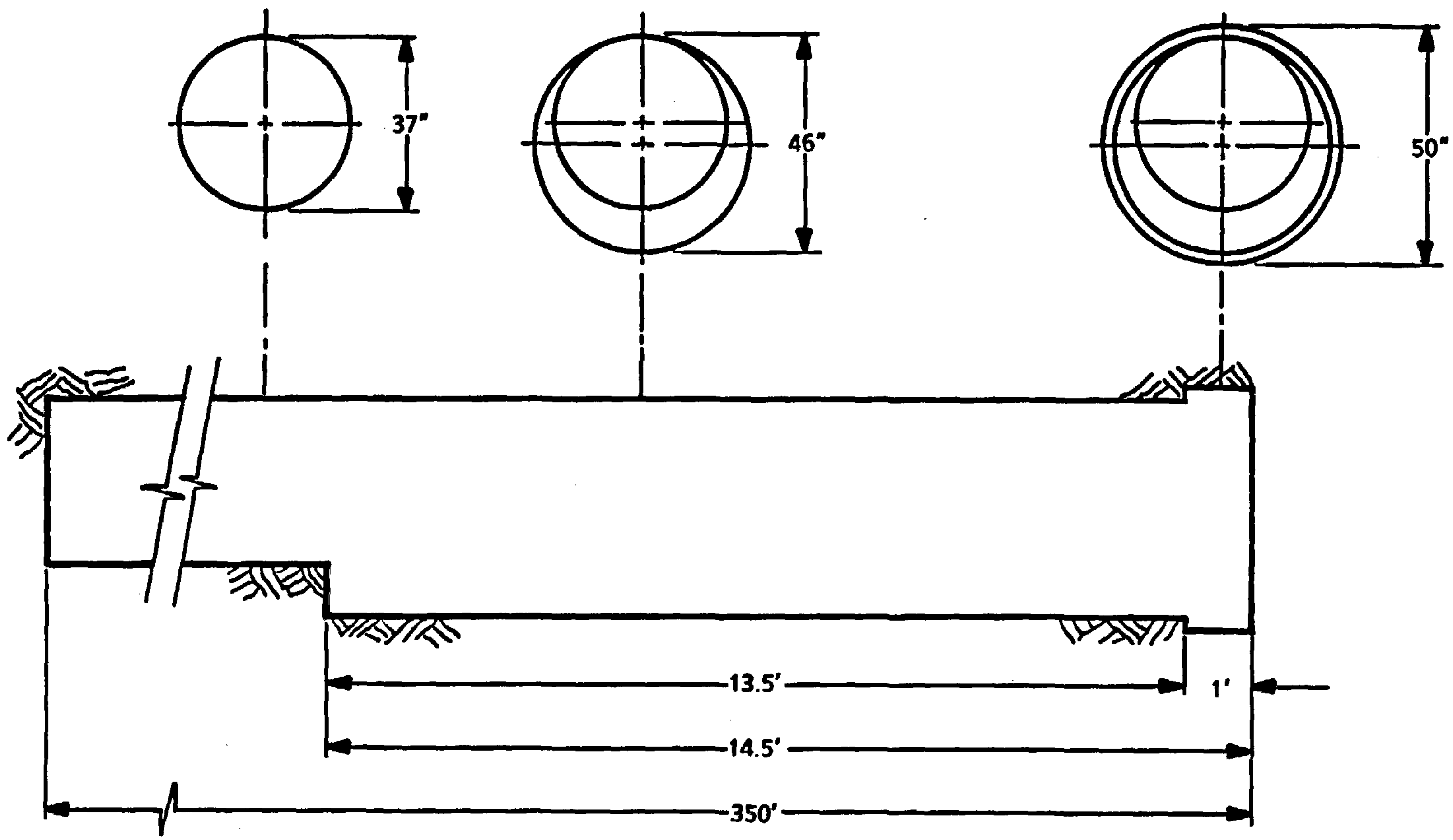


Figure D-15. Horizontal Emplacement Borehole Dimensions

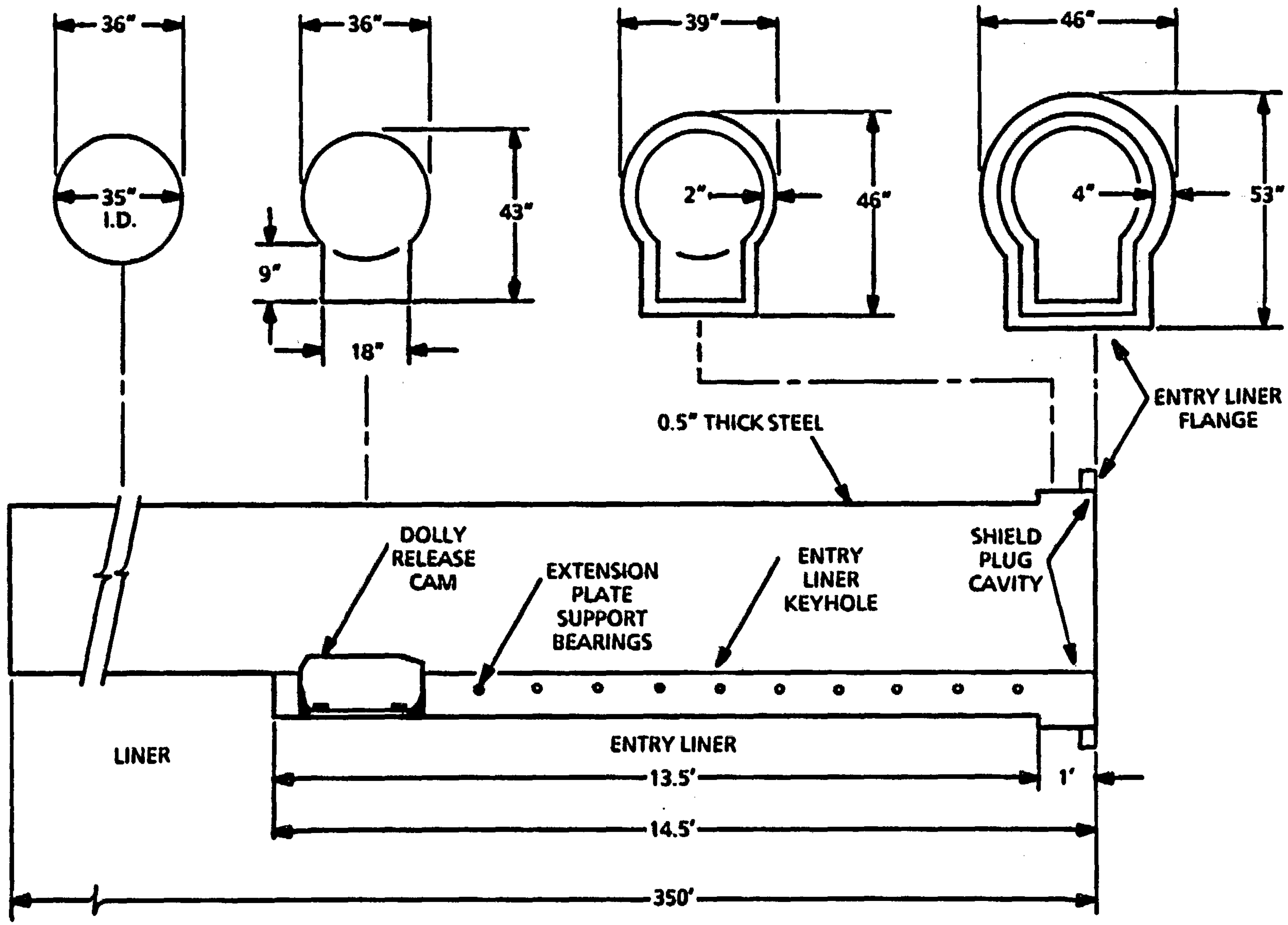
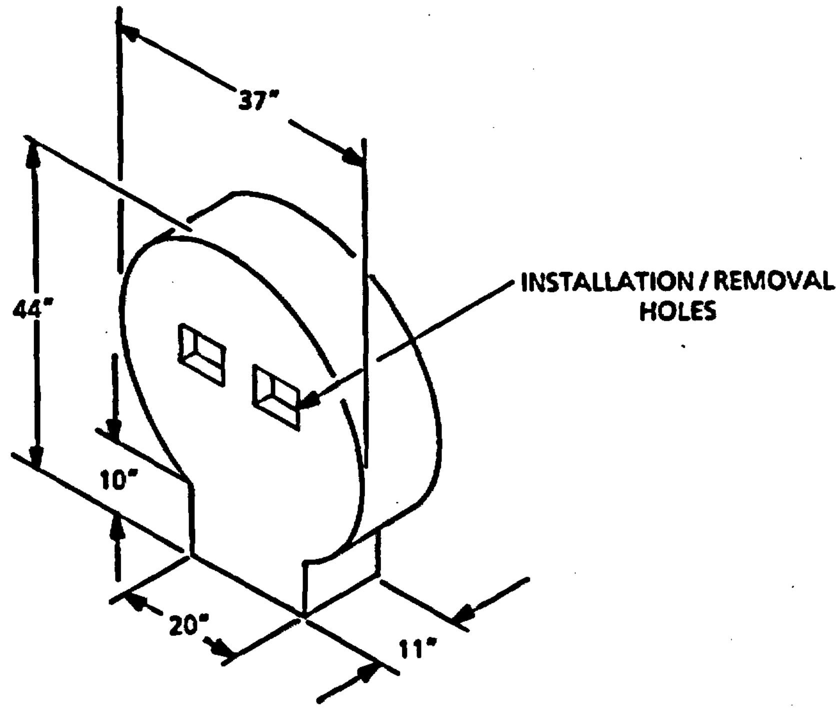


Figure D-16. Horizontal Borehole Liner and Entry Liner

SHIELD PLUG



BOREHOLE COVER

FRONT

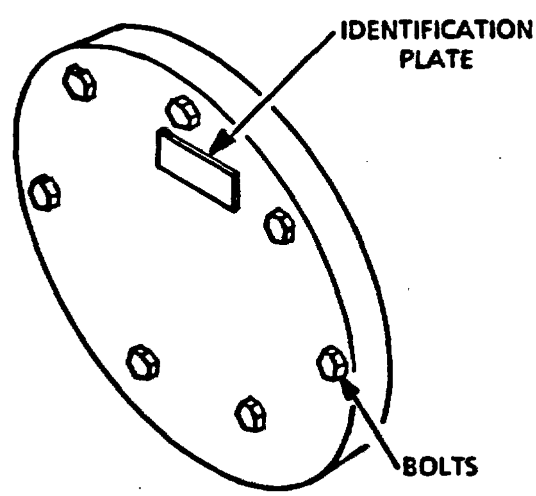


Figure D-17. Horizontal Borehole Shield Plug and Cover will accept both the cask pusher plate/hook and dolly hook. The hook and shackle allow a string of dollies to be attached together for retrieval from the horizontal borehole. The waste container and dolly are illustrated in Figure D-14.

4.2.2.2 Waste Container Transporter

The waste transporter, illustrated in Figure D-18, has five main parts: (1) the transporter cab, (2) the frame and running gear, (3) the hydraulic leveling and electrical rotation systems, (4) the transporter cask, and (5) the cask emplacement/retrieval mechanism. These parts are described below.

Transporter Cab

The cab will be partially sealed and the pressure inside the cab kept greater than the pressure outside the cab. The inlet air will be temperature-conditioned and filtered. The operator will be able to select one of two filtration modes: a normal dust removal mode or a high-efficiency mode in which inlet air is filtered through HEPA filters. The transporter cab will be shielded to reduce the radiation dose to the occupants. The small rear windows (facing the cask) will be made of leaded glass. The cab is designed to limit the operator dose to less than 1 rem/yr. (The allowable dose is 5 rem/yr.)

The transporter cab is designed to accommodate two occupants. The cab contains the driving controls and separate controls for emplacement functions.

Frame and Running Gear

The running gear (Figure D-18) is eight-wheeled with electric hub-mounted DC motors powered by two 150-kW diesel generators and mounted on a rigid frame. The transporter will use a steering system that will achieve a minimum turning radius of 25 ft.

Hydraulic Leveling and Electrical Rotation Systems

The transporter cask is mounted on a 5-ft-diameter thrust bearing, which is mounted on four hydraulic cylinders located between the transporter frame and the cask thrust bearing mountings. These cylinders will operate simultaneously or individually to level the transporter cask and to provide height, pitch, and roll adjustments. The forward two cylinders will be connected so that the load is shared by all cylinders.

Rotation of the cask (Figure D-19) from the parallel transport position to the perpendicular emplacement/retrieval position is achieved by turning the cask on the thrust bearing with the use of a geared electric motor. The rotation mechanism is designed to rotate the cask 90° in either direction, which allows emplacement or retrieval on both sides of the drift. Optical and electronic guidance systems will assist the operator in leveling and rotating the transporter cask.

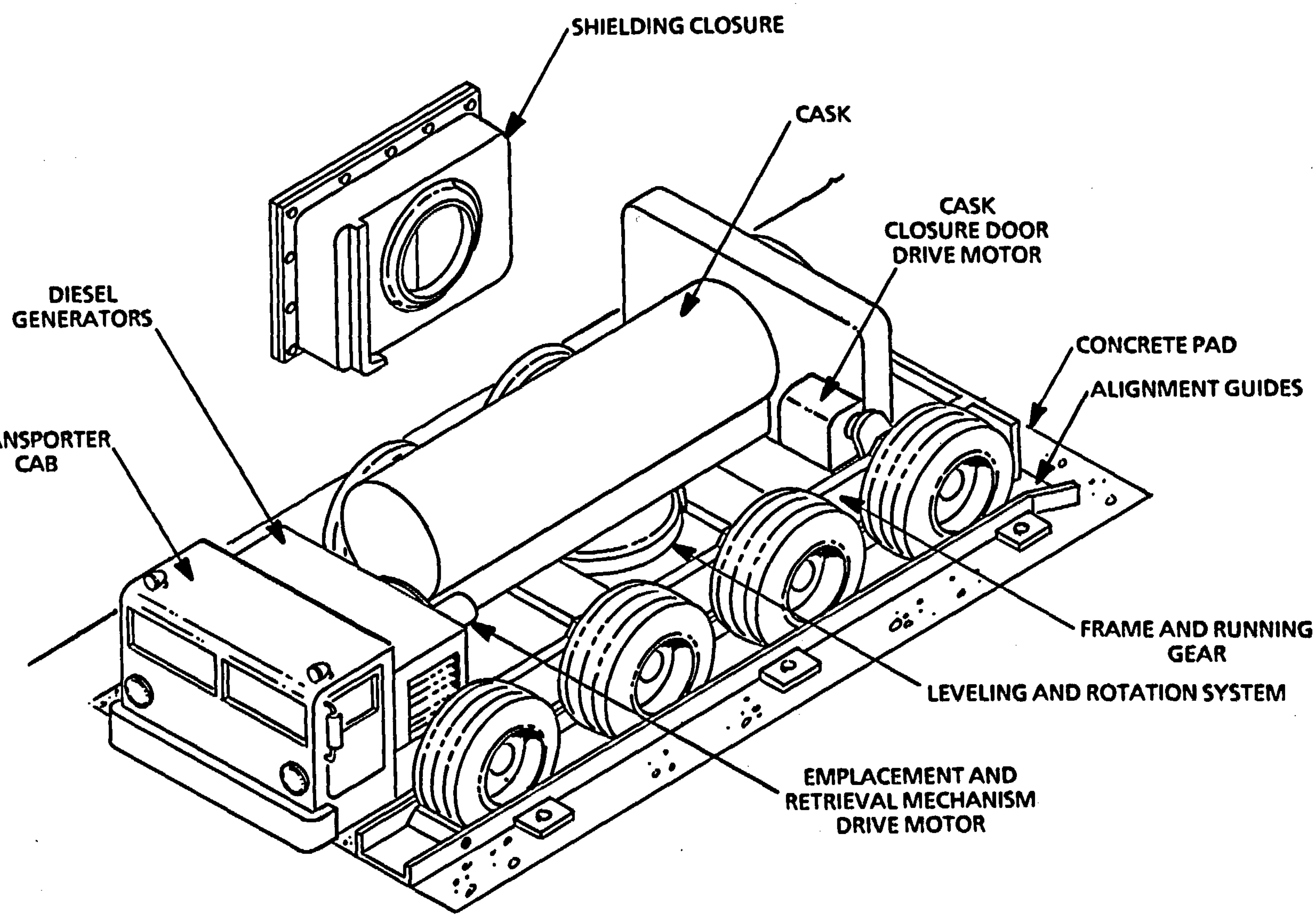


Figure D-18. Waste Container Transporter in Transport Mode (Horizontal Configuration)

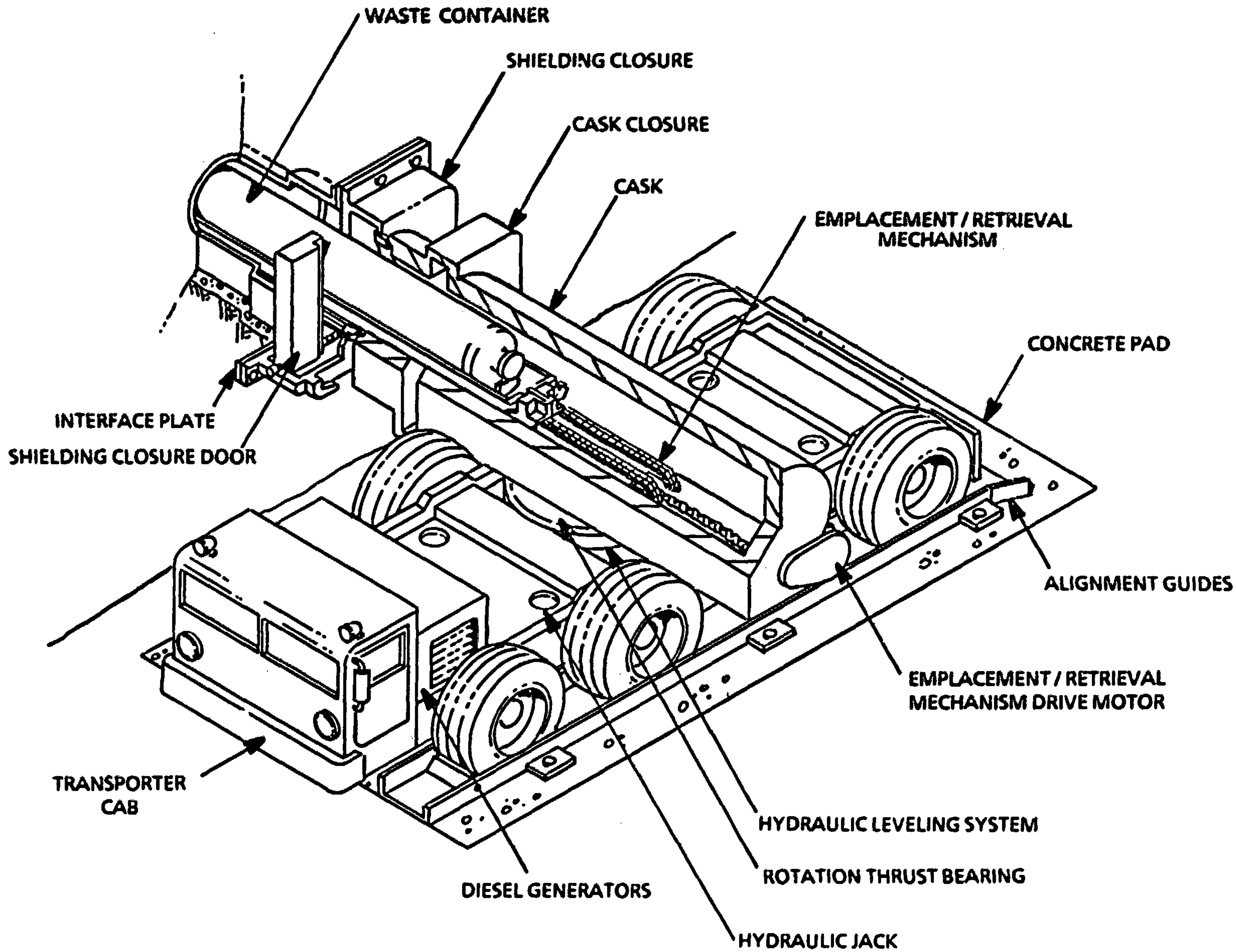


Figure D-19. Waste Container Transporter in Emplacement/Retrieval Mode (Horizontal Configuration)

Four hydraulic jacks, attached to the transporter frame, will be used to stabilize the transporter and compensate for weight redistribution during cask rotation and emplacement or retrieval.

Transporter Cask

The cask design and construction materials will limit the dose rate on the exterior surface of the cask to approximately 50 mrem/hr and to 10 mrem/hr at 2 m from the cask surface. The cask (Figure D-20) consists of a shell, shielding cylinder, and a shielding closure at the end of the shielding cylinder.

The cask closure housing will be designed so that shielding will be maintained with the closure door open or closed. Instrumentation will be provided to indicate the fully open and fully closed positions. These indicators will be displayed on an instrument panel in the transporter cab.

The cask closure consists of two opposing doors. The closure doors are driven by a motorized ballscrew and are controlled from the transporter cab. The high pitch of the ballscrew provides positive locking of the cask doors in both the open and closed positions.

Cask Emplacement/Retrieval Mechanism

The cask emplacement/retrieval mechanism, located inside the transporter cask, consists of an extension plate, a motorized ballscrew, roller chains, a pusher plate/hook, and associated cams. This mechanism is designed to develop a pushing or pulling force of 100,000 lb. The emplacement/retrieval mechanism is illustrated in Figures D-20 and D-21.

Extension Plate

The purpose of the extension plate is to transport the waste container and dolly into the emplacement borehole. The plate is supported in the cask by a series of support bearings and the entry liner or surface facility trough, when extended.

Ballscrew

The ballscrew (Figure D-22) is located inside the length of the extension plate and is driven by a 7-hp electric geared motor located outside the forward end of the cask. The ballscrew is supported at the forward end by the cask wall as it passes through to the drive motor and at the back by a rotation/translation bearing attached to the inside of the extension plate. As the ballscrew shaft turns, it can extend or retract the extension plate 14 ft.

Roller Chains

When the extension plate is extended or retracted, two heavy-duty roller chains (Figure D-20), supported at each end of the plate by idler sprockets, advance or retreat around the plate carrying the attached pusher plate/hook. The chains are attached at a single point to the bottom of the cask near the cask closure door.

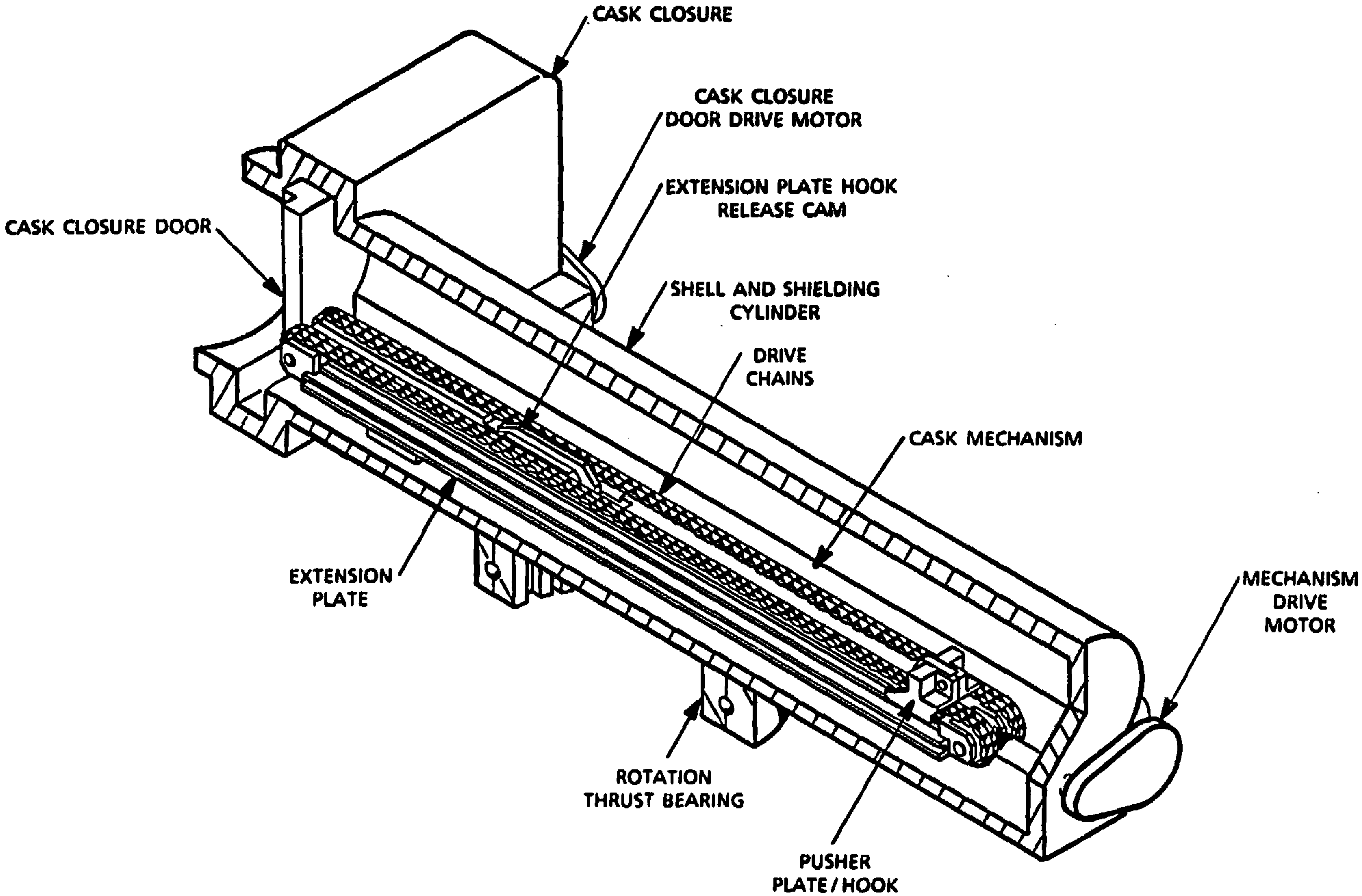


Figure D-20. Transporter Cask (Horizontal Configuration)

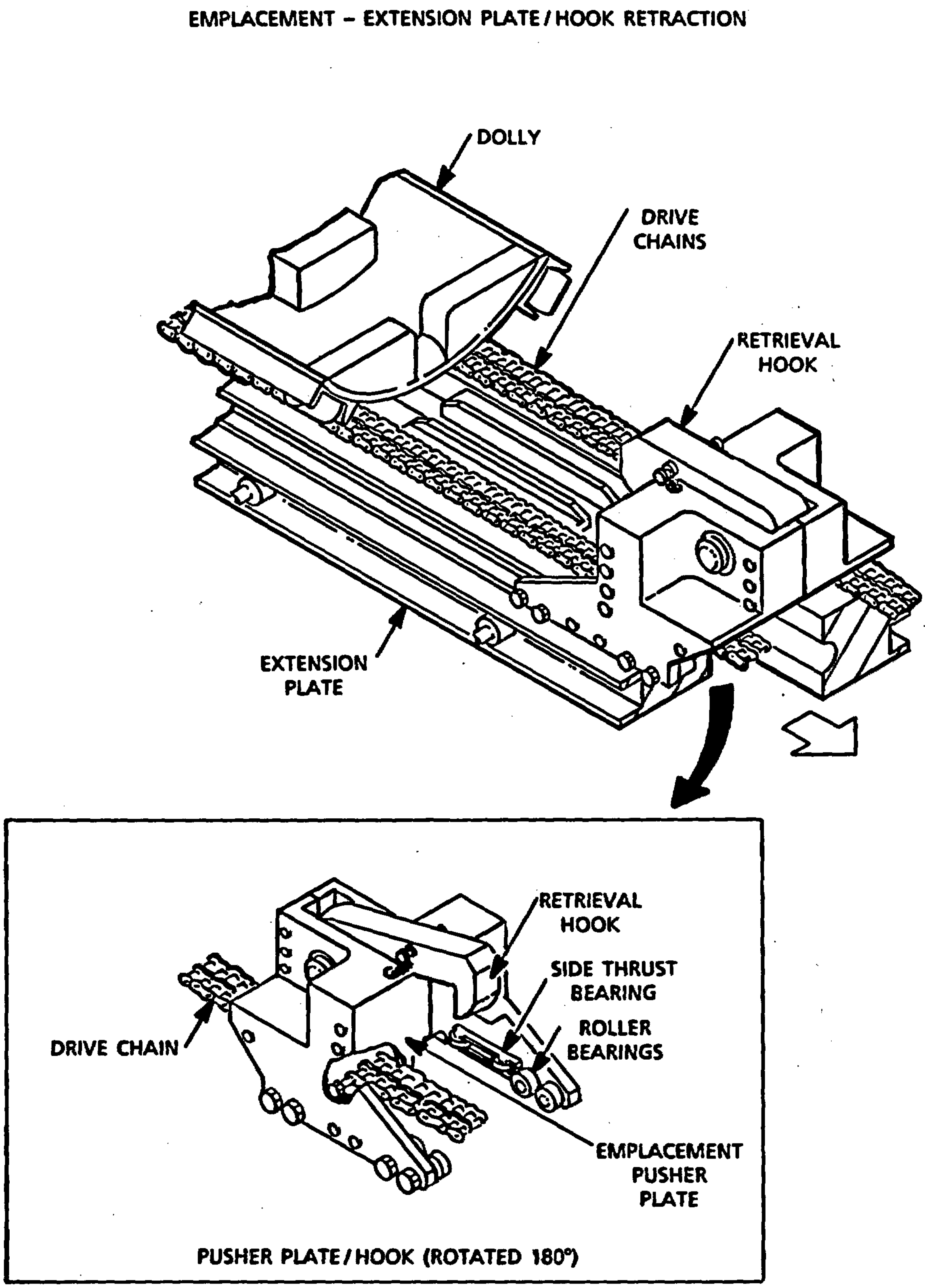
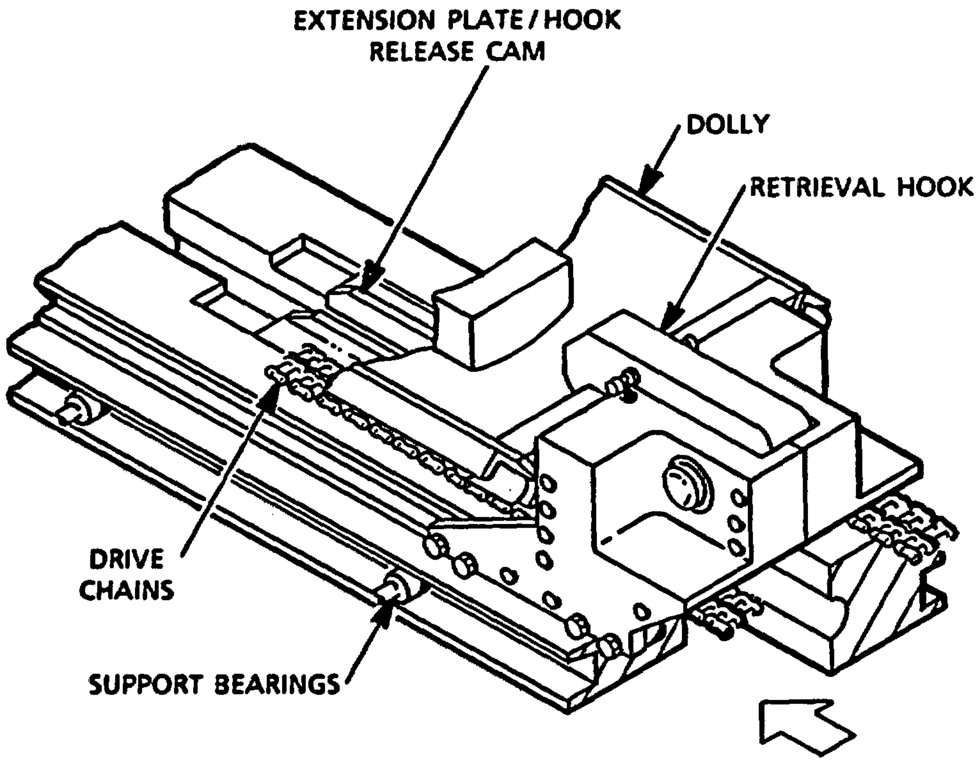
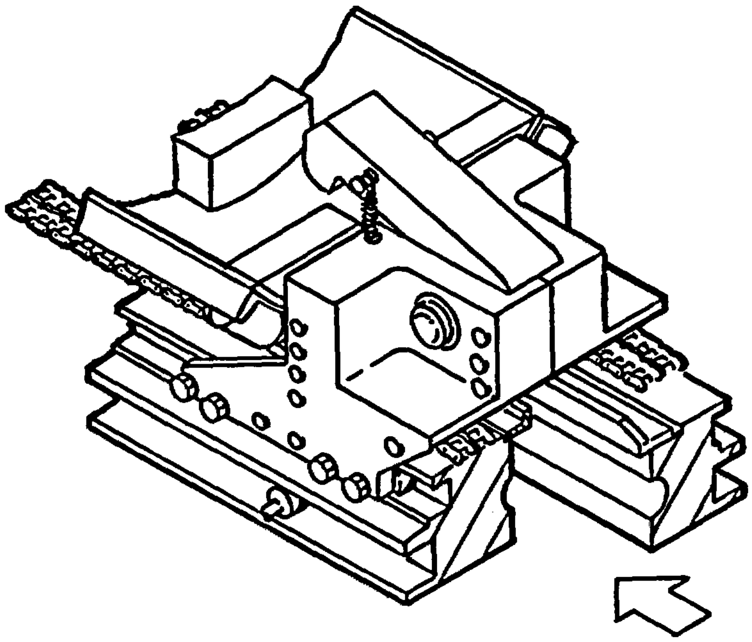


Figure D-21. Horizontal Emplacement/Retrieval Mechanism



EMPLACEMENT – APPROACHING RELEASE CAM



EMPLACEMENT – HOOK RAISED BY CAM

Figure D-21. Horizontal Emplacement/Retrieval Mechanism (concluded)

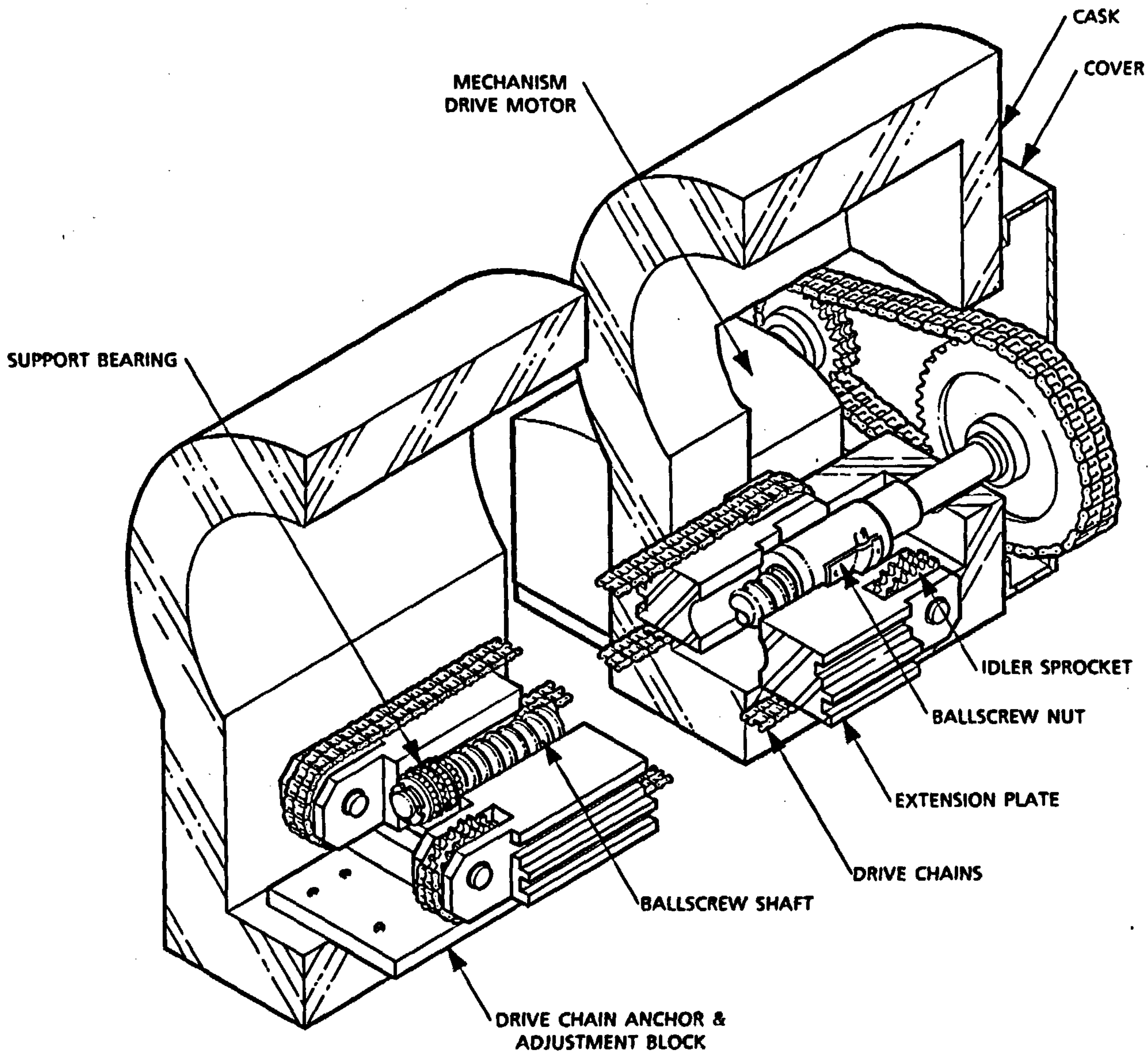


Figure D-22. Ballscrew Mechanism

Pusher Plate/Hook and Hook Release Cam

The pusher plate/hook (Figure D-21) is mounted, by roller bearings, on the top of the extension plate. The compound action of the extension plate movement and the pusher plate/hook attached to the roller chains provides a total travel distance of up to 28 ft for the waste container and dolly.

A spring-loaded hook with an extending release lobe is located on the front of the pusher plate. The front end of the hook and release lobe are tapered to effect a smooth attachment to or release from the dolly. During emplacement the hook release cam on the extension plate lifts the pusher plate/hook, releasing the dolly and waste package inside the borehole. During retrieval the hook release cam releases the dolly inside the surface facility port.

As each subsequent waste container is emplaced, it pushes the previously emplaced waste packages and dollies farther into the lined borehole. At the same time the dolly hook latches to the front of the previously emplaced dolly.

During retrieval, the hook release cam, located on the extension plate, is moved forward 1 ft. The pusher plate/hook is then extended to engage the dolly before it reaches the release cam. The ballscrew motor is then reversed, retracting the extension plate and pulling the attached dolly and waste container into the transporter cask.

Dolly Release Cam

As the first dolly is pulled into the cask during retrieval, the entire string of dollies in the borehole moves forward one dolly length. When the back of the first dolly, attached to the front of the second dolly, reaches the dolly release cam in the entry liner keyhole, their connecting hook rides over the cam and disconnects the two dollies (Figure D-23). The first dolly continues into the cask. The remaining dollies are now in position for retrieval.

At the surface facility the extension plate and pusher plate/hook are extended 14 ft each (28 ft total), which causes the hook lobe to engage the hook release cam on the extension plate and release the retrieved dolly and waste package.

4.2.2.3 Modified Forklift

The modified forklift (Figure D-24) is used to transport and install various items of equipment used for waste emplacement and retrieval. The modified forklift consists of a commercially available extending-boom forklift modified for use in the repository. The forklift will carry a 15-kW diesel electric auxiliary power supply. The dimensions of the modified forklift are given in Table D-4.

Forklift Cab

The forklift cab will be equipped with radiation shielding to minimize radiation exposure to the operator. The windows will be small

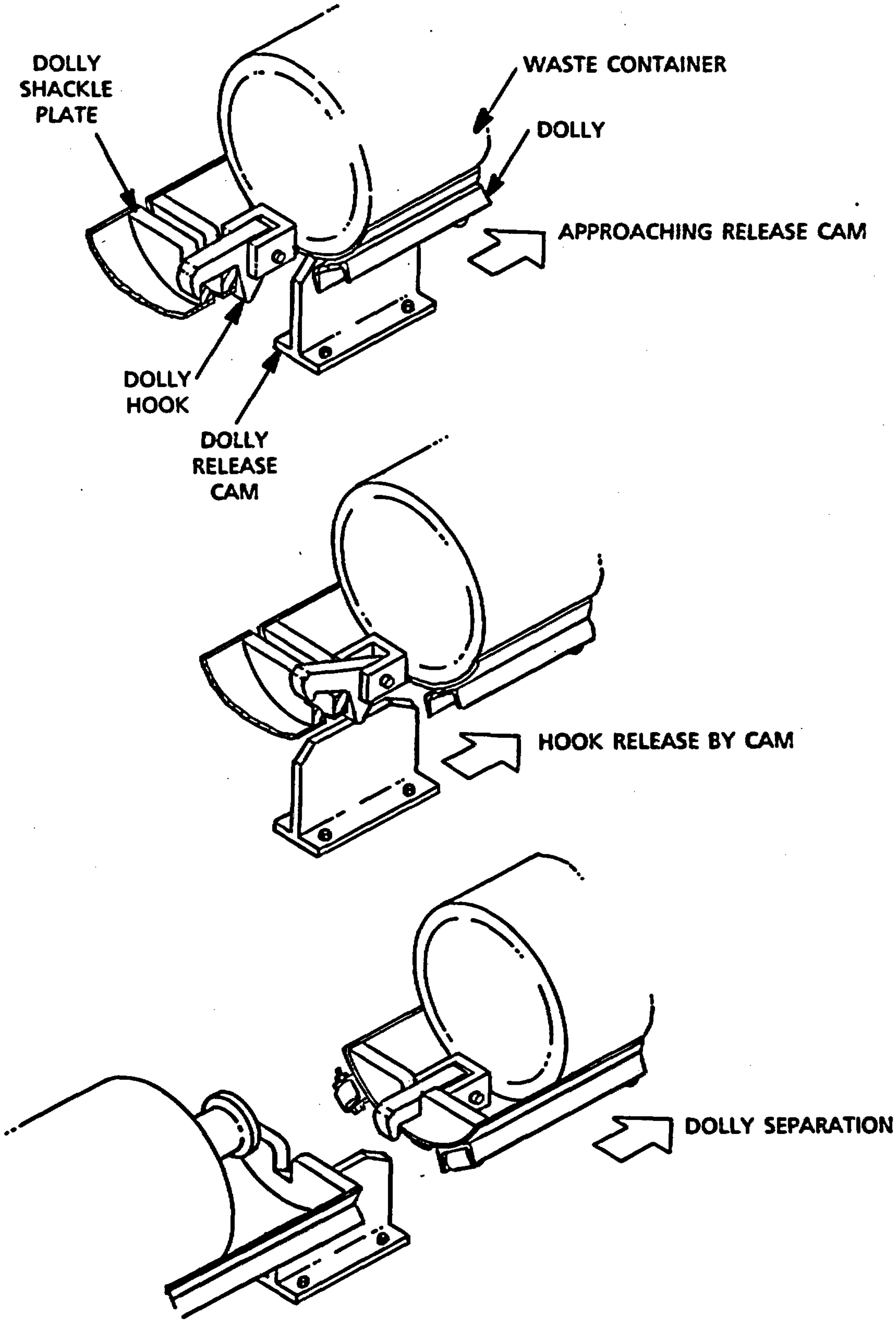


Figure D-23. Dolly Hook Release with Dolly Release Cam

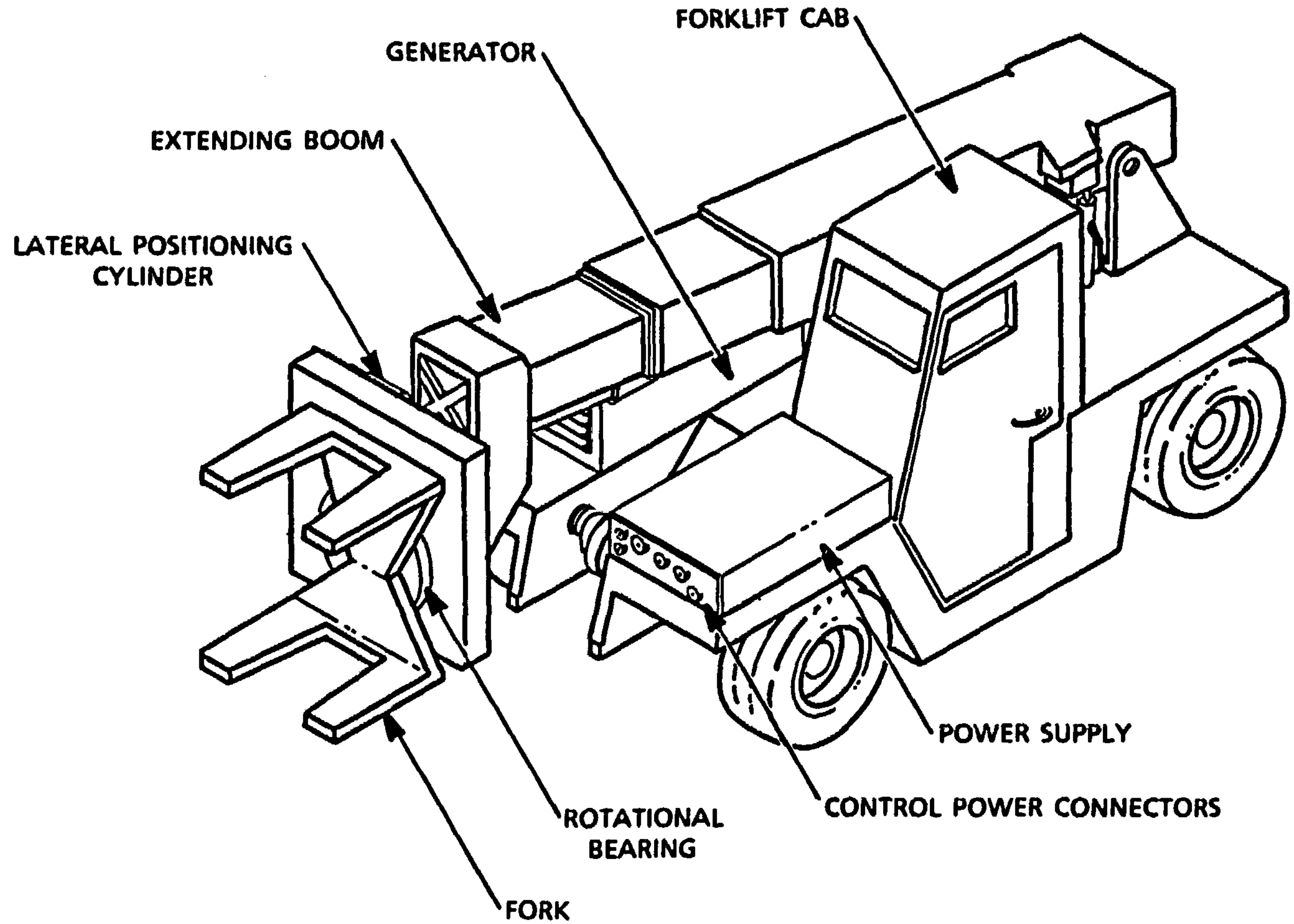


Figure D-24. Modified Forklift and Special Fork (Horizontal Configuration)

TABLE D-4

DIMENSIONS OF MODIFIED FORKLIFT (HORIZONTAL CONFIGURATION)

	Weight	Length	Width	Height
Boom Retracted (with ballast)	20,000 lb	19 ft	8 ft	8 ft
Boom Extended (with ballast)	20,000 lb	39 ft	8 ft	8 ft

and made with shielding glass. The cab will be partially sealed so that the interior environment can be controlled, and inside air pressure will be kept higher than outside air pressure. Air entering the cab will be filtered. The operator will be able to select either normal or HEPA filtration.

The cab of the special forklift will be equipped with a communications system enabling the operator to communicate with emplacement operations control personnel.

Running Gear

The forklift will be rear-wheel steered. Each wheel of this four-wheeled vehicle will be independently driven by the hydraulic motor.

Extending Boom

The load-handling boom will extend up to 20 ft from the retracted position. When the boom is extended 2 ft, the forklift will be able to pick up and haul 36,000 lb. With the boom extended 18 ft, the forklift will be able to lift and transport 9,000 lb.

Special Fork

The standard fork tines on the basic commercial vehicle must be replaced by a special fork (Figure D-24) that can be shifted laterally or rotated to align the temporary shield closure mechanism, shield plug installer/remover, and shield plate attachment.

4.2.2.4 Borehole Shielding Closure

The borehole shielding closure (Figure D-25) consists of a solid housing that encloses and supports the two opposing, sliding closure doors and a cylindrical shield collar, which extends outward to engage and shield the cask closure mechanism. The closure doors are electrically driven by a motorized ballscrew mechanism, which also extends the collar using an integral linkage system. Electrical

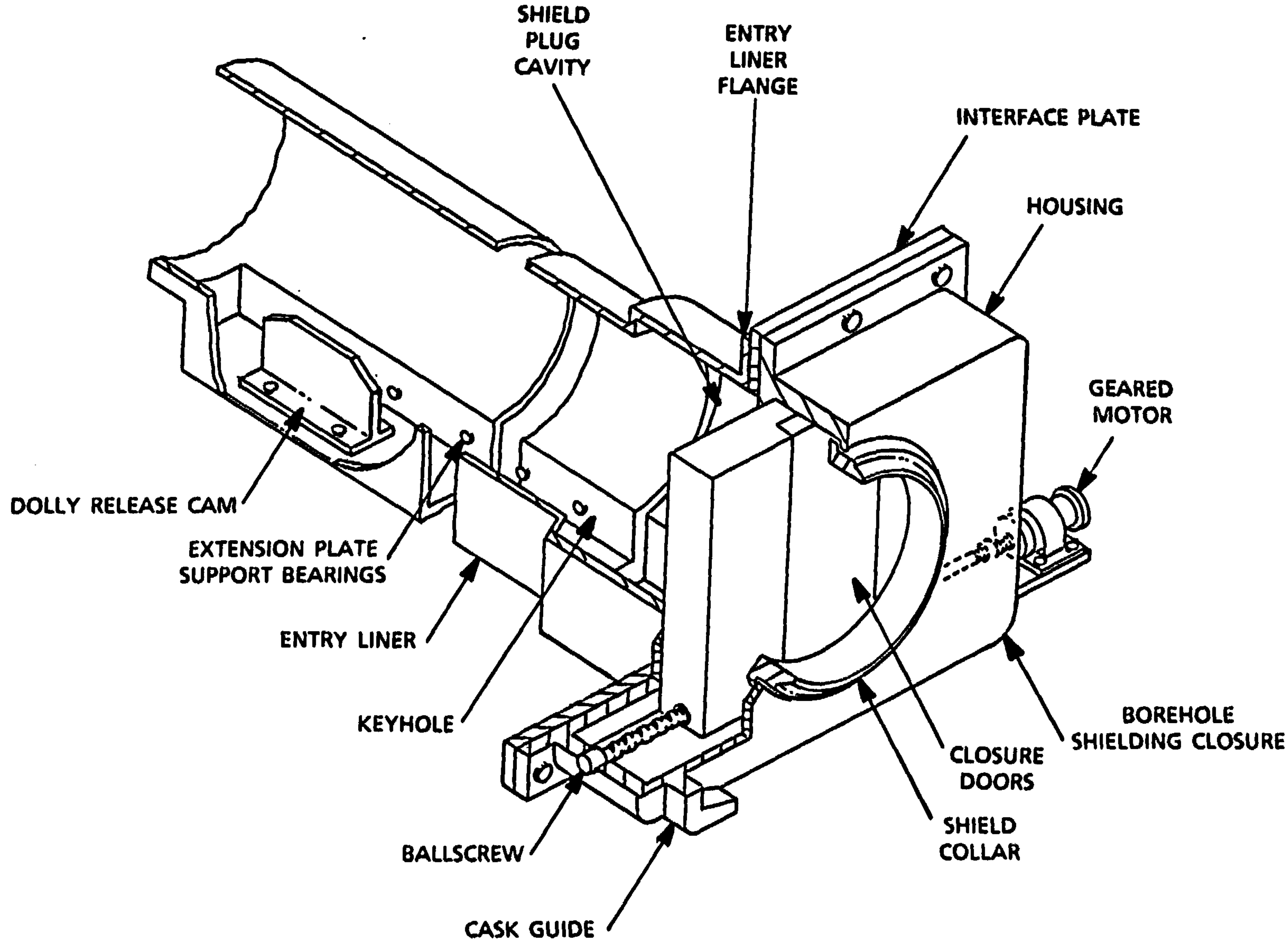


Figure D-25. Horizontal Borehole Shielding Closure connection is established when the transporter cask engages the cask guide on the front of the shield closure. This connection allows the closure to be operated from within the transporter cab. After waste container emplacement or retrieval, the door motor is reversed, the ballscrew closes the doors, and the lever action retracts the collar.

A manually operated mechanical backup is provided to open or close the shield closure if the electrical motor fails.

4.2.2.5 Shield Plug Installer/Remover

The shield plug installer/remover (Figure D-26) attaches to the special fork of the modified forklift and consists of three major elements: the housing, a pusher/remover plate, and a drive mechanism.

The plug installer/remover is equipped with forklift sockets that are compatible with the special fork. It is designed to connect to the borehole shielding closure. The connection includes mating of the control connector on the shield closure so that the shield closure can be controlled from the cab of the forklift. The shield plug installer/remover consists of the following parts.

Housing

The housing that surrounds the shield plug will be compatible with the borehole shielding closure and extension collar and will provide shielding during installation and removal.

Pusher/Remover Plate

The pusher/remover plate pushes the seal plug into the entry liner through the shield closure.

Drive Mechanism

The drive mechanism for the plug installer/remover is a hydraulic system.

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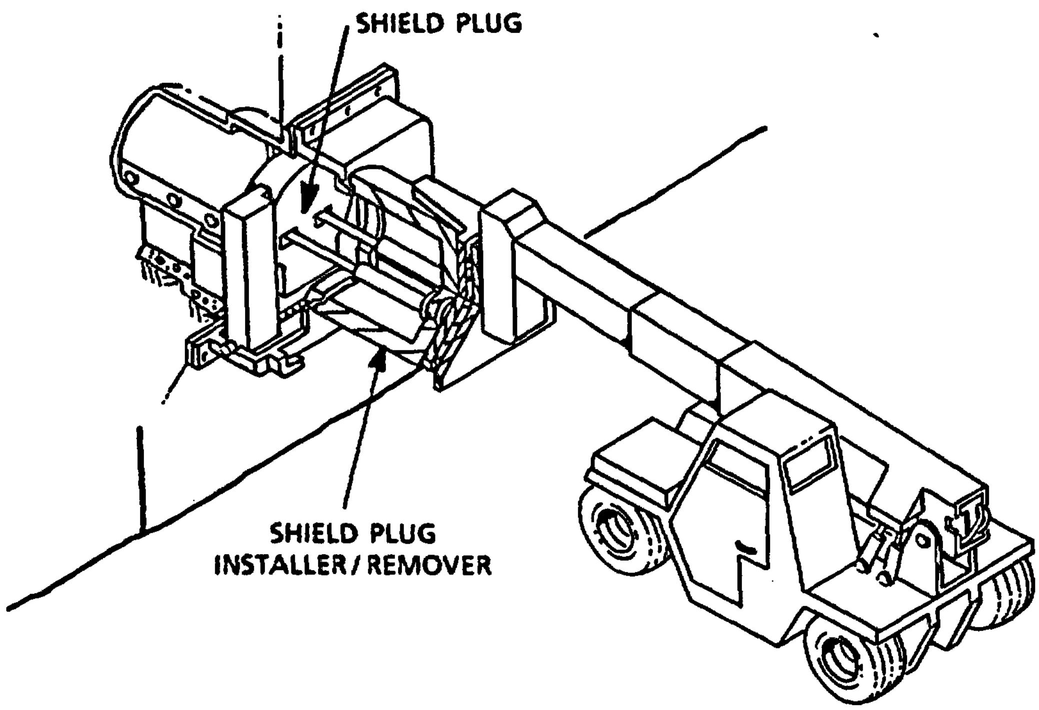

Figure D-26. Shield Plug Installer/Remover (Horizontal Configuration)

5.0 WASTE RETRIEVAL EQUIPMENT

5.1 Description of Equipment for Normal Retrieval Operations

The waste emplacement hardware described in Section 4 of this appendix will be designed so that it can also be used for retrieval operations. This will enable more rapid and lower-cost reconfiguration of the underground waste handling facilities from emplacement to retrieval mode, should retrieval be mandated. Because of site characteristics and repository design, normal retrieval operations are expected to be not much different from emplacement conditions. Existing differences will be accommodated during further development of the present designs. For example, the emplacement hardware will be designed to operate normally at the elevated borehole temperatures (>200°C) expected during retrieval. Also, the emplacement hardware will be designed to operate in a reverse mode and to have the capability of pulling the higher loads that may be required for normal waste removal.

5.1.1 Vertical Configuration

Equipment used for preparing vertical boreholes for retrieval, removing waste containers, and transporting and delivering containers to the surface facility under normal conditions is the same as that used in the vertical emplacement operations. This equipment is described in Section 4.1.1 of this appendix.

5.1.2 Horizontal Configuration

Two concepts are under consideration for waste removal operations with the horizontal configuration under normal conditions. The baseline design employs coupled dollies, where the cask mechanism is used to remove each waste container and dolly from a standard removal position in the borehole, while pulling the next container and dolly into position. The alternative design employs uncoupled dollies and a retrieval cart, where the cart is used to pull each waste container and dolly from its storage position to a standard removal position for subsequent removal with the cask mechanism.

5.1.2.1 Baseline Design for Waste Removal Equipment

With the baseline waste removal system design, equipment used for preparing horizontal boreholes for retrieval, removing waste containers, and transporting and delivering containers to the surface facility under normal conditions is the same as that used in the horizontal emplacement operations described in Section 4.1.2 of this appendix.

5.1.2.2 Retrieval Cart System for Alternative Waste Removal Concept

The concept for pulling waste containers to a standard removal position with a retrieval cart for subsequent removal with the cask emplacement/retrieval mechanism is still in the design concept stage. Detailed design work on the required equipment has not been completed, but descriptions of the general design concepts and considerations are available and are presented in CDR Appendix J.

5.2 Description of Equipment for Off-Normal Retrieval Conditions

Concepts for retrieving waste under off-normal conditions in both the vertical and horizontal configurations are presented in CDR Appendix J. These concepts are still in conceptual design. Detailed design work on the required equipment has not been completed, but descriptions of the general design concepts and considerations are available and are presented in CDR Appendix J.

6.0 UNDERGROUND EQUIPMENT DEVELOPMENT PROGRAM

Before license application for the repository, a complete emplacement/retrieval system must be designed and proof-of-principle demonstrations completed. After license application, construction and testing of prototype equipment may be necessary to answer any remaining questions regarding the performance of the emplacement/retrieval system under actual repository conditions. Production equipment will be built after construction is authorized, before initiation of repository waste emplacement operations.

6.1 Design of Emplacement and Retrieval System

Before a complete emplacement/retrieval system can be designed, the waste emplacement orientation (vertical or horizontal) must be selected. Information necessary to make the selection will come from two areas of underground waste handling equipment development work.

- Emplacement Equipment--An advanced conceptual design will be completed for the vertical and horizontal emplacement systems. Design alternatives will be evaluated to determine their feasibility and advisability. Key components of the selected alternatives will be designed in detail and, if necessary to prove feasibility, will be subjected to rigorous functional tests that include intentional overloading and cycling to ascertain durability. These key components may include items such as the turntable alignment system and the cask mechanism for waste insertion into the borehole.

- Retrieval Equipment--Conceptual design studies will be conducted on the various concepts presented in this report for retrieving waste from vertical and horizontal boreholes under normal and off-normal conditions. The design studies will identify design considerations that need further investigation, determine the extent to which reasonably available technology can be used in the designs, and identify key components that must be tested to prove feasibility. Further analysis of off-normal conditions will be conducted to more accurately identify conditions that could credibly occur and affect retrieval operations. Key retrieval equipment required for normal and credible off-normal conditions will be designed in detail and tested, as necessary, to prove feasibility. These key components may include items such as the retrieval cart drive train and the dolly uncoupling mechanism.

After the emplacement orientation is decided, development work will concentrate on equipment and operations needed for the selected emplacement orientation and credible off-normal retrieval conditions. Detailed design of the equipment will be completed, and key equipment systems will be fabricated for proof-of-principle demonstrations. In addition to detailed equipment layout, the emplacement/retrieval system design will also address the following items:

- the sequence of emplacement operations, with remedial operations for equipment malfunction or failure,
- the sequence of retrieval operations under normal and off-normal conditions,
- anticipated time to emplace and retrieve individual waste containers,
- potential exposure hazards to personnel, and
- excavation techniques for dealing with off-normal retrieval conditions.

6.2 Proof-of-Principle Demonstrations

Proof-of-principle demonstrations for equipment systems and operations that have a significant degree of performance uncertainty must be conducted and documented before license application is made to the NRC. These demonstrations must provide evidence, with reasonable assurance, that the planned emplacement/retrieval method will function under both normal and credible off-normal conditions (DOE, 1986a, Appendix D).

The demonstrations will take place in one or more facilities that simulate those aspects of the emplacement and retrieval environments that could potentially affect the operation of the equipment. The facilities will not be required to completely fabricate the repository environment, but rather to simulate specific normal and off-normal conditions that are relevant to the repository and equipment designs. Surface and underground mockups of the emplacement borehole will be used for this purpose. The use of radioactive materials or radiation safety equipment is not required in these demonstrations.

The equipment models used to conduct these demonstrations will be complete in all details that affect the ability of the equipment to fulfill its designed function. More design work and analysis are necessary to determine which components and systems require proof-of-principle demonstration. A decision on the demonstrations that will be conducted will be made at the time of the emplacement orientation selection. At this time, the most likely equipment candidates for emplacement and retrieval demonstrations under normal conditions are the following.

Vertical

- cask alignment and rotation mechanism
- cask closure doors
- borehole shielding closure
- waste container hoisting system
- waste container grapple
- shield plug installer

Horizontal

- cask alignment and rotation mechanism
- cask closure doors
- borehole shielding closure
- cask mechanism
- retrieval cart
- coupled and uncoupled dolly train
- shield plug installer
- horizontal borehole drilling and lining machine

Some equipment used in the emplacement/retrieval system will not require proof-of-principle demonstrations because similar equipment is commercially available and used in similar underground environments. Examples include the transporter drive and ventilation systems and the special forklift.

Evaluation of the probability of events will effect proof-of-principle demonstrations conducted for off-normal conditions. Systems developed for credible off-normal conditions will be tested under simulated conditions. For example, if it is determined that binding of a waste container in a borehole is a credible off-normal condition, then systems selected and designed for removing such containers will be tested under conditions that simulate a bound waste container. The emplacement/retrieval system will also be tested to demonstrate the ability to recover from equipment malfunction and failure.

6.3 Prototype Equipment Development

After completion of the proof-of-principle tests and submission of the license application to the NRC, unanswered questions concerning the performance of equipment under actual repository conditions may remain. In this case, it will be necessary to construct and test prototype equipment to resolve those questions (DOE, 1986a, Appendix D).

Prototype equipment demonstrations will simulate geotechnical conditions, stresses, and opening geometries that may reasonably be expected at the repository location at the time of retrieval. This will probably require the use of an existing underground installation, such as G-Tunnel at the Nevada Test Site or the Exploratory Shaft Facility at Yucca Mountain.

The waste container(s) used in the prototype equipment demonstration will be of the same size and weight as actual containers to be used in the repository. Any potential change in the shape, orientation, or other physical condition of the container that may affect operations will be simulated as necessary during these demonstrations. Although the use of radioactive material is not required in these demonstrations, prototype equipment will incorporate radiation safety equipment, as necessary, to test the mechanical systems.

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REFERENCES FOR APPENDIX D

DOE (U.S. Department of Energy), "Generic Requirements for a Mined Geologic Disposal System," DOE/RW-0090, Office of Civilian Radioactive Waste Management, Washington, D.C., June 1986a.

DOE (U.S. Department of Energy), "Environment, Safety, and Health Program for Department of Energy Operations," Order 5480.1B, Washington, D.C., September 1986b.

The Robbins Co., "Final Report--Repository Drilled Hole Methods Study," SAND83-7085, Sandia National Laboratories, Albuquerque, NM, July 1984.

The Robbins Co., "Design of a Machine to Bore and Line a Long Horizontal Hole in Tuff," SAND86-7004, Sandia National Laboratories, Albuquerque, NM, in preparation.

Stinebaugh, R. E., and J. C. Frostenson, "Disposal of Radioactive Waste Packages in Vertical Boreholes--A Description of the Operations and Equipment for Emplacement and Retrieval," SAND84-1010, Sandia National Laboratories, Albuquerque, NM, March 1987.

Stinebaugh, R. E., I. B. White, and J. C. Frostenson, "Disposal of Radioactive Waste Packages in Horizontal Boreholes--A Description of the Operations and Equipment for Emplacement and Retrieval," SAND84-2640, Sandia National Laboratories, Albuquerque, NM, March 1987.

Townes, G. A., W. L. Godfrey, and K. J. Anderson, "Nevada Nuclear Waste Storage Investigations Project: Spent-Fuel Consolidation System," SAND84-7130, prepared by BE, Inc., under subcontract to GA Technologies, Inc., for Sandia National Laboratories, Albuquerque, NM, in preparation (a).

Townes, G. A., W. L. Godfrey, K. J. Anderson, "Nevada Nuclear Waste Storage Investigations Project: Conceptual Design of Facilities for Unloading Radioactive-Waste from Shipping Casks," SAND85-7102, prepared by BE, Inc., under subcontract to GA Technologies, Inc., for Sandia National Laboratories, Albuquerque, NM, in preparation (b).

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APPENDIX E

AN ASSESSMENT OF THE FEASIBILITY OF DISPOSING OF NUCLEAR WASTE IN A HORIZONTAL CONFIGURATION

SLTR86-4001

February 1987
Rev. 2

AN ASSESSMENT OF THE FEASIBILITY OF DISPOSING OF NUCLEAR WASTE IN A HORIZONTAL CONFIGURATION

D. A. Glowka and R. E. Stinebaugh

Geotechnical Design Division
Sandia National Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

Vertical and horizontal orientations are currently being considered for disposal of high-level nuclear waste at the proposed Yucca Mountain repository. This report summarizes the emplacement configurations under consideration and compares the performance and cost parameters associated with each. Concepts for vertical and horizontal emplacement equipment appear to be technically feasible, and no significant differences in repository performance have been identified. Significant cost savings are predicted for the horizontal orientation. The feasibility of developing the more complex equipment required for horizontal emplacement is assessed by presenting and discussing current design concepts for that equipment. It is concluded that horizontal emplacement equipment appears feasible but that further work is required to prove feasibility. A proposed equipment development program that addresses the needed future work is outlined.

SLTR 86-4001 August, 1986

An Assessment of the Feasibility of Disposing of Nuclear Waste in a Horizontal Configuration

D. A. Glowka and R. E. Stinebaugh

Peer Reviewers:

R. J. Flores, 6314 — Date 9/2/86

K. D. Young, 6314 — Date 9/2/87 9/2/86

Approved:

J. R. Tillerson, 6314 — Date 9/2/86

NOTICE

QA checks on data contained here have only been performed to determine that these data have been obtained and documented properly. Information is preliminary and subject to change as further analyses are performed or as an enlarged and perhaps more representative data base is accumulated. These data and interpretations should be used accordingly.

E-

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1.0 EXECUTIVE SUMMARY

Horizontal and vertical emplacement orientations are being considered for the storage of high-level nuclear waste in the proposed repository at Yucca Mountain, Nevada. Studies are being performed under the Nevada Nuclear Waste Storage Investigations Project to identify issues and develop data that are needed to select an emplacement configuration for the repository.

A pertinent issue at the current stage of repository development is whether or not it is feasible to develop the equipment facilities and operating procedures necessary for horizontal emplacement. Previous experience with vertical emplacement has been obtained at Project Salt Vault in Lyons, Kansas, and the Climax facility at the Nevada Test Site. Vertical and horizontal emplacement procedures are sufficiently different, however, that the results for underground applications have only limited applicability to the issue of horizontal emplacement feasibility.

This report addresses the issue of horizontal emplacement feasibility and outlines further work required to firmly establish feasibility. In addition, this report compares the attributes of the vertical and horizontal emplacement configurations in order to demonstrate the advantages of the horizontal configuration and to establish the rationale for further investigation of that configuration.

To provide a basis for comparing the vertical and horizontal configurations, design concepts for the emplacement and retrieval systems are described for both configurations. In the vertical configuration, one waste container is emplaced in each vertical borehole drilled into the floor of the emplacement drifts. In the horizontal configuration, 15 waste containers are emplaced in each horizontal borehole drilled into the walls of the emplacement drifts.

Emplacement in both configurations involves transporting a single waste container from the surface facility to an underground emplacement borehole, placing the container in the borehole through a shielded closure, and repeating the process until all waste containers have been emplaced. Concepts for equipment and procedures to perform this function are presented. For the vertical configuration, the equipment includes:

- a waste transport vehicle
- a shielded cask for transporting the waste container underground
- a cask rotation and alignment system for mating the cask with the borehole shielding closure
- a waste container hoist system for lowering the waste container into and lifting the container out of the borehole

For the horizontal configuration, the equipment includes:

- a waste transport vehicle
- a shielded cask for transporting the waste container underground
- a dolly to carry each waste container as it is transferred from the surface storage vault to the cask to the borehole

- a cask rotation and alignment system for mating the cask with the borehole shielding closure
- an emplacement/retrieval system for pushing the waste container into and pulling the container out of the borehole

If required, retrieval of emplaced waste under normal conditions would employ the same equipment as emplacement and would generally employ the reverse procedure. If off-normal conditions are encountered during retrieval, special procedures or equipment would be required to remove the waste. Discussion is provided on the identification of off-normal conditions that could impact the ability to retrieve waste or significantly delay retrieval. Although further evaluation is necessary to determine the credibility of the off-normal conditions that have been identified, procedures and equipment necessary to remove waste under those conditions have been developed and are presented. These include procedures and equipment for removing waste under conditions that result from:

- failure or malfunction of retrieval equipment
- binding of the shield plug in the emplacement borehole
- loss of the pintle on a waste container in a vertical borehole
- breakage of a coupling between waste containers in a horizontal borehole
- collapse or deformation of a borehole, resulting in a blocked waste container
- collapse or deformation of a borehole, resulting in a bound waste container

The procedures and equipment used for each of these conditions would depend on the emplacement configuration and the severity of the condition.

Based upon the repository design for the vertical and horizontal configurations, several significant advantages are identified for the horizontal configuration. These include:

- The containment and isolation environment would be disturbed less because the volume of material mined during repository development would be reduced by approximately 60%.

- The overall extraction ratio for the underground development would be reduced from 18.3% to 7.1%.

- The temperature increase in the emplacement drifts would be delayed and reduced in magnitude. This would result in a better environment for emplacement drift inspection and maintenance and, consequently, a better environment for retrieval.

- The underground ventilation system would be greatly simplified as a result of the reduction in the number of mined drifts.

- The surface mined material disposal pile would be reduced in volume by a factor of three.

- The number of workers involved in underground development and waste emplacement operations would be reduced, resulting in two major benefits: (1) the number of workers exposed to the hazards of the mining operation would be reduced; and (2) the integrated radiation dose to the waste emplacement personnel would be reduced.

- A reduction in repository cost of approximately $1 billion would be realized.

The only potentially significant disadvantage of the horizontal configuration identified to date is that a larger development effort would be required to demonstrate proof-of-principle for the required emplacement and retrieval equipment. Before any significant development effort can be undertaken for either configuration, however, it is necessary to determine the feasibility of horizontal emplacement in order to provide information necessary to select the emplacement configuration. Further work is required to rigorously evaluate horizontal emplacement feasibility, but the preliminary assessment performed in this report indicates that it is feasible.

The feasibility of horizontal emplacement is assessed with a combination of calculations, engineering analysis, and comparison of equipment and conditions with those of existing working systems. Feasibility considerations addressed include:

Equipment Feasibility

The feasibility of horizontal emplacement/retrieval equipment for normal and off-normal conditions is assessed by comparing equipment concepts and design requirements with those of known, existing systems. It is concluded that there are enough similarities between the emplacement/retrieval (E/R) equipment and existing systems that the E/R equipment can be developed using reasonably available technology. Special design considerations must be taken into account in order to adapt existing technology to this application, but no significant feasibility concerns are apparent.

Long-Term Access to the Emplacement Boreholes

It is concluded that underground drifts in the horizontal configuration will be stable over the retrievability period, thereby ensuring that access to the boreholes for retrieval operations will be maintained. This conclusion is based on analyses that predict rock stresses up to 100 years after emplacement, as well as comparison with experience obtained over many years with openings in similar rock formations.

Long-Term Stability of Emplacement Boreholes

Preliminary analysis indicates that by using steel liner in the horizontal boreholes, long-term stability will be assured. Stresses in the liner due to rock fall, thermal expansion, and corrosion will remain below the strength of the liner over the retrievability period if the liner and borehole are properly designed.

Emplacement Dynamics

The dynamics of emplacing a number of waste containers in each horizontal borehole requires further analysis to quantify the potential for adverse consequences such as buckling and corkscrewing of the waste container dolly train. Preliminary analysis indicates that these problems will not be severe but in any case can be minimized by incorporating a rail or channel in the liner design to guide the dolly train in the boreholes.

Synergistic Effects

The impact of synergistic effects on the ability to emplace and retrieve waste in the horizontal configuration is assessed by examining several combinations of conditions and discussing the anticipated system response. The conditions considered include:

- a partially filled borehole
- a partially filled borehole, combined with elevated temperatures, a high radiation field, and earthquake- or underground nuclear explosion-induced ground motion
- an earthquake occurring during emplacement operations
- water intrusion into a filled borehole

It is concluded that these conditions do not present significant problems for horizontal emplacement in that they can be readily included in the design basis or do not result in a significantly different emplacement environment from that anticipated under normal conditions.

As a result of the work presented in this report, it is concluded that horizontal emplacement offers significant advantages over vertical emplacement and that the concepts that have been developed for horizontal emplacement appear feasible. Although there is not sufficient information to allow an emplacement orientation decision to be made at this time, there is sufficient justification to warrant further investigation of the horizontal configuration.

2.0 COMPARISON OF HORIZONTAL AND VERTICAL WASTE EMPLACEMENT

Section 2.1 describes the emplacement designs that are used for comparing vertical and horizontal emplacement. This section includes as part of this comparison a pictorial description of the operational sequences required to emplace and retrieve waste containers for each of the emplacement orientation options. Section 2.2 summarizes the benefits that can be obtained if the feasibility of horizontal emplacement can be verified so that it can be adopted in lieu of the vertical emplacement base case. These advantages are grouped into two categories: technical advantages described in Section 2.2.1 and cost advantages described in Section 2.2.2. Section 2.3 itemizes some potential disadvantages associated with horizontal emplacement. The specific equipment concepts developed for horizontal emplacement are presented in Section 3 as part of the discussion of feasibility.

2.1 Description of Waste Emplacement Options

In this subsection, the waste emplacement options are described for both the emplacement and retrieval modes of operation.

2.1.1 Emplacement Mode

2.1.1.1 Vertical Configuration

In the vertical waste emplacement configuration, waste containers are emplaced in 25-foot deep boreholes drilled into the emplacement drift floor. Due to the limited thickness of the candidate repository horizon, only one waste package is placed in each emplacement borehole. Figure 1 shows a cross-section of the emplacement drift and emplacement borehole for vertical emplacement. The current design for vertical emplacement is depicted in Figure 2. In this design, a fabricated plug is used after emplacement to provide the shielding required to protect personnel working in the drift.

Figures 3 and 4 illustrate a typical waste emplacement operational cycle for the vertical configuration. After transfering a single waste container from the surface facility storage vault into the transporter cask, the transporter is driven underground to the emplacement borehole and positioned over a temporary shielding closure. The cask that carries the container and provides primary shielding for the transporter operators is then rotated to a vertical position, and the shield doors are opened. The waste container is lowered into the borehole, and the grapple is disconnected from the waste container pintle and retracted back into the cask. The shield doors are then closed, the cask is rotated to its transport position, and the transporter is returned to the surface facility.

Following waste emplacement, final borehole closure is accomplished by replacing the temporary shielding enclosure with a shield plug and borehole cover. This allows the shielding closure to be used for waste emplacement operations at other boreholes. Closure is accomplished using a shielded plug installer transported with a special forklift, as shown in Figure 4.

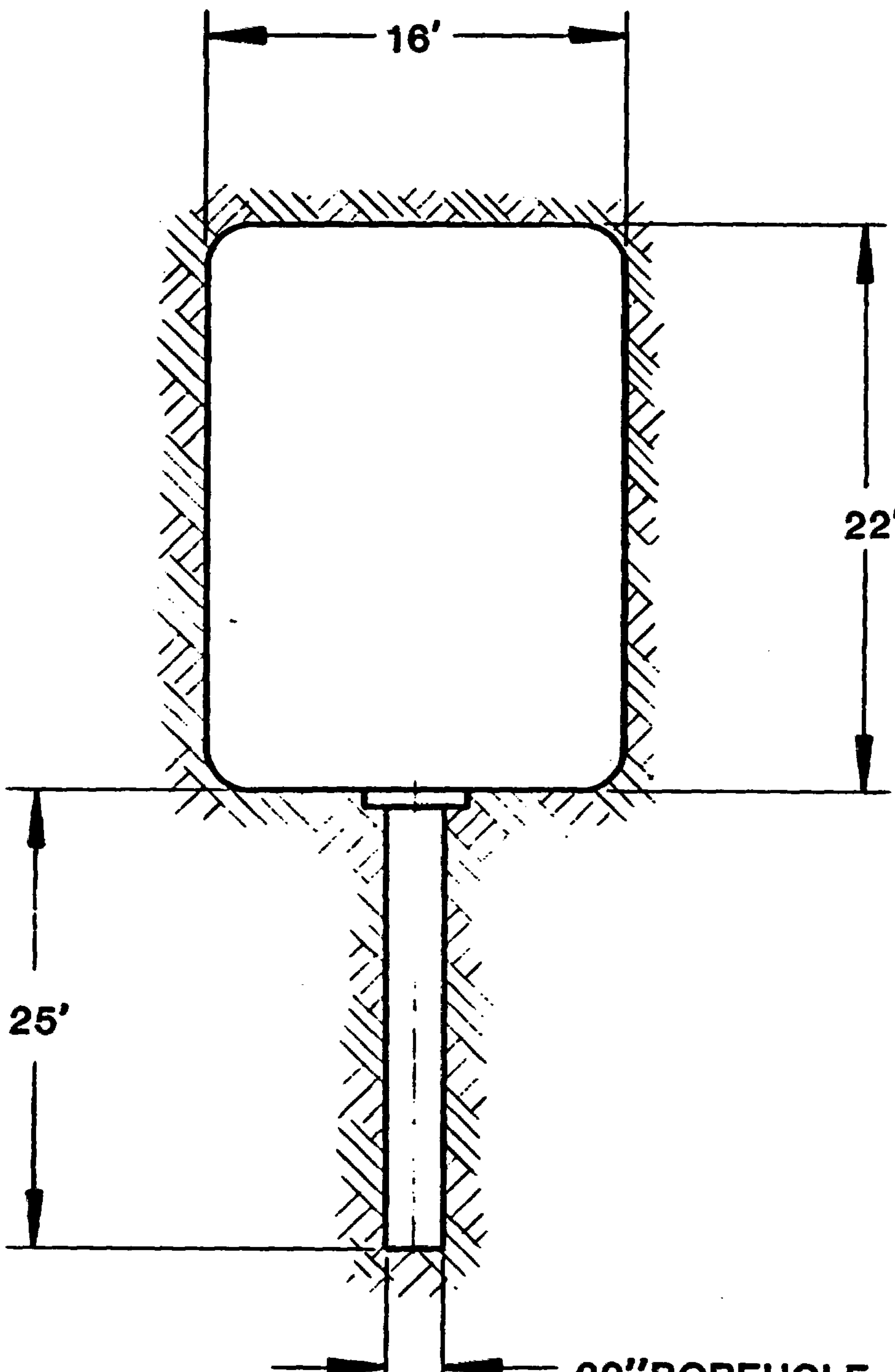


Fig. 1 - Cross-section of vertical emplacement borehole and drift

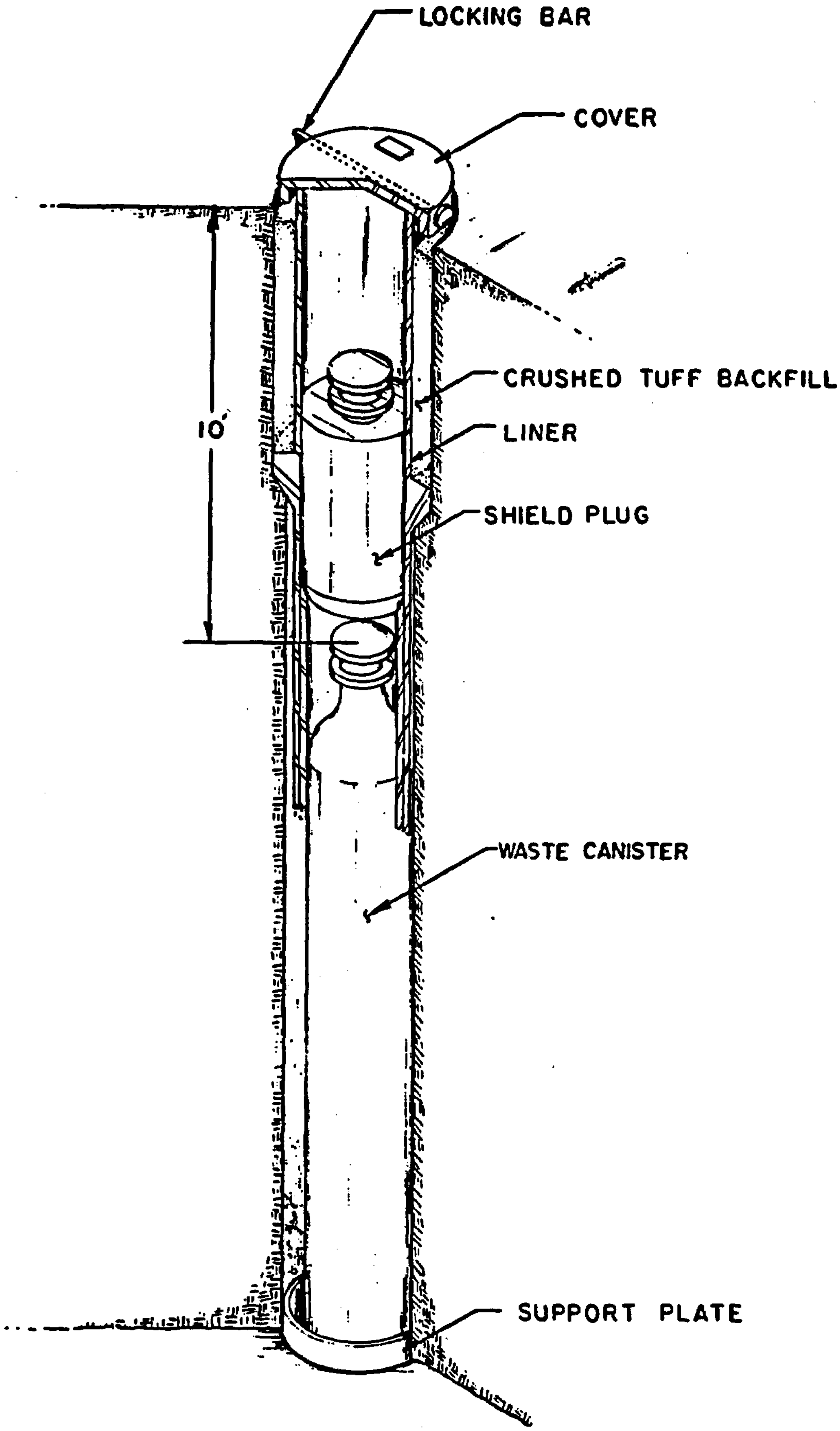


Fig. 2 - Design configuration for vertical emplacement

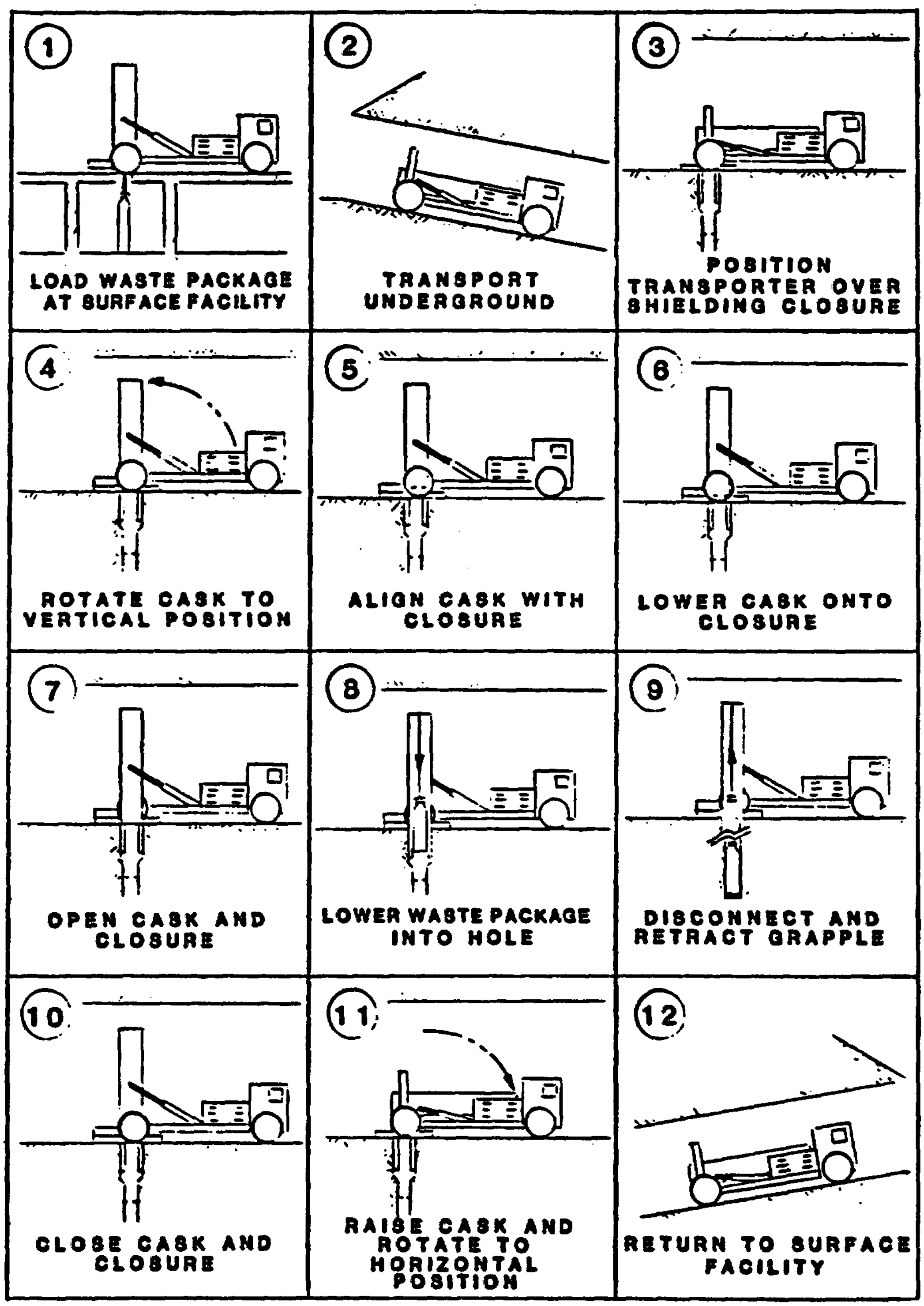


Fig. 3 - Sequence of emplacement operations for vertical configuration

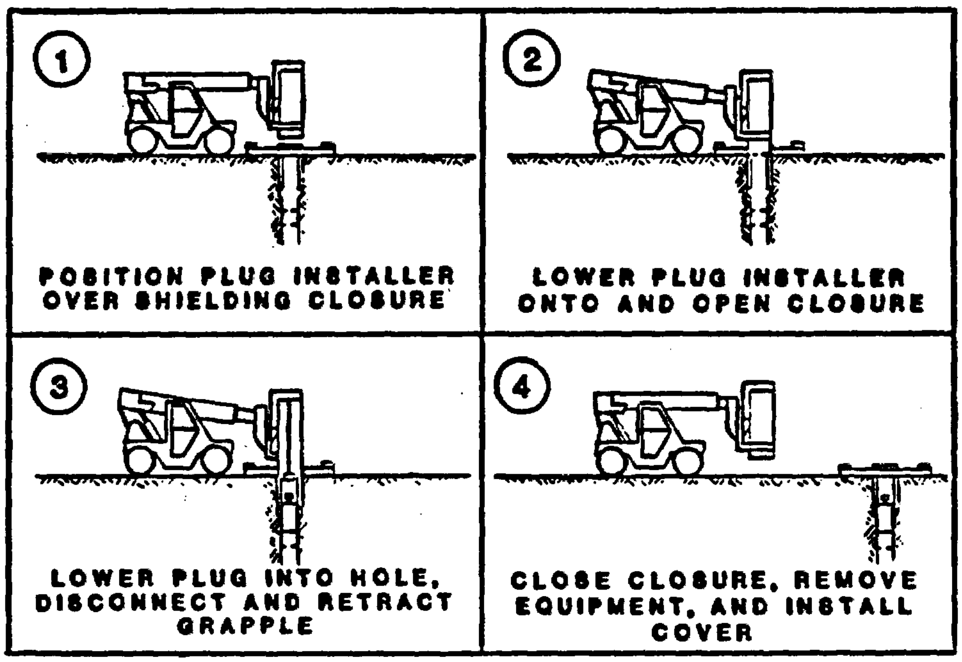


Fig. 4 - Plug and backfill installation for vertical configuration

2.1.1.2 Horizontal Configuration

The horizontal waste emplacement configuration uses long boreholes drilled horizontally into the ribs (sides) of the emplacement drifts, as shown in Figure 5. The current concept for waste storage in this orientation is shown in Figure 6. The emplacement boreholes are currently planned to be 350 feet long, and each will contain 15 waste packages. The holes are lined with a steel liner to facilitate waste emplacement and retrieval. In this configuration, there will be no waste packages stored in the first 100 feet of the borehole. This is done to delay the temperature increase in the emplacement drifts and thereby provide a less severe environment for retrieval operations. This 100 foot dimension is referred to as standoff. The standoff dimension is currently being analyzed, and it may be shortened as analyses are completed and the trade-off between repository cost and emplacement drift temperatures are further compared. A fabricated plug is used after emplacement to provide the shielding required to protect personnel working in the drift.

Figures 7 and 8 illustrate a typical waste emplacement operational cycle for the horizontal configuration. With this configuration, each waste container is carried on its side on a dolly. After transfering a single waste container and dolly from the surface facility storage vault into the transporter cask, the transporter is driven underground to the emplacement borehole and positioned at a temporary shielding closure. The cask is then rotated 90°, and the shield doors are opened. The waste container and dolly are pushed into the borehole with the emplacement/retrieval (E/R) mechanism, and the E/R mechanism is disconnected from the dolly and retracted back into the cask. The shield doors are then closed, the cask is rotated to its transport position, and the transporter is returned to the surface facility. The procedure is repeated until the borehole has been filled to design capacity.

Achieving standoff to delay the onset of elevated temperatures in the emplacement drift can be accomplished at least three ways. The first way is to use dummy containers or empty dollies that are emplaced in the same manner as a conventional waste package. The second method is to use a pusher mechanism employing hydraulic cylinders and coupled tubing to push the waste packages to the desired position. Finally, the last few packages emplaced in each borehole could be filled with defense high-level waste (DHLW), which has very low thermal output.

After all waste containers for a given borehole have been emplaced and standoff operations have been completed, final borehole closure is accomplished by replacing the temporary shielding enclosure with a shield plug and borehole cover. This allows the shielding closure to be used for waste emplacement operations at other boreholes. Closure is accomplished using a shielded plug installer transported with a special forklift, as shown in Figure 8.

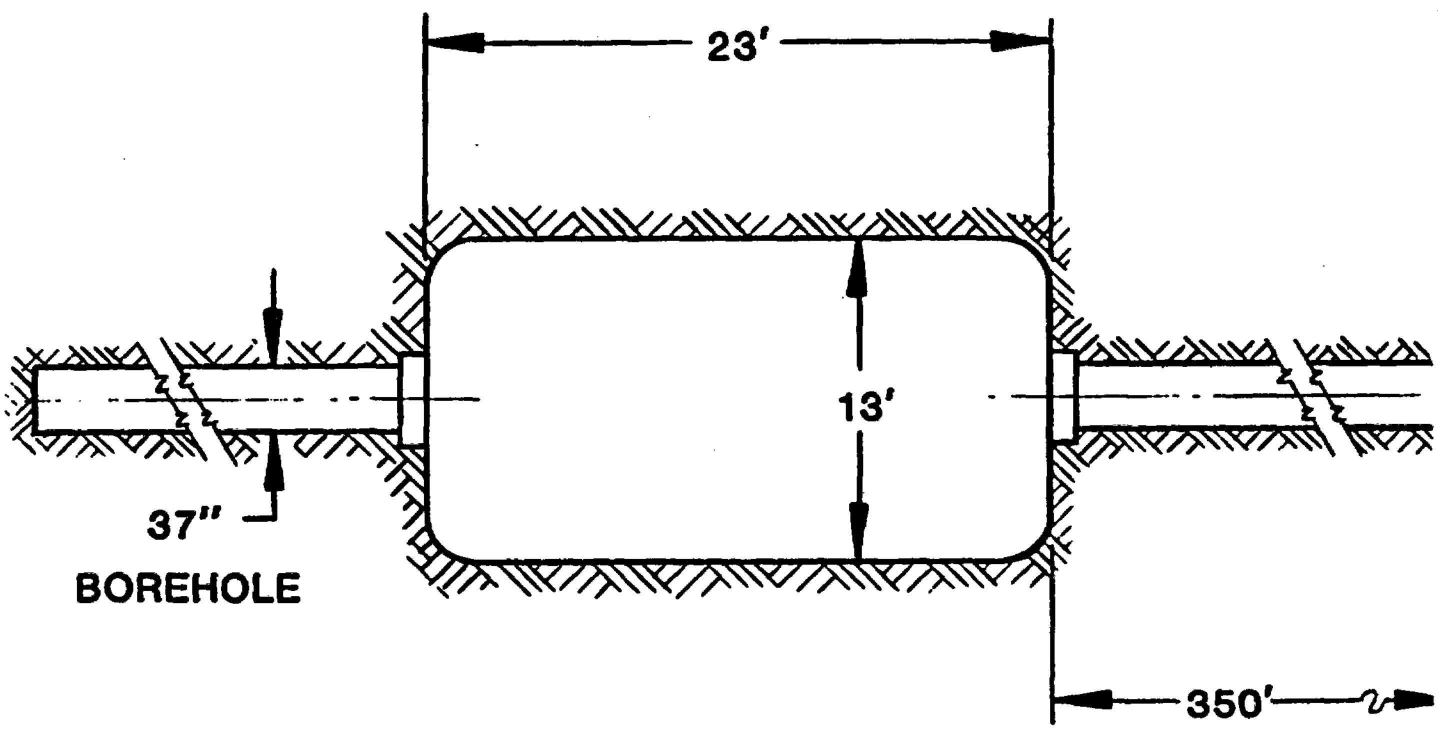


Fig. 5 - Cross-section of horizontal emplacement boreholes and drift

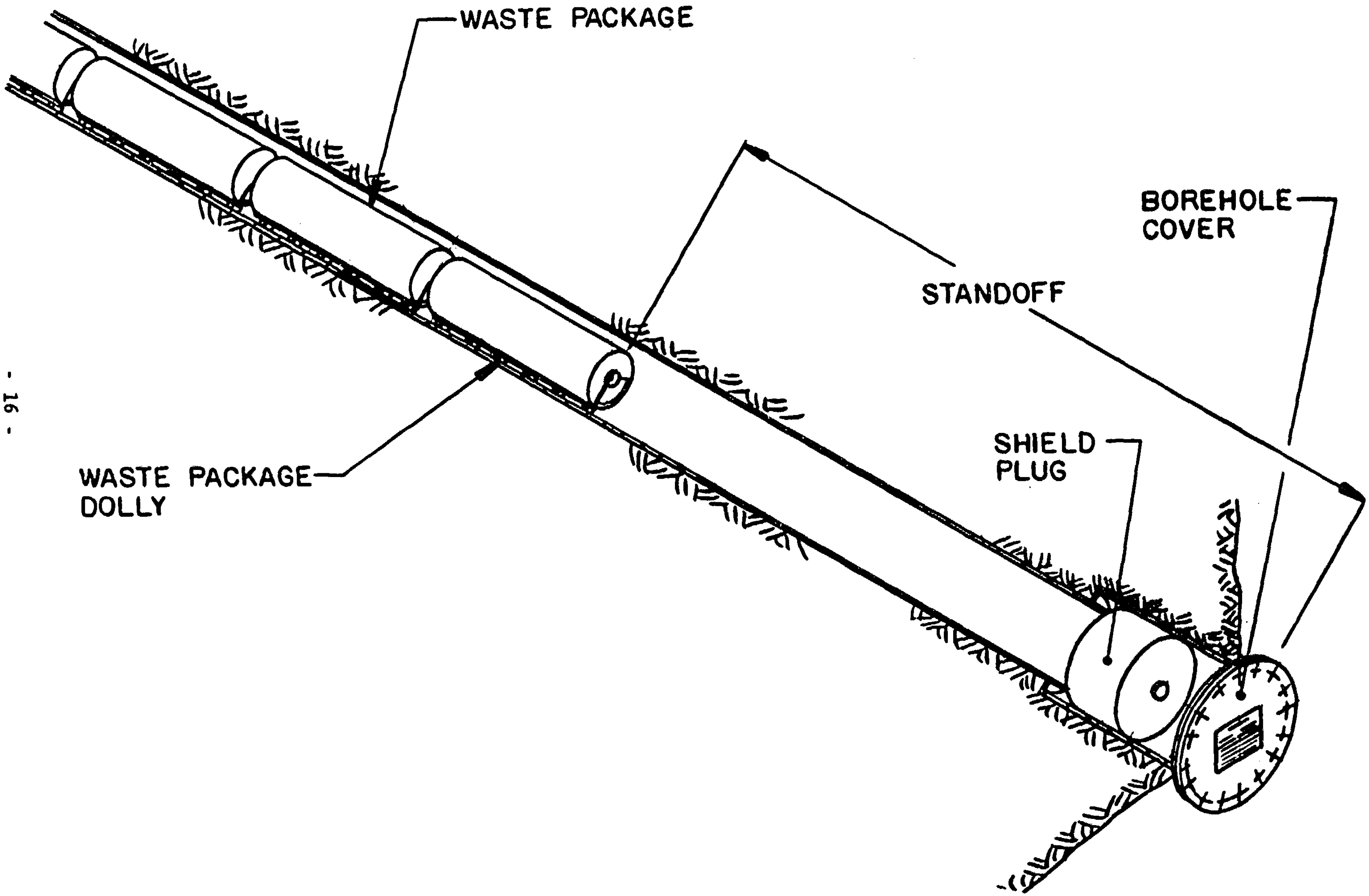


Fig. 6 - Design configuration for horizontal emplacement

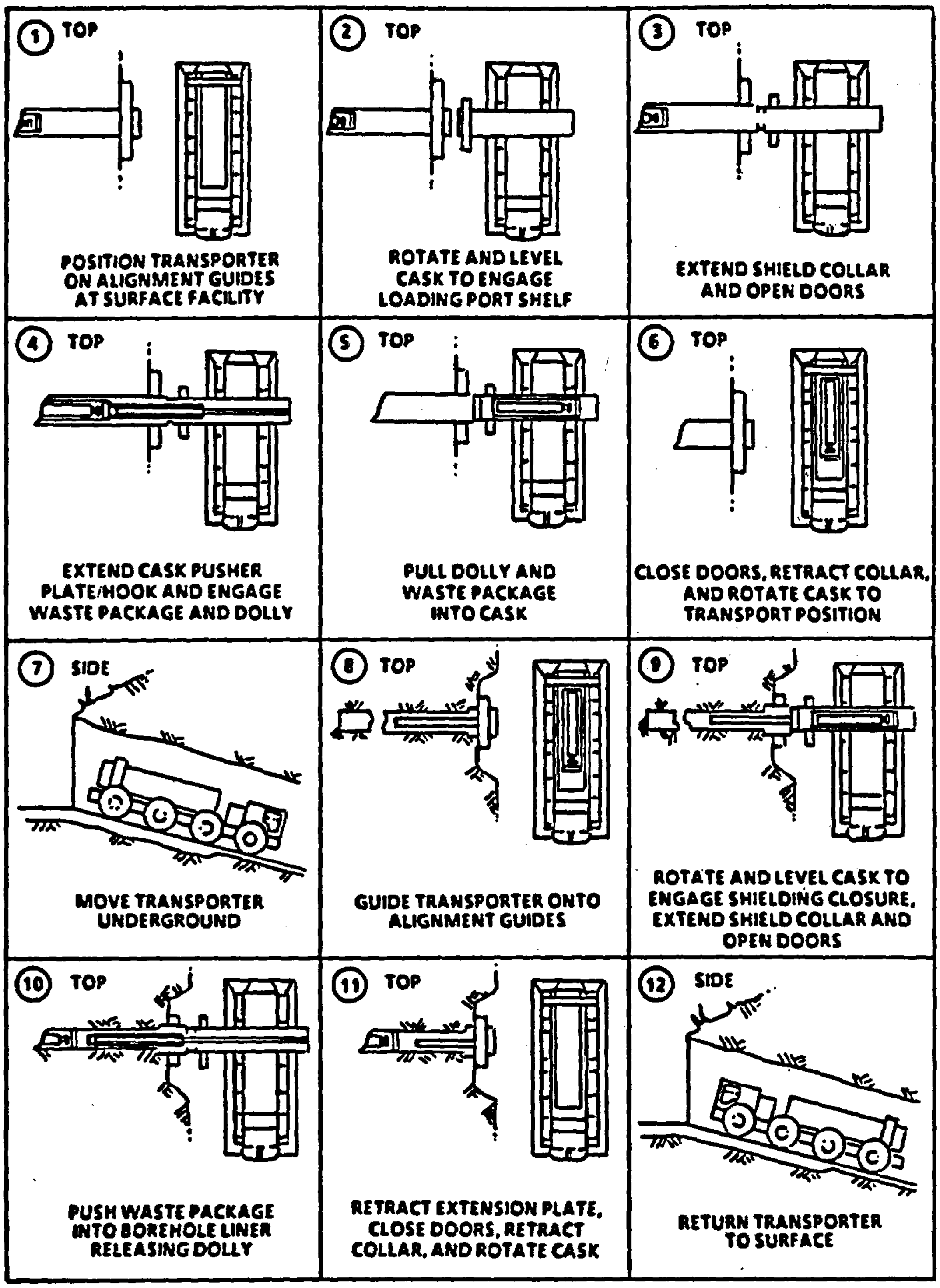


Fig. 7 - Sequence of emplacement operations for horizontal configuration

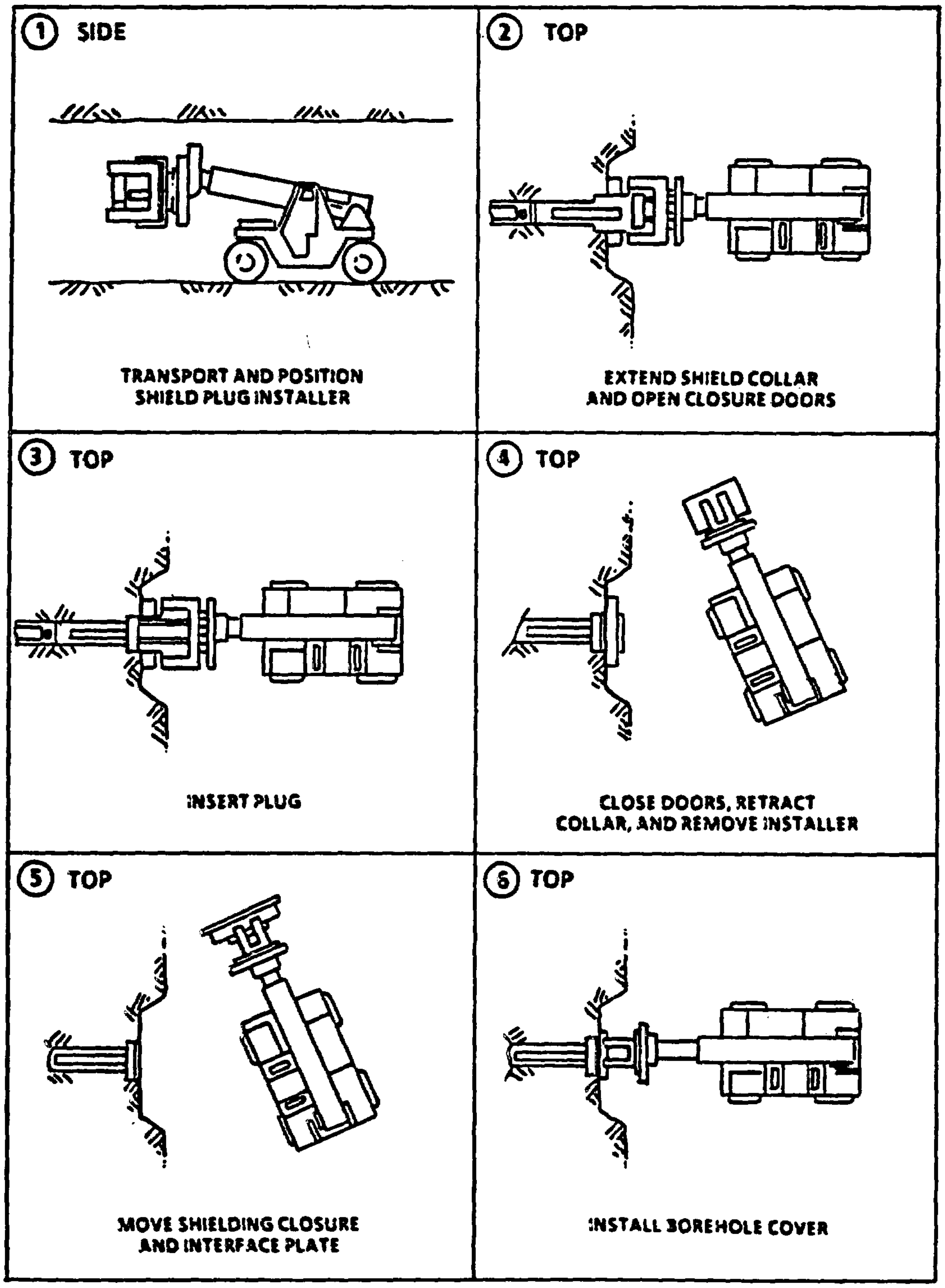


Fig. 8 - Borehole plug and cover installation for horizontal configuration

2.1.2 Retrieval Mode

When discussing waste retrieval, it is necessary to consider both normal and off-normal retrieval conditions. Normal retrieval conditions are defined as conditions under which standard procedures and equipment can be used to retrieve waste. Off-normal conditions are conditions under which special procedures or equipment must be used in order to retrieve the waste.

2.1.2.1 Retrieval Under Normal Conditions

Waste emplacement hardware will be designed so that it can also be used for retrieval operations under normal conditions. This has the adavantage of more rapid and lower-cost reconfiguration of the underground waste handling facilities from emplacement to retrieval mode, should retrieval be required. Because of site characteristics and repository design, normal retrieval oporations are not expected to be extremely different from emplacement conditions. The differences that do exist will be accomodated during further development of the presented designs. For example, the emplacement hardware will be designed to operate normally at the elevated borehole temperatures (>200°C) that could be expected during retrieval. Also, the emplacement hardware will be designed to operate in a reverse mode and to have the capability of pulling the higher loads that may be required for normal waste removal.

2.1.2.1.1 Vertical Configuration

Prior to removing waste from each vertical borehole, the borehole must be prepared for removal operations. This involves replacing the borehole cover and shield plug with the borehole shielding closure so that shielding can be maintained as the waste container is lifted from the borehole into the transporter cask. This is accomplished by: (1) removing the borehole cover; (2) installing the borehole shielding cover; and (3) removing the shield plug. Operationally, vertical borehole preparation is the reverse of that presented in Figure 4 for borehole closure after waste emplacement.

Following borehole preparation, the waste container is removed from the borehole and transported and delivered to the surface facility. The required procedures are the reverse of those presented in Figure 3 for vertical waste emplacement.

2.1.2.1.2 Horizontal Configuration

Prior to removing waste from each horizontal borehole, the borehole must be prepared for removal operations. This involves replacing the borehole cover and shield plug with the borehole shielding closure so that shielding can be maintained as the waste container is pulled from the borehole into the transporter cask. Operationally, borehole preparation is the reverse of that presented in Figure 8 for horizontal borehole closure after waste emplacement.

Two concepts have been presented for waste container removal from horizontal boreholes. The first of these concepts employs coupled waste container dollies, and the second employs uncoupled dollies.

Normal Retrieval Operations With Coupled Dollies

With this concept, as each waste container and dolly is emplaced in the borehole with the E/R mechanism, the dolly is coupled to the dolly of the waste container positioned at the borehole entrance, and the entire dolly train is pushed into the borehole. Similarly, as each waste package and dolly are removed from the borehole with the E/R mechanism during retrieval, the entire dolly train is pulled toward the borehole entrance, and the waste container being removed is unhooked from the train. This concept offers efficiency in waste removal operations because each container is always in a standard position for removal. Waste removal operations for this concept are the reverse of those shown in Figure 7 for horizontal waste emplacement.

Normal Retrieval Operations With Uncoupled Dollies

Coupling the dollies together as in the baseline waste removal concept could potentially complicate retrieval. These complications include:

(1) If a coupling between two dollies breaks, an off-normal condition will be created which will necessitate the use of special equipment and procedures in order to remove the waste containers left in the borehole.

(2) If a single waste container becomes blocked or bound in the borehole, removal of containers between the borehole entrance and the blocked or bound container cannot proceed until the dolly train is uncoupled from the dolly of the blocked or bound container.

An alternative concept for removing waste containers uses a design in which dollies are not coupled. With this design, all containers are pushed into the borehole as each container is emplaced; but since the dollies are not coupled, each container during retrieval must be pulled from its storage position in the borehole. This concept is illustrated in Figure 9. Here, a retrieval cart is used to pull the waste container to a standard removal position near the borehole entrance. Following this operation, procedures for removing the container from the borehole and transporting and delivering it to the surface facility are the reverse of those shown in Figure 7 for horizontal waste emplacement.

2.1.2.2 Retrieval Under Off-Normal Conditions

Work is currently underway to identify off-normal conditions that have a significant probability of delaying waste retrieval or impacting the ability to retrieve waste. The work began by developing a list of approximately 75 processes, events, and conditions of potential concern ("Items Important to Safety, Waste Isolation, and Retrievability fo the Yucca Mountain Respository", SLTR86-1008, to be published as an appendix in the SCP-CDR). An initial screening of this list was performed, and the following processes, events, and conditions were identified as having a potential for affecting the ability to retrieve:

- tectonics
- variability in rock characteristics
- aging/corrosion of equipment and facilities
- radiolysis
- human error

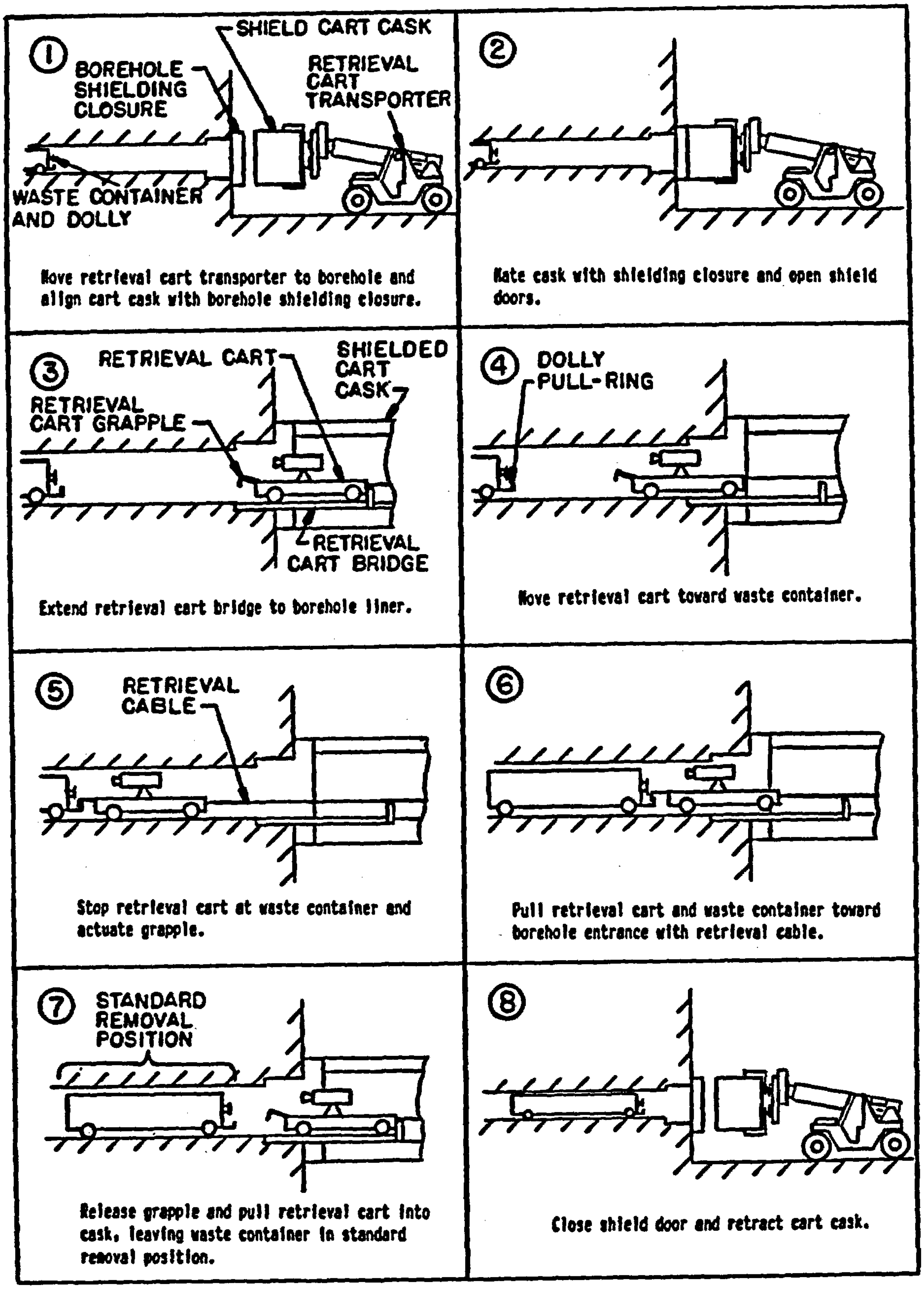


Fig. 9 - Pulling a waste container from its storage position to the standard removal position

Using engineering judgement, these items were evaluated relative to the repository and equipment design and the four functions that must be performed to complete the retrieval operation:

(1) provide access to the emplacement boreholes;
(2) provide access to the waste containers;
(3) remove the waste containers; and
(4) transport and deliver the waste containers to the surface facility.

As a result of this evaluation, several off-normal conditions having the potential for affecting retrievability were identified and are listed in SLTR86-1008. Further work is required, however, to determine the probability of occurrence for each of the off-normal conditions.

Concepts for procedures and equipment for retrieving waste under each of the off-normal conditions have been developed. Procedures and equipment for overcoming off-normal conditions that affect access to and removal of waste containers from emplacement boreholes are presented below to facilitate comparison of the vertical and horizontal configurations. Off-normal conditions that affect access to the emplacement boreholes and tranport and delivery of waste containers to the surface facility have the same impact on retrieval from vertical boreholes as they do on retrieval from horizontal boreholes. As a result, procedures for dealing with those conditions are not discussed in this report.

No attempt is made in this report to determine the probability of occurrence of any of the off-normal conditions, although it is believed that the probabilities are relatively low for all off-normal conditions considered. As a result, it should not be inferred from the presentation of off-normal retrieval concepts that these off-normal conditions are expected to occur on a frequent basis. Rather, these concepts are presented to reflect the level of importance placed on maintaining the option to retrieve waste and to demonstrate that credible concepts have been developed for maintaining that option under all conditions that have the potential for affecting retrievability.

2.1.2.2.1 Vertical Configuration

Off-normal conditions that affect access to and removal of waste containers from vertical boreholes are those that result in a container being temporarily detained in a vertical borehole. These include conditions that result from:

(1) failure of retrieval equipment, due to events such as structural failure or malfunction of components in the retrieval or shield door systems;

(2) binding of the shield plug in the borehole, due to seismic events, thermal loading, or fabrication error.

(3) loss of the pintle on a waste container, due to structural failure, or the pintle otherwise becoming incapable of being grapped by the retrieval grapple; and

(4) binding of a waste container by the surrounding rock or partial liner so that the container cannot be pulled out of the borehole without possible structural damage to the container.

Procedures for Surmounting Equipment Failure

Retrieval equipment will be designed so that most failures in the system for lifting containers out of a vertical borehole and into the transporter cask can be repaired from outside the cask. For example, the cable reel and motor for lifting the waste container out of the borehole will be located outside the cask where it can be accessed. Since detailed design of the system has not yet been initiated, it is not possible to delineate the exact procedures that would be used. In general, they would consist of repairing or replacing the defective components using maintenance procedures to be developed. The system will also be designed with a backup system so that the waste container can be lowered back into the borehole if the primary retrieval system fails and cannot be repaired on-site. Electric or hydraulic systems for closing shield doors will be designed so that their functions can be manually overridden with hand cranks.

Procedures for Removing a Bound Shield Plug

The shield plug must be removed from the borehole in order to provide access to the waste container. In the unlikely event that, for some reason, the shield plug becomes bound by the partial liner, it will be necessary to use special equipment and procedures to remove the shield plug before waste container removal can proceed. Two approaches could be used to remove a bound shield plug, depending on the severity of the problem:

(1) A system for vibrating the shield plug could be incorporated into the shield plug remover. Vibration, coupled with an upward tensile force, may be sufficient to free the shield plug if friction against the partial liner is the only force binding the shield plug in the borehole.

(2) A system for coring the rock and cutting the liner surrounding the shield plug could be used if the liner has collapsed on the shield plug and the vibratory method does not free it. The procedure would consist of replacing the standard borehole shielding closure with a closure of similar design but larger opening, moving a coring machine into place, and performing the coring operation. These procedures would be similar to those described below for the coring operation required to remove a bound waste container from a vertical borehole.

Procedures for Removing Detained Waste Containers

In the unlikely event that a waste container loses its pintle or is otherwise incapable of being grabbed by the retrieval grapple in order to pull it out of the borehole, it will be necessary to employ special equipment and procedures in order to remove the container. The procedure for removing such containers is to first conduct a borehole inspection operation to verify the condition, followed by an operation employing a waste container removal sleeve.

Vertical Borehole Inspection Operations

Inspection of a vertical borehole may be required if problems arise during removal of a waste container. Reasons for conducting an inspection include: to determine if the problem is borehole-related or retrieval system-related; to determine if breaching of a waste container has occurred; and to provide data on the nature and extent of the problem for use in subsequent waste removal operations.

The procedure for inspecting a vertical borehole is shown in Figure 10. Data obtained with instruments mounted on the inspection module would include borehole temperature, radiation level, gas composition, and remote visual data.

Removal Sleeve Operations

If borehole inspection and assessment indicate that the waste container has lost its pintle but is not bound by the surrounding rock, a system employing a sleeve that would fit over and around the waste container might be used to remove the container from the borehole. Depending upon the design of the system, the first step may be to replace the standard borehole shielding closure with a closure of similar design but larger opening to permit passage of the removal sleeve. The sleeve would consist of a hollow cylinder with hydraulic pistons mounted inside its inner wall. The sleeve would be pushed over the container and the pistons actuated to squeeze the container and hold it tightly. The sleeve and container would then be withdrawn into a shielded cask and transported to the surface facility for container cleaning and further processing.

Procedures for Removing Bound Waste Containers

In the unlikely event that a waste container is bound in a vertical borehole by the partial liner or rock surrounding the waste container, special procedures and equipment will be required to remove the container. Two approaches could be used, depending on the severity of the problem:

(1) A system for vibrating the waste container could be incorporated into the vertical retrieval system. Vibration, coupled with an upward tensile force, may be sufficient to free the container if friction against the surrounding rock or partial liner is the only force binding the container in the borehole.

(2) A system for coring the rock surrounding the waste container could be used if the rock or partial liner has collapsed on the container and the vibratory method does not free it. The procedures are described below.

Vertical Coring Operations

The vertical core drill concept is shown in Figure 11. With this concept, a core drill contained within a shielded cask is positioned above the borehole shielding closure and used to drill the rock surrounding the partial liner. When the core containing the liner and surrounding rock has been lifted out of the borehole and temporarily stored in the liner storage cask, core drilling of the rock surrounding the waste container is

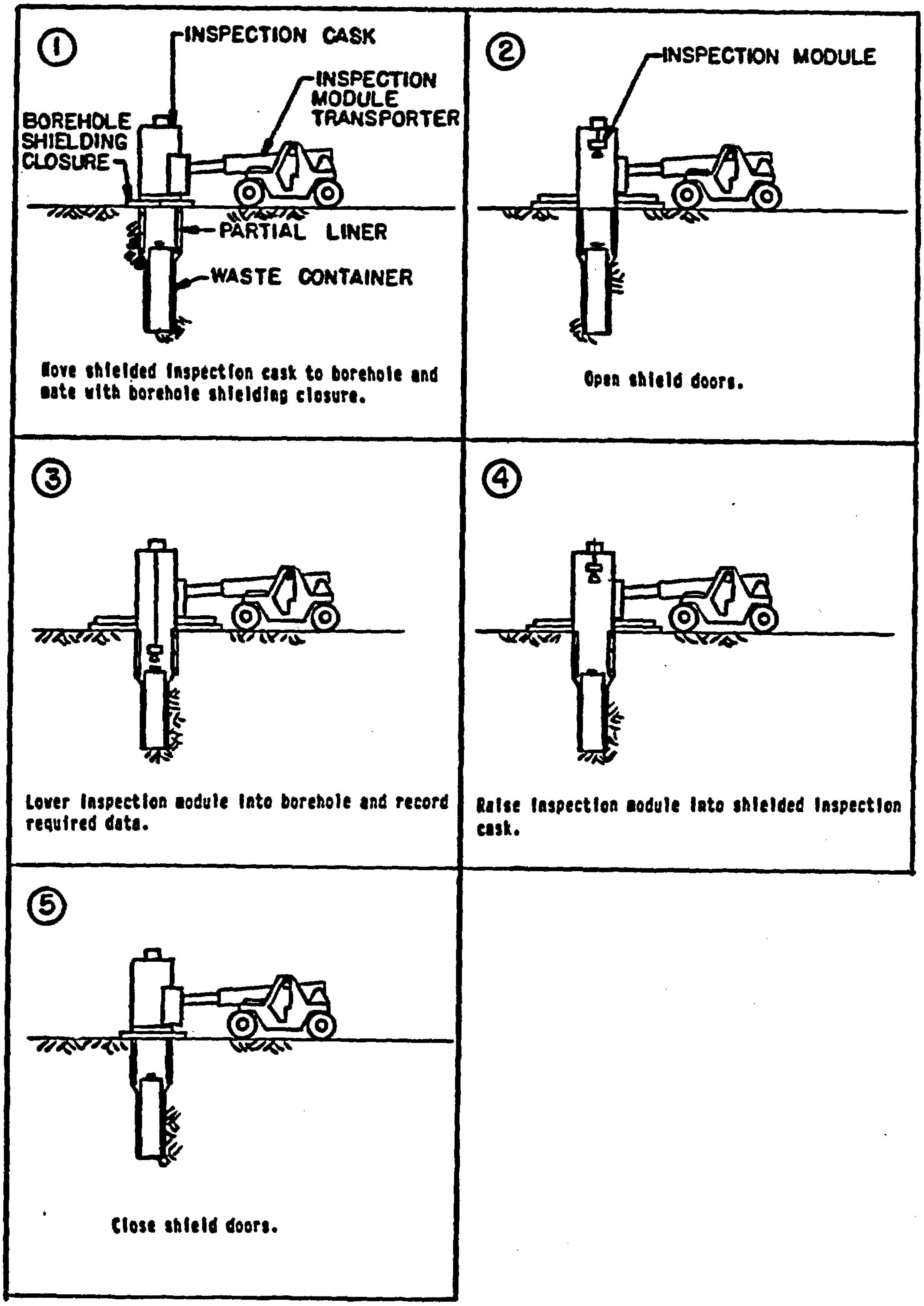


Fig. 10 - Inspecting a vertical borehole

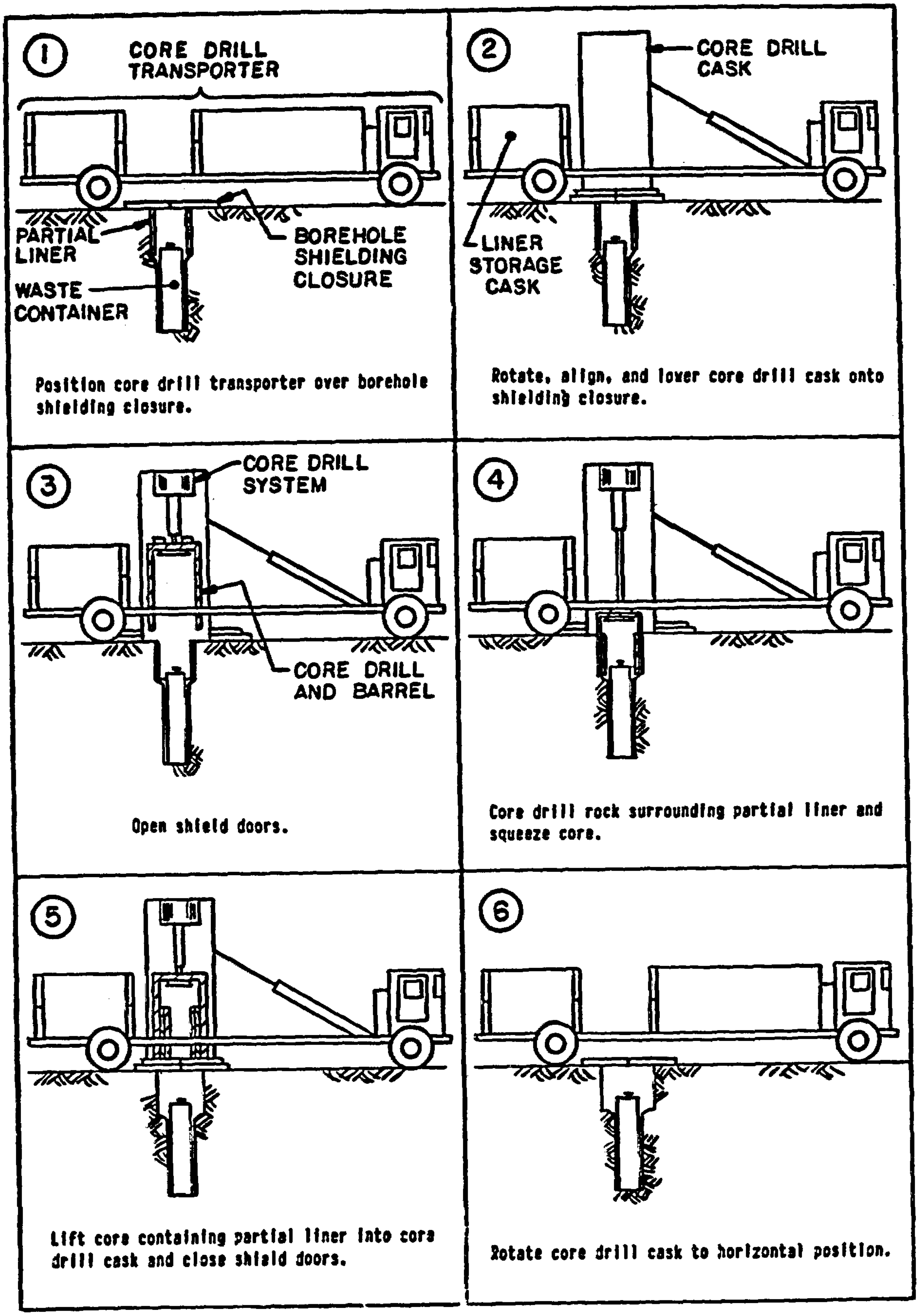


Fig. 11 - Removal of a bound waste container from a vertical borehole

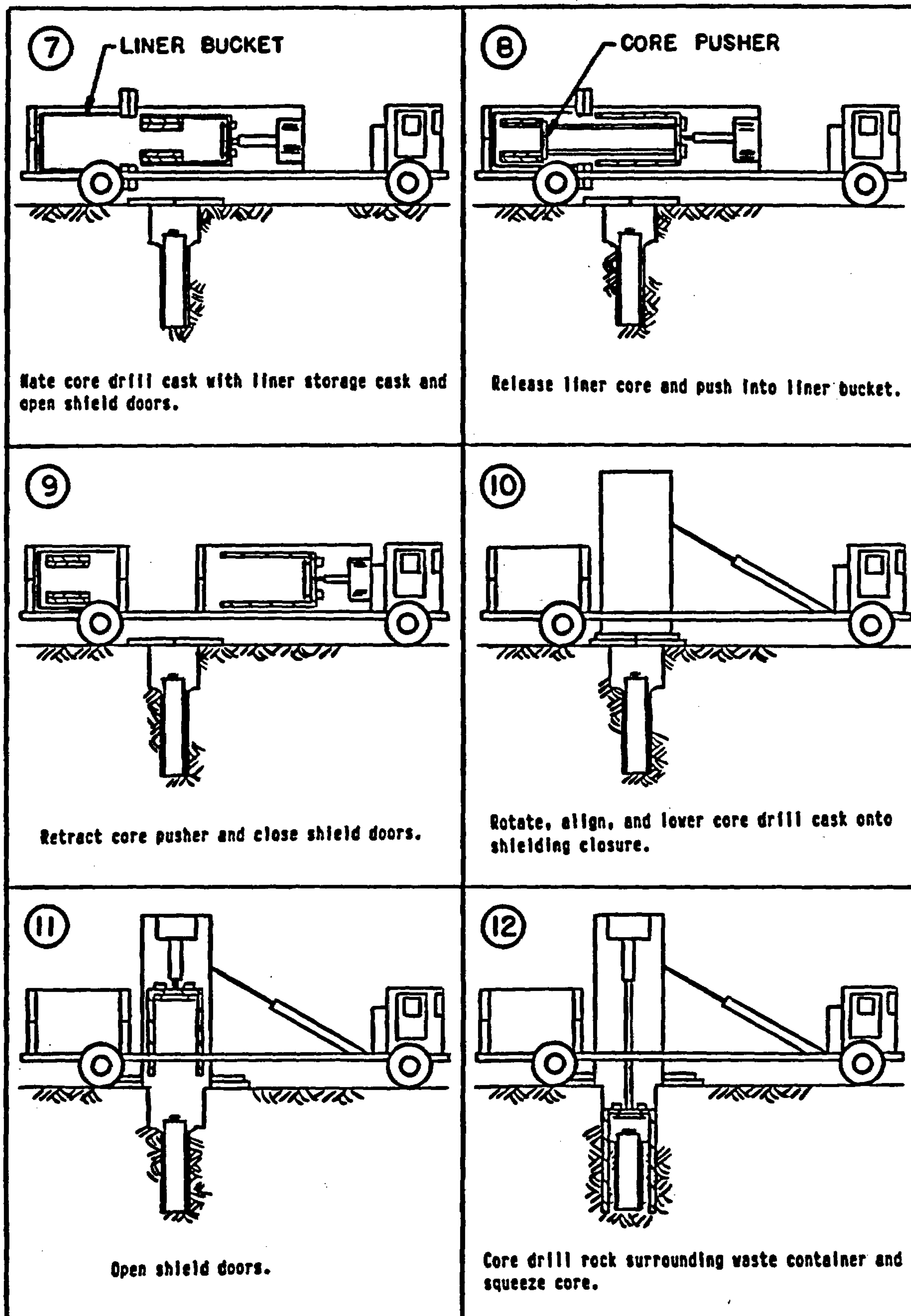

7
LINER BUCKET
Mate core drill cask with liner storage cask and open shield doors.
8
CORE PUSHER
Release liner core and push into liner bucket.
9
Retract core pusher and close shield doors.
10
Rotate, align, and lower core drill cask onto shielding closure.
11
Open shield doors.
12
Core drill rock surrounding waste container and squeeze core.

Fig. 11 (cont'd)

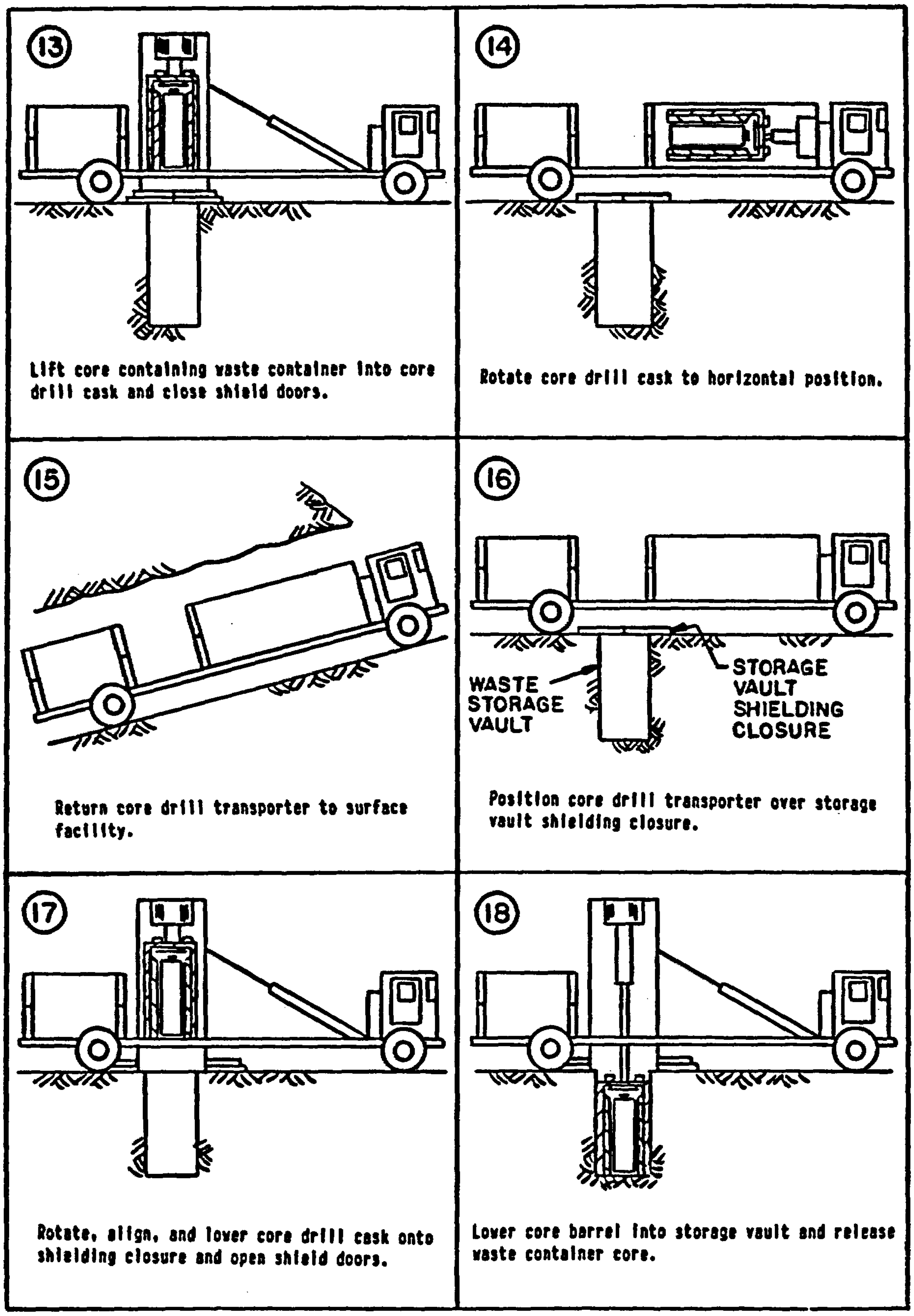

13
Lift core containing waste container into core drill cask and close shield doors.
14
Rotate core drill cask to horizontal position.
15
Return core drill transporter to surface facility.
16
WASTE STORAGE VAULT
STORAGE VAULT SHIELDING CLOSURE
Position core drill transporter over storage vault shielding closure.
17
Rotate, align, and lower core drill cask onto shielding closure and open shield doors.
18
Lower core barrel into storage vault and release waste container core.

Fig. 11 (cont'd)

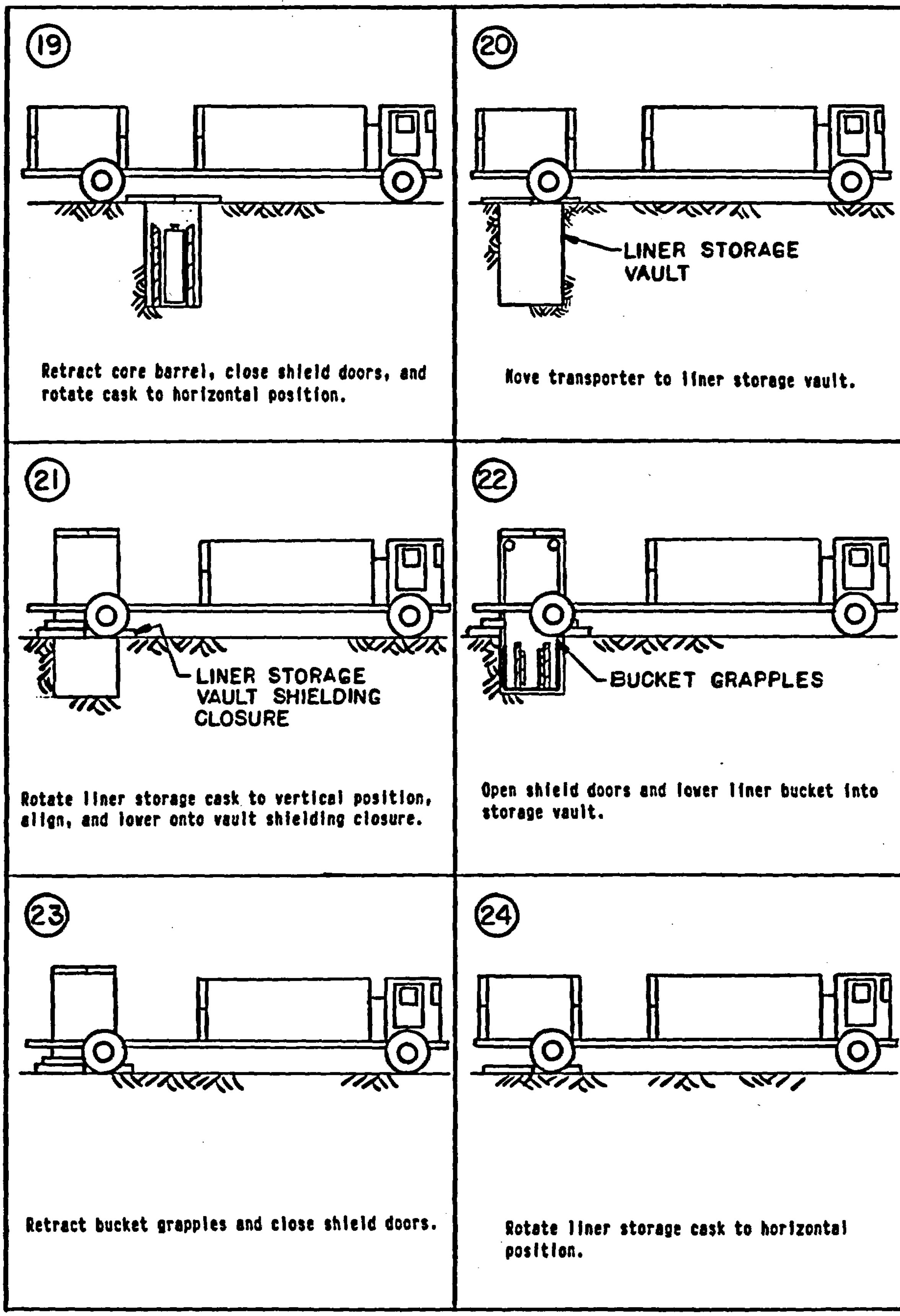

19
Retract core barrel, close shield doors, and rotate cask to horizontal position.
20
LINER STORAGE VAULT
Move transporter to liner storage vault.
21
LINER STORAGE VAULT SHIELDING CLOSURE
Rotate liner storage cask to vertical position, align, and lower onto vault shielding closure.
22
BUCKET GRAPPLES
Open shield doors and lower liner bucket into storage vault.
23
Retract bucket grapples and close shield doors.
24
Rotate liner storage cask to horizontal position.

Fig. 11 (cont'd)

accomplished, and the waste container core is withdrawn into the shielded cask. The cores containing the waste container and partial liner are then transported to the surface facility and deposited in separate storage vaults, completing retrieval operations for a single bound waste container from a vertical borehole.

Auxiliary Liner Cutting Operations

In the unlikely event that the top of a waste container is bound in the partial liner, it may be necessary to cut the liner above the waste package in order to remove the liner core separately from the waste package core. As illustrated in Figure 12, this operation can be done either of two ways:

(a) with a separate auxiliary liner cutting operation in which an expandable liner cutter is inserted into the borehole and used to cut the liner prior to the coring operation; or

(b) with liner cutters that are carried in the core barrel and are hydraulically extended radially inward to cut the liner after the rock surrounding the liner is cored.

After the liner is cut, coring operations can then proceed as described above.

2.1.2.2.2 Horizontal Configuration

Off-normal conditions that affect access to and removal of waste containers from horizontal boreholes are those that result in a container being temporarily detained in a horizontal borehole. These include conditions that result from:

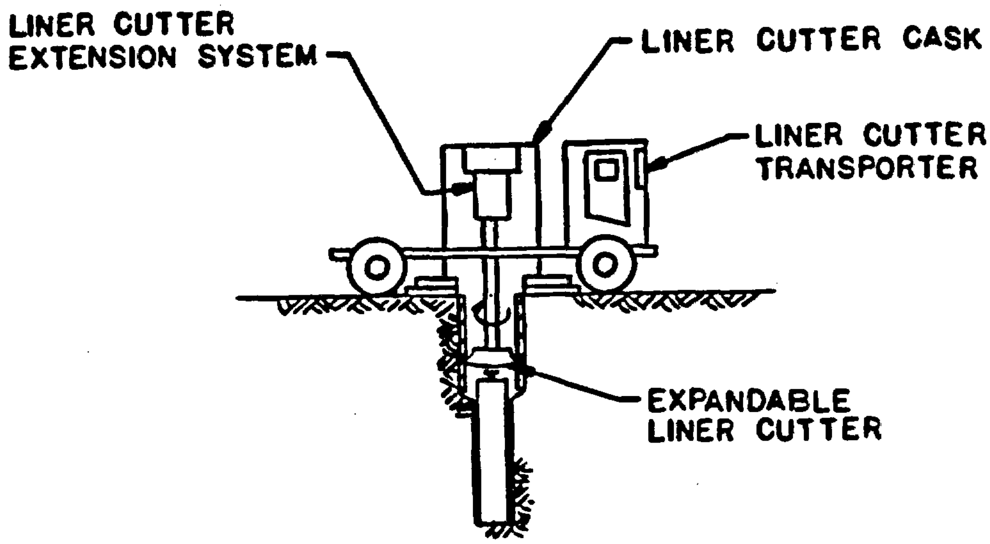
(1) failure of retrieval equipment, due to events such as structural failure or malfunction of components in the retrieval or shield door systems;

(2) binding of the shield plug in the borehole, due to seismic events, thermal loading, or fabrication error.

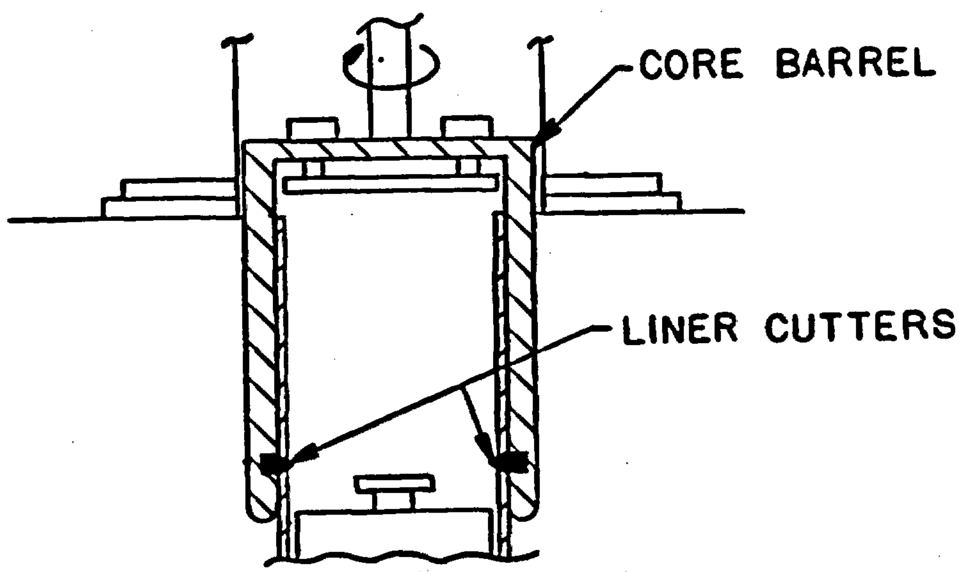
(3) collapse or severe deformation of the liner in the standoff region, causing one or more waste containers to become blocked but not actually bound by the liner; and

(3) binding of one or more waste containers in the borehole liner, due to either liner collapse or structural failure of a dolly and waste container.

Under the first three of these categories, it is possible that the detained container could be retrieved through the borehole liner using special procedures and equipment described in this subsection. Under the fourth category, the conditions are so extreme that it would probably be necessary to remove a portion of the liner and the surrounding rock in order to free the container. It is highly unlikely that such extreme conditions would ever exist in lined horizontal boreholes (see Subsection 3.2.2); however, for the sake of conservatism, concepts for dealing with such conditions have been developed and are also presented in this subsection.



(a) Auxiliary liner cutting operation using an expandable liner cutter



(b) Liner cutting operation using cutters carried in core barrel.

Fig. 12 - Concepts for cutting the partial liner above the waste container

Procedures for Surmounting Equipment Failure

The cask retrieval system will be designed so that failures in the system for pulling containers out of a horizontal borehole and into the transporter cask can be repaired from outside the cask when possible. For example, the motor that powers the emplacement/retrieval (E/R) mechanism will be located outside the cask for easy access and repair or replacement. Since detailed design of the system has not yet been initiated, it is not possible to delineate the exact procedures that would be used. In general, they would consist of repairing or replacing the defective components using maintenance procedures to be developed. The system will also be designed with a backup system so that the waste container can be fully pushed back into the borehole if the primary retrieval system fails and cannot be repaired on-site. Electric or hydraulic systems for closing shield doors will be designed so that their functions can be manually overridden with hand cranks.

With the coupled dolly concept, if a coupling between two dollies breaks, the retrieval cart used with the uncoupled dolly design can be used to enter the borehole, grab the remaining dollies, and pull them to the standard removal position for subsequent removal with the E/R mechanism. In this case, an additional pull-ring for mating with the retrieval cart grapple would be required on each dolly.

Several alternatives exist for overcoming failure of the retrieval cart system when used either as a backup to the coupled dolly design or as a primary system in the uncoupled dolly design. If the retrieval cart grapple malfunctions and fails to release a dolly when required, decoupling can be accomplished with manual override using a remotely actuated mechanism extended from the retrieval cart cask. In the event of retrieval cable failure, a second retrieval cart can be used to enter the borehole and manually override the grapple of the first cart in order to release it from the waste container. A pull-ring on the rear of the first retrieval cart would then allow the grapple of the second cart to grab the first cart in order to retract it back into the retrieval cart cask. After this is accomplished, the second retrieval cart could be used to reenter the borehole and pull the waste package to its standard removal position for subsequent removal with the E/R mechanism.

Procedures for Removing a Bound Shield Plug

The shield plug must be removed from the borehole in order to provide access to the waste container. In the unlikely event that, for some reason, the shield plug becomes bound in the borehole, it will be necessary to use special equipment and procedures to remove the shield plug before waste container removal can proceed. Two approaches could be used to remove a bound shield plug, depending on the severity of the problem:

(1) A system for vibrating the shield plug could be incorporated into the shield plug remover. Vibration, coupled with an outward tensile force, may be sufficient to free the shield plug if friction against the borehole walls is the only force binding the shield plug in the borehole.

(2) A system for coring the rock surrounding the shield plug could be used if the vibratory method does not free it. The procedure would consist of replacing the standard borehole shielding closure with a closure of similar design but larger opening, moving a coring machine into place, and performing the coring operation. These procedures would be similar to those described below for the coring operation required to remove a bound waste container from a horizontal borehole.

Procedures for Removing Blocked Waste Containers

In the unlikely event that the liner collapses in the standoff region or between waste containers, it will be necessary to employ special equipment and procedures in order to remove the blocked containers. In this subsection, concepts for removing blocked (but not bound) waste containers are presented. The first two concepts are related to preparation for removal operations, and the final two concepts are related to the actual removal operations.

Selective Dolly Uncoupling Operation

With coupled dollies, liner collapse or severe deformation between dollies would effectively detain all waste containers in the borehole. In order to remove the detained dollies, the dollies must first be uncoupled.

The concept for uncoupling dollies is shown in Figure 13. With this concept, a remotely actuated uncoupling mechanism is inserted into the borehole and used to release the dolly couplings so that removal of the uncoupled dollies and waste containers can then be completed using the retrieval cart and E/R mechanism. This leaves the borehole ready for inspection and operations required to remove the remaining blocked containers.

Alternatively, the retrieval cart could be used to uncouple the dollies. The procedure would be to run the retrieval cart in the borehole to the first waste container, where a remote mechanism on the cart would be actuated to uncouple the dolly from the dolly train and grab the dolly for pulling to the standard removal position. The remote mechanism could be designed to slide beneath the dolly; or the dolly could be designed so that it could be uncoupled from the same side that the dolly grabs for retrieval.

With the uncoupled dolly design, the uncoupling operation is not necessary. Removal of all waste containers between the borehole entrance and the collapsed liner section can be performed using the retrieval cart and cask mechanism, leaving the borehole ready for inspection and operations required to remove the remaining blocked containers.

Horizontal Borehole Inspection Operation

Prior to implementation of procedures for removing blocked containers from a horizontal borehole, inspection of the borehole should be performed to assess the situation. The retrieval cart used in the alternative waste removal concept can be used to perform these operations. The cart can be fitted with an inspection module containing various equipment in order to provide inhole data. This equipment might include: a video camera and

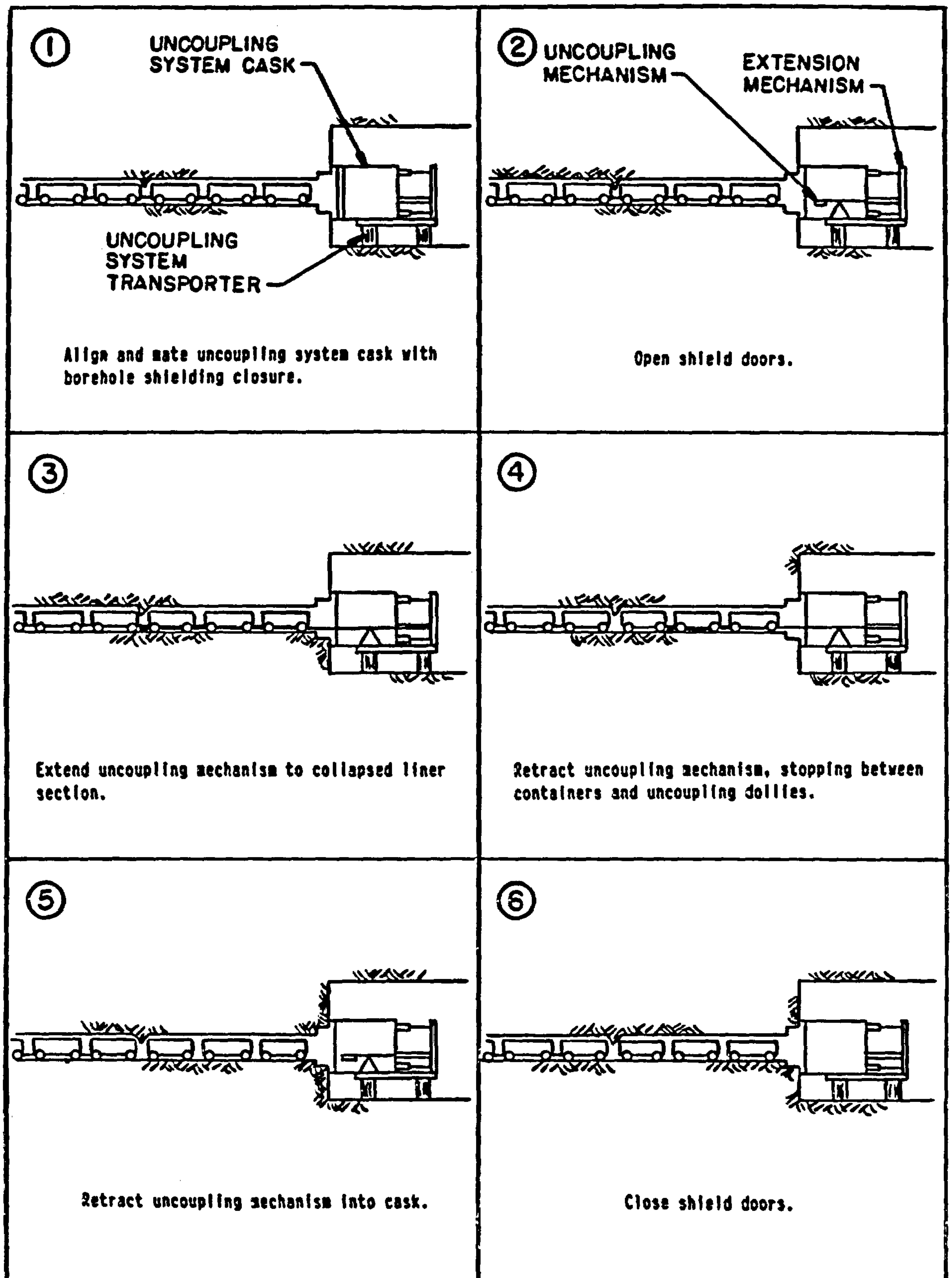


Fig. 13 - Uncoupling dollies with the uncoupling mechanism

lights to provide remote visual inspection of the borehole; an instrument similar to borehole calipers used in deep wells to provide measurements of the liner inner diameter in order to detect and assess the severity of collapsed or deformed liner sections; and instruments such as temperature probes, radiation monitors, and gas sampling equipment to provide accurate measurements of local inhole conditions. These data would be extremely useful in assessing the nature of off-normal conditions and determining possible remedies.

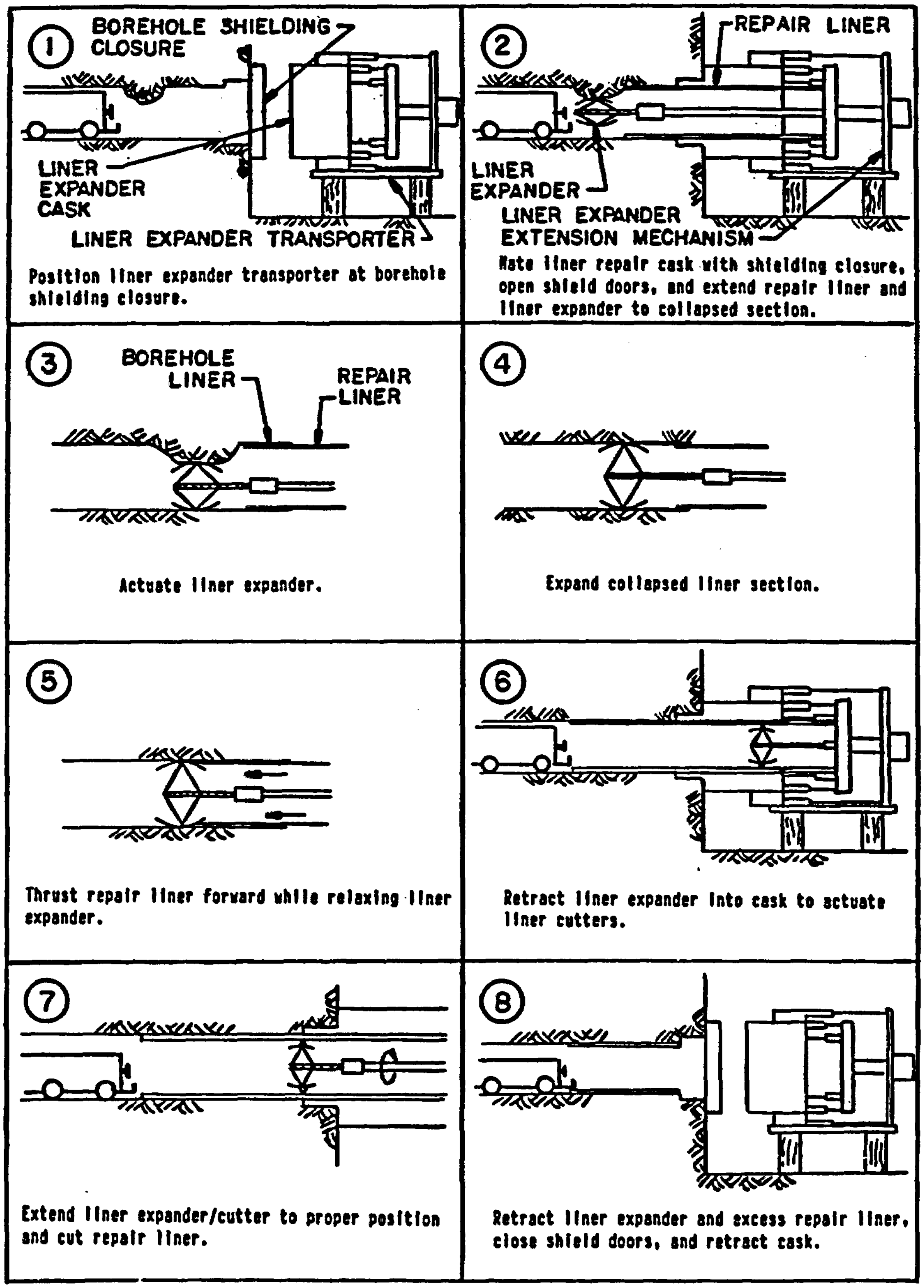
If the uncoupled dolly design is adopted, the instrumented retrieval cart could also be used to help prevent waste containers from becoming bound in a deformed liner section. For example, automatic sensing of the liner diameter during borehole entry for normal waste removal operations could be used to alert operators in the event that a liner section is deformed beyond some acceptable limit for waste container passage. Liner repair procedures such as those described below could then be performed before waste container removal is attempted, thereby preventing possible binding of the waste container and worsening of an off-normal condition.

Liner Repair Operations

In the unlikely event that the liner collapses in the standoff region between the borehole entrance and the last container emplaced, it may be possible to effect repairs of the liner and thereby restore the capability to remove waste containers with the retrieval cart and cask mechansim. Two procedures for performing this operation are being considered for further evaluation.

The first of these concepts is illustrated in Figure 14. This figure assumes that the instrumented retrieval cart has been used to assess the liner damage and to measure the inner diameter of the liner between the borehole entrance and the collapsed section. This data is used to select a diameter and thickness of the repair liner which are compatible with the inner diameter of the undamaged liner and the outer diameter of the waste container. A remotely actuated mechanism is then inserted to the damaged liner section and expanded to reopen the collapsed section. Repair liner is then inserted to line the damaged section.

The second concept for liner repair differs from the first in only one aspect: the liner expander is replaced with a rotating drill bit with expandable reaming arms that allow the bit to drill a hole larger than the repair liner outside diameter but also retract in order to fit inside the repair liner for withdrawal from the borehole. The drill bit used for this purpose must be capable of cutting the damaged steel liner, the repair liner, and any rock that may protrude into the borehole. The repair liner in this case is advanced into the borehole as the drill bit progresses through the damaged section, thereby preventing subsequent rock fall and binding of the drill bit. When the damaged section has been completely drilled and reopened, the bit is withdrawn and the repair liner is cut to length, leaving the repair liner in the borehole to keep it open.



1. Position liner expander transporter at borehole shielding closure.
2. Nate liner repair cask with shielding closure, open shield doors, and extend repair liner and liner expander to collapsed section.
3. Actuate liner expander.
4. Expand collapsed liner section.
5. Thrust repair liner forward while relaxing liner expander.
6. Retract liner expander into cask to actuate liner cutters.
7. Extend liner expander/cutter to proper position and cut repair liner.
8. Retract liner expander and excess repair liner, close shield doors, and retract cask.

Fig. 14 - Repairing a section of damaged liner

Alternate Access Concept

If it is not possible to repair a collapsed liner section in order to free blocked containers, it will be necessary to create alternate access to the containers in order to ensure removal. The proposed repository design features parallel emplacement drifts in each emplacement panel and main, perimeter, and panel access drifts along the perimeter of each emplacement panel (see Subsection 2.2.1). As a result, alternate access to a given borehole can be provided by constructing a drift parallel to the emplacement drift serving that borehole.

The concept is illustrated in Figure 15. The alternate access drift shown provides access to the blocked waste containers from the end of the borehole opposite that used in normal retrieval. For this concept to be viable, the first dolly emplaced in each borehole must contain a shield plug rather than a waste package. This would allow construction of the alternate access drift and preparation of the newly exposed end of the borehole to be completed without significant radiological exposure to the workers from the emplaced waste. Following borehole preparation, retrieval operations could continue using the retrieval cart and cask mechanism. Of course, this implies that pull-rings used by the retrieval cart grapple must be placed on both ends of the waste dollies prior to emplacement.

Procedures for Retrieving Bound Waste Containers

In the unlikely event that the liner collapses on a container or the container is otherwise bound in a horizontal borehole, it will be necessary to create alternate access to the waste container and free it prior to removal. (If the dollies are coupled, it will be necessary to first uncouple the dollies between the borehole entrance and the bound waste container and to remove the unbound waste containers using the retrieval cart.) Two concepts for removing bound waste containers are being considered for further evaluation: (1) reaming and coring through the original borehole; and (2) reaming and coring through the original borehole, coupled with construction of an auxiliary access drift for performing an auxiliary liner-cutting operation.

Horizontal Reaming and Coring Operations

The concept for reaming and coring operations to remove a bound waste container from a horizontal borehole is shown in Figure 16. With this concept, a reaming drill system is used to enlarge the borehole between the entrance and the bound waste container. A core drill system is then used to core the rock surrounding the waste container, cut through the liner at the end of the waste container, and retrieve the waste container core into a shielded cask for subsequent transport and delivery to the surface.

If other containers are still in place in the borehole, the procedure described above may be repeated in order to retrieve them. Alternatively, if the remaining containers are not blocked or bound, they may be retrieved through the alternate access drift previously described or through the original enlarged borehole, using the retrieval cart. In the latter case, it would be necessary to emplace a ramp in the borehole for the cart to use in climbing the step from the enlarged borehole section into the original

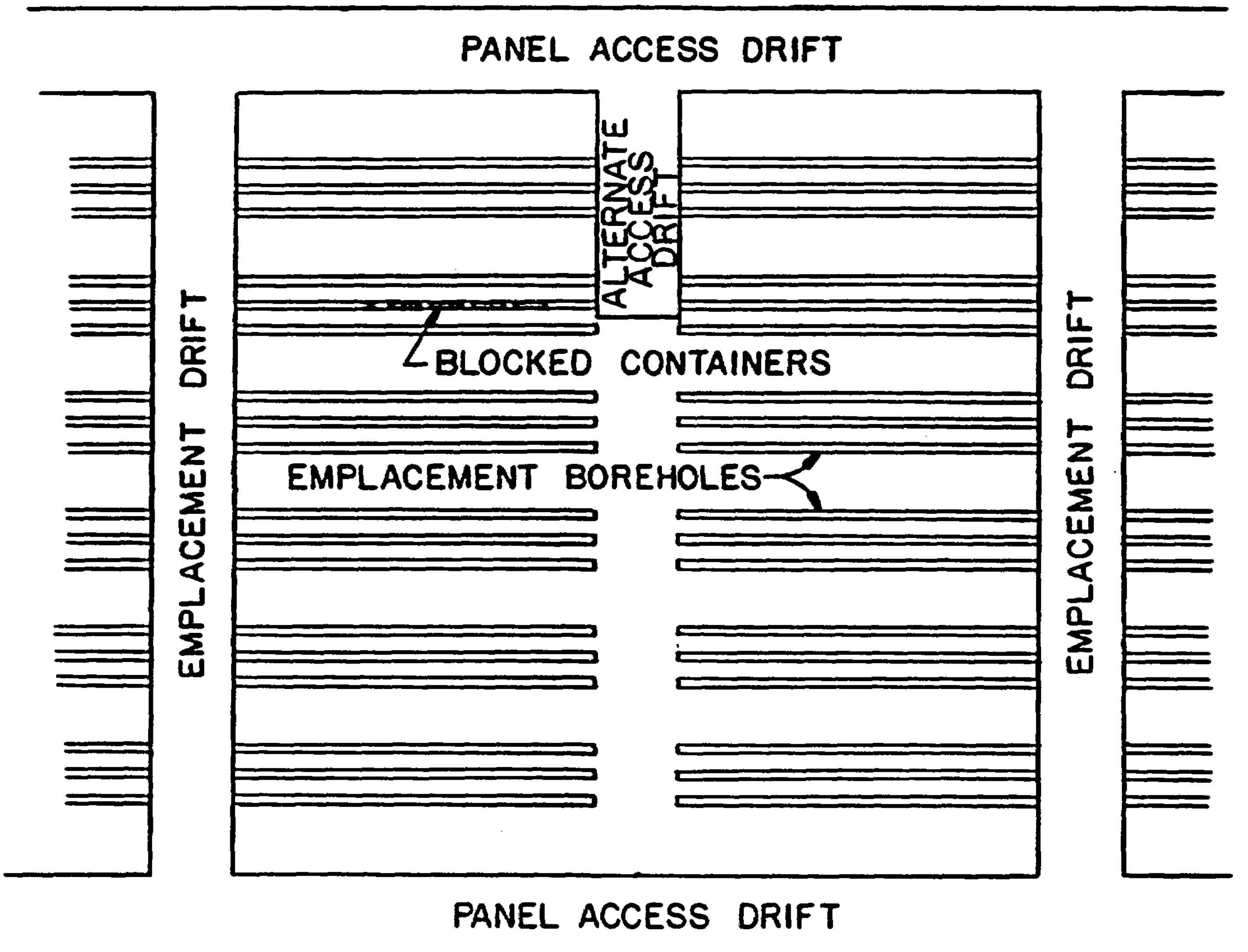


Fig. 15 - Concept for providing alternate access to blocked waste containers

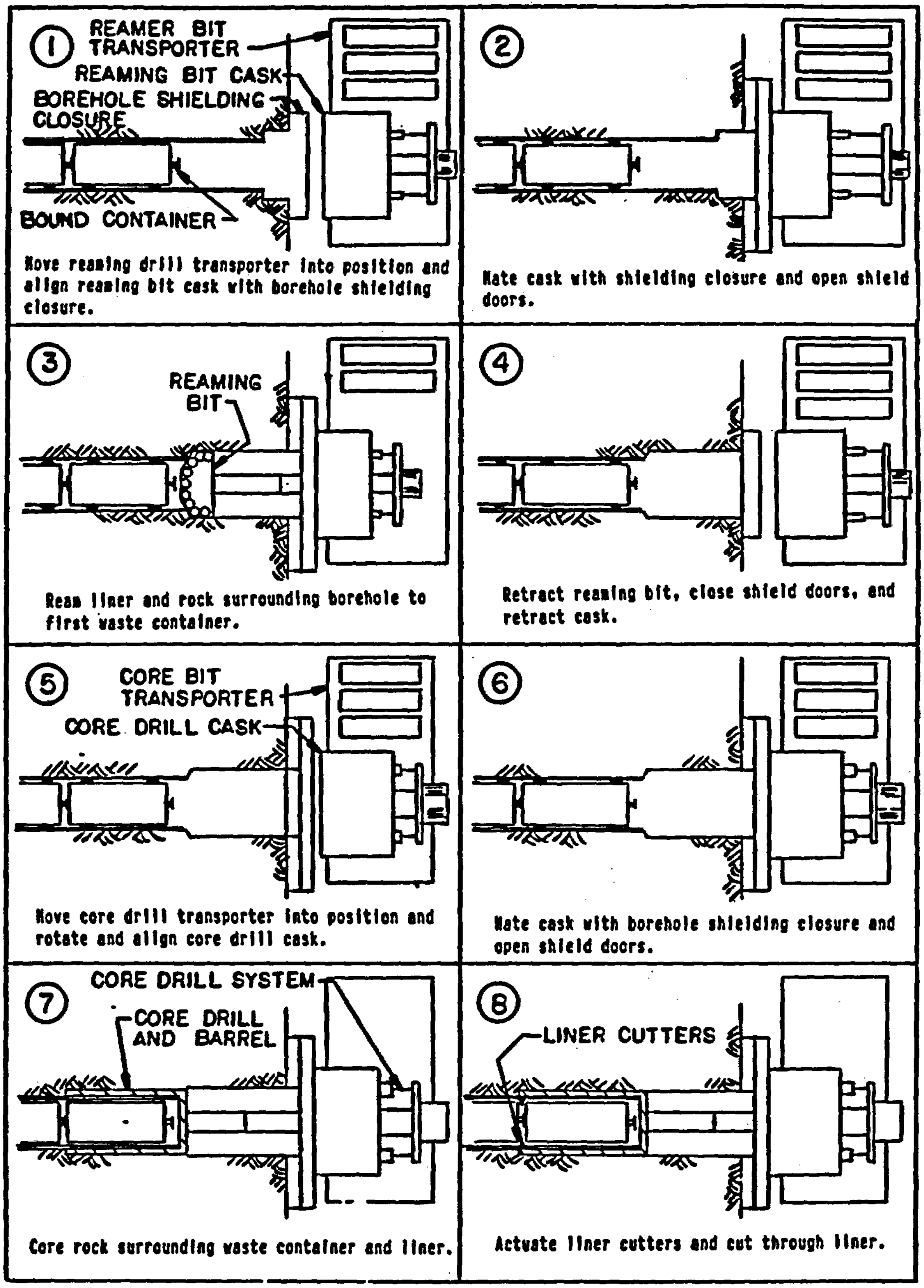


Fig. 16 - Reaming and coring through the original borehole to remove a bound waste container

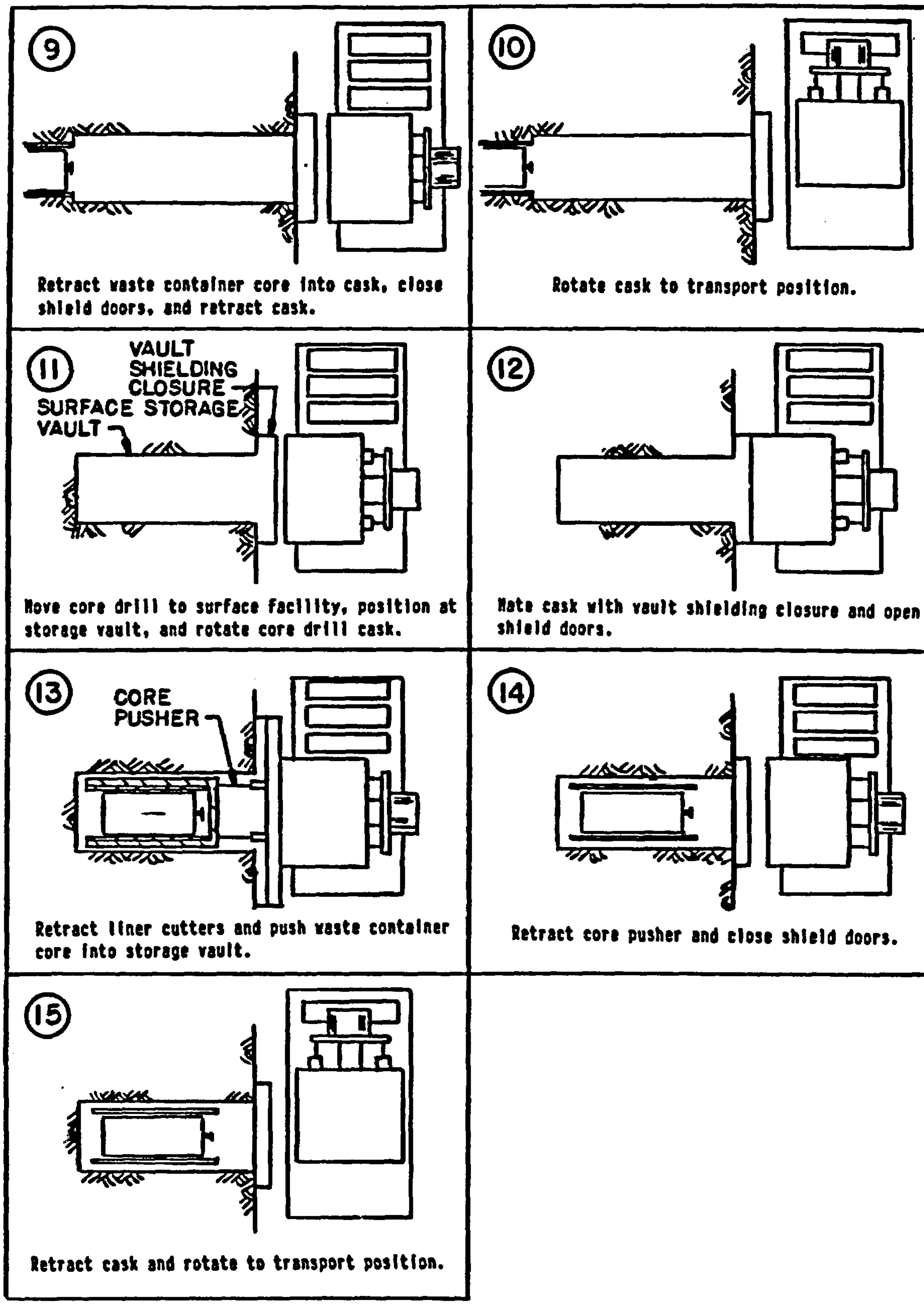

9
Retract waste container core into cask, close shield doors, and retract cask.
10
Rotate cask to transport position.
11
VAULT SHIELDING CLOSURE
SURFACE STORAGE VAULT
Move core drill to surface facility, position at storage vault, and rotate core drill cask.
12
Mate cask with vault shielding closure and open shield doors.
13
CORE PUSHER
Retract liner cutters and push waste container core into storage vault.
14
Retract core pusher and close shield doors.
15
Retract cask and rotate to transport position.

Fig. 16 (cont'd)

borehole section. If sloughing of the borehole walls proves to be a problem in the enlarged borehole section, it may be necessary to insert a liner in the enlarged section.

Auxiliary Liner Cutting Operations

In some cases, for example with a heavily deformed liner, it may not be possible to cut the liner at the end of the waste container core as described above in order to free the core for retrieval. Furthermore, if the dollies are coupled, it may not be possible to uncouple the dolly of the bound container from the remaining dollies. In such cases, it will be necessary to construct an auxiliary access drift to provide access for equipment used to cut the liner and dolly coupling from the side. The concept is illustrated in Figure 17.

The first step in this procedure is to construct an auxiliary access drift parallel to the emplacement borehole at a distance which provides workers with adequate shielding from the emplaced waste by the intervening rock during drift construction. At the location where the liner must be cut, a borehole shielding closure is installed on the rib of the auxiliary access drift.

A shielded drill machine is then moved into place in the auxiliary access drift to drill an auxiliary borehole to the emplacement borehole liner. Following this operation, a shielded liner cutter is moved into place to cut through the liner (and dolly coupling, if necessary). The waste container core can then be removed through the original borehole into the core drill cask.

2.2 Potential Advantages of Horizontal Emplacement

The basis on which the comparisons of vertical and horizontal emplacement are made are the reference designs that are presented or will be presented in the following reports:

SAND84-1351 Two-Stage Repository Development at Yucca Mountain: An Engineering Feasibility Study

SAND84-2641 Site Characterization Plan Conceptual Design Report (in progress)

2.2.1 Technical advantages

Analyses to date reveal several technical advantages of horizontal emplacement over vertical emplacement. These advantages result in a simpler, safer, and more effective repository configuration. They include a decreased extraction ratio, lower emplacement drift temperatures, simplification of the underground ventilation system, a smaller surface muck pile, and several safety and performance advantages.

Decreased Extraction Ratio

Figures 18 and 19 show the underground layout and a typical emplacement panel for vertical emplacement. Figures 20 and 21 show the underground

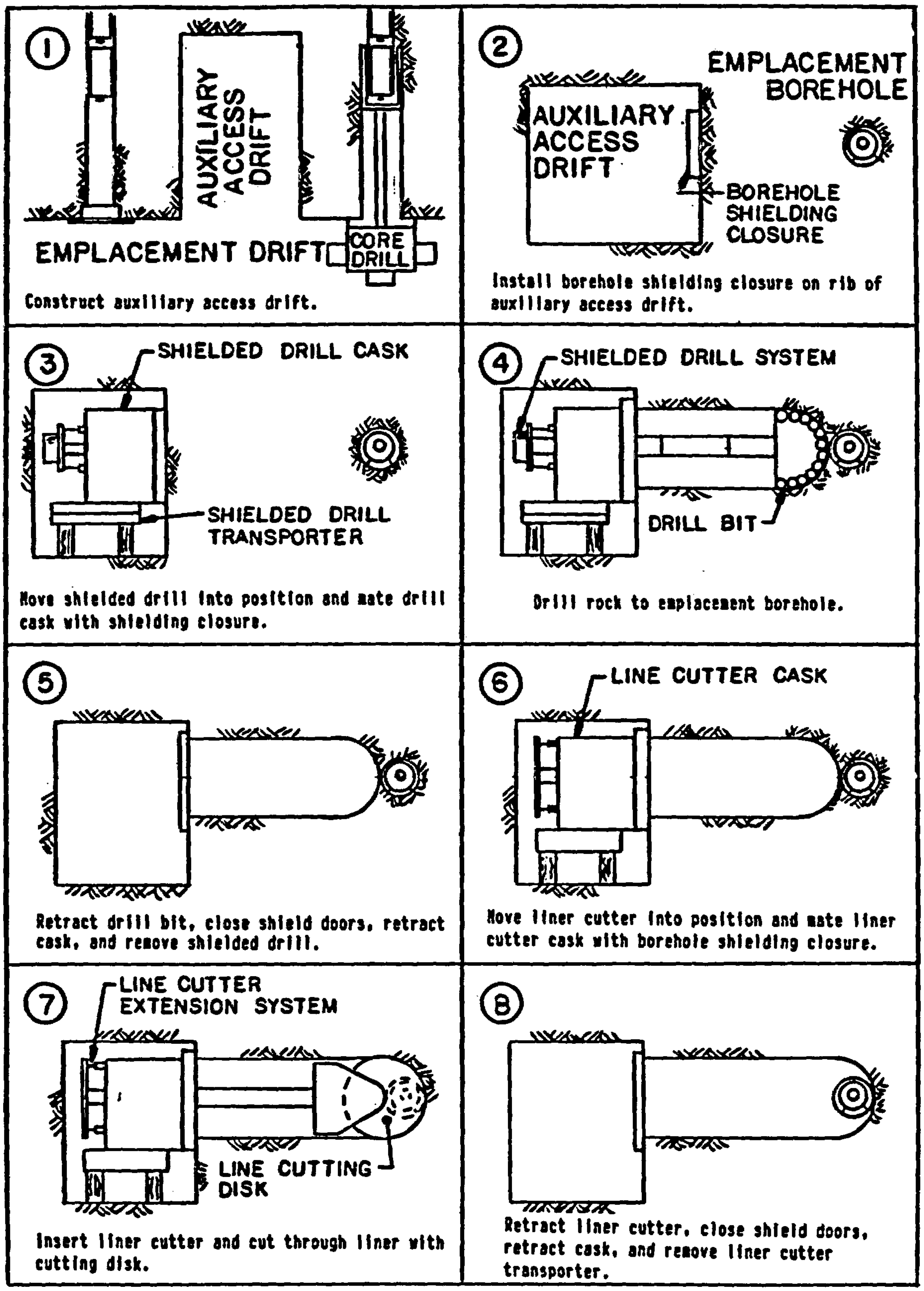


Fig. 17 - Performing auxiliary liner cutting operations from the auxiliary access drift

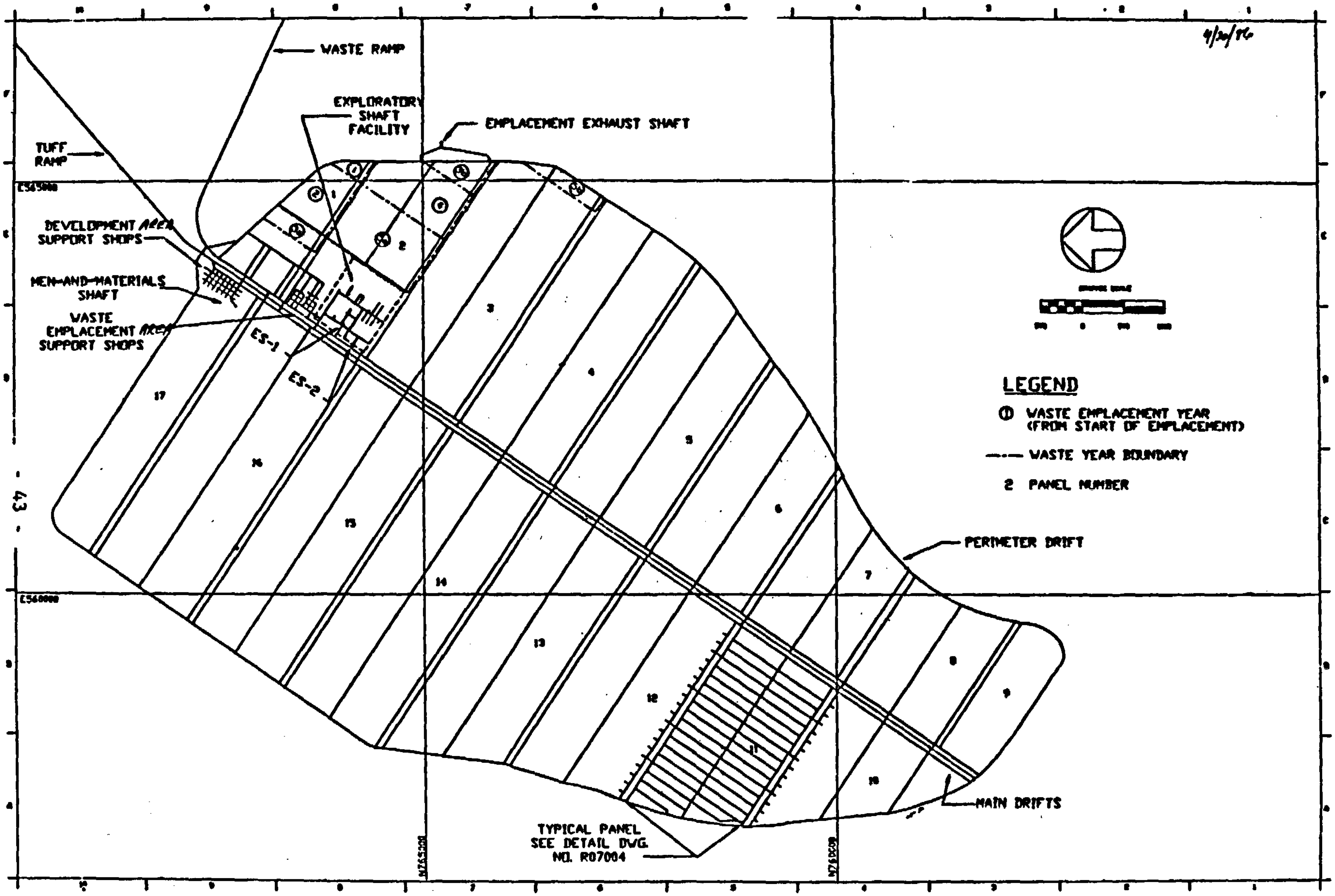


Fig. 18 - Underground facility layout for vertical emplacement

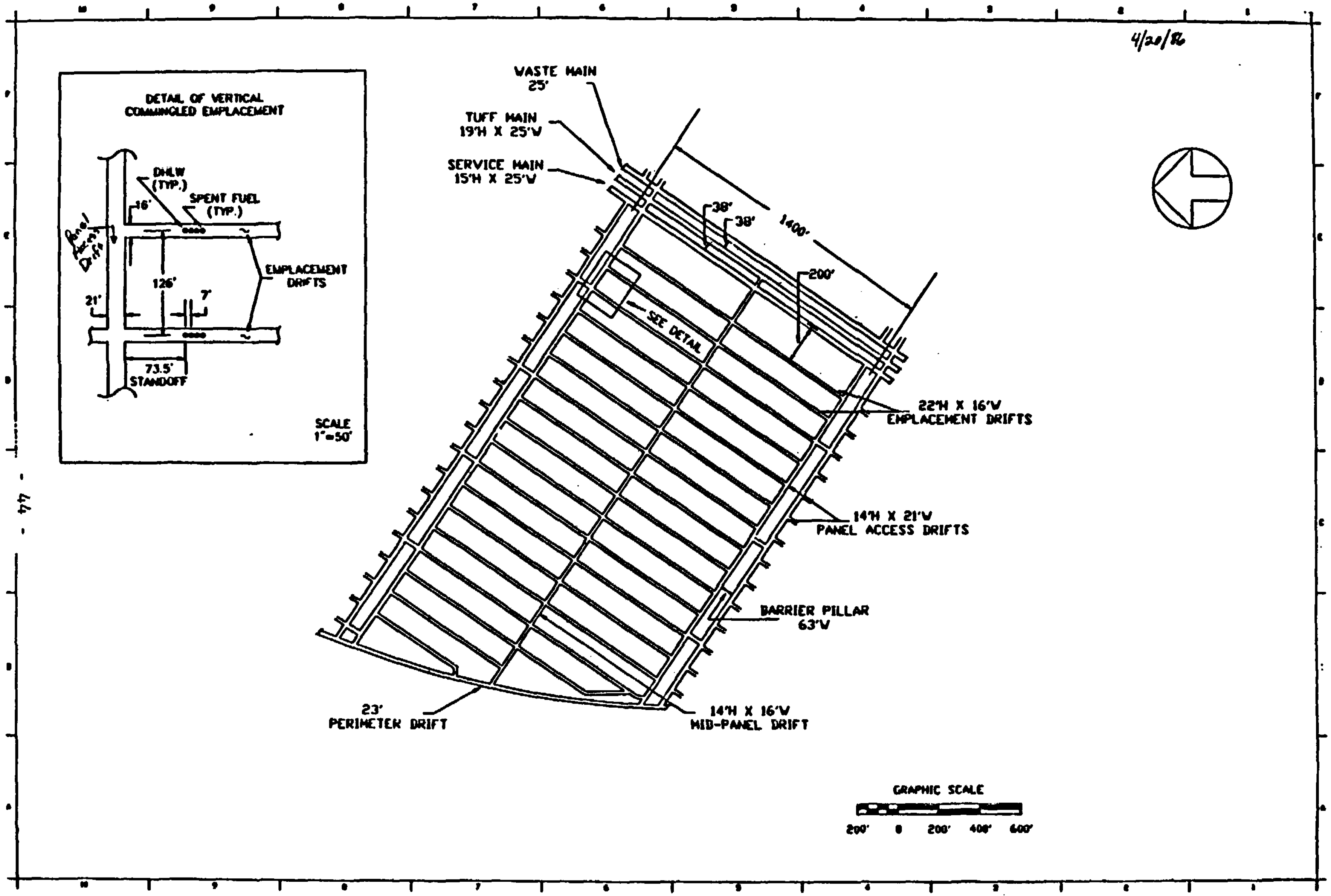


Fig. 19 - Panel layout for vertical emplacement

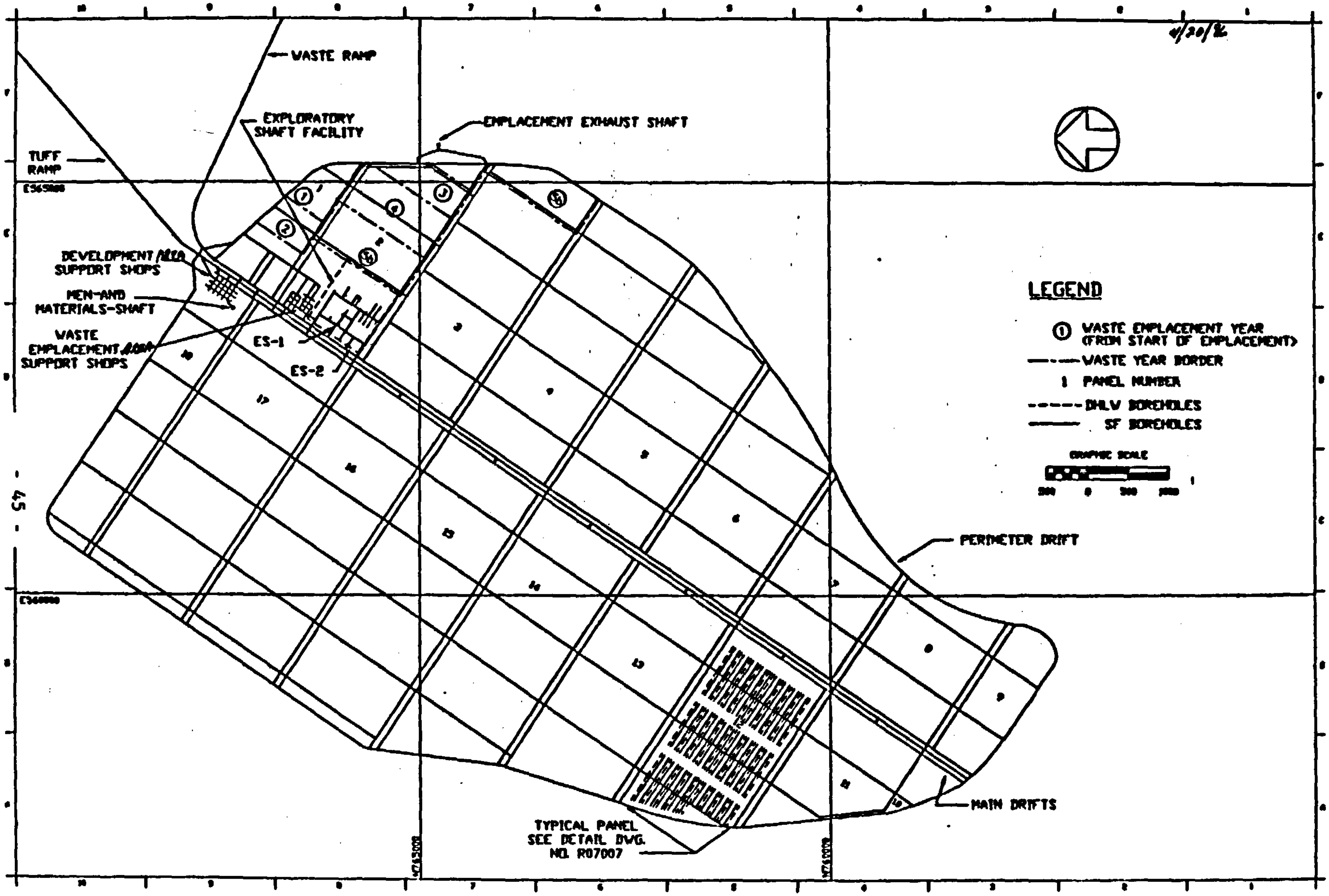


Fig. 20 - Underground facility layout for horizontal emplacement

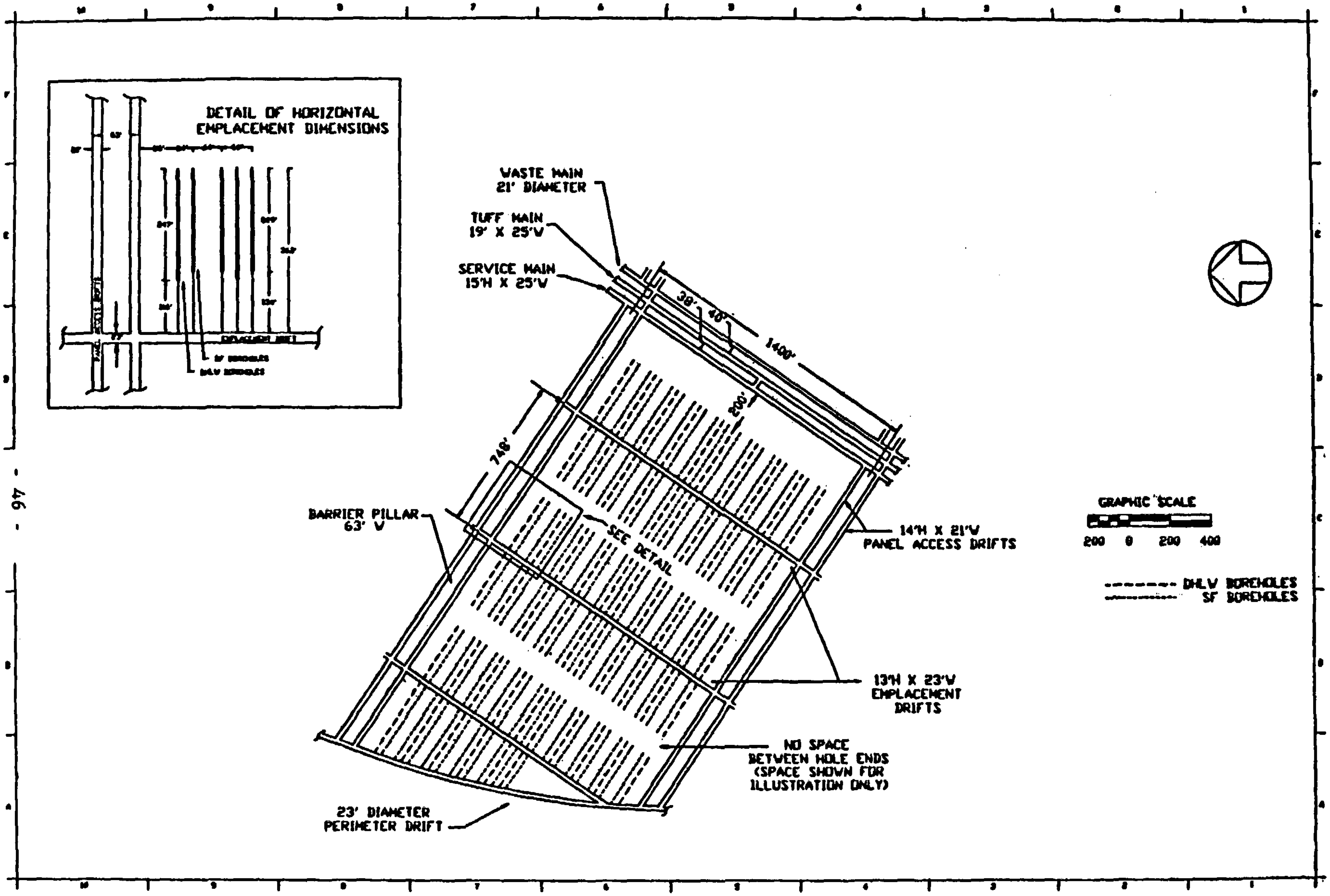


Fig. 21 - Panel layout for horizontal emplacement

layout and a typical panel for horizontal emplacement. Based on a single emplacement panel, including the drifts that provide access and ventilation to the waste emplacement drifts, the extraction ratio for vertical emplacement is approximately 18.3%. On the same basis, for the same quantity of stored waste, the extraction ratio for horizontal emplacement is 7.1%.

Within a single emplacement panel, a comparison of extraction ratios can be made by comparing the number and widths of drifts for each configuration. For horizontal emplacement (Figure 21), the distance between the 23 foot-wide emplacement drifts is 748 feet. For vertical emplacement (Figure 19), there are seven drifts, each 16 feet wide, within the same 748-foot width. The ratio of vertical to horizontal extraction of rock, based on these considerations, is thus

$$\text{vertical extraction/horizontal extraction} = (7 \times 16)/(1 \times 23) = 4.87.$$

Lower extraction ratios result in less potential subsidence and hence less disturbance of the natural state of the emplacement and overlying geological horizons.

Lower Emplacement Drift Temperatures

The last waste package installed in a horizontal emplacement borehole can be emplaced with sufficient standoff from the emplacement drift wall to delay an increase in the temperature of the emplacement drift. This temperature delay can be adjusted by varying the standoff. A relatively small standoff is sufficient to retard the increase in drift temperatures for a long period of time. The lower temperature allows repository personnel access to the emplacement drifts for inspection, instrument observation, maintenance, and other tasks without the need to reestablish large ventilation flows for cooling of the drift.

Figure 22 shows drift temperatures versus time since emplacement for the vertical and horizontal configurations. Note from the figure that the emplacement drift for horizontal emplacement is calculated to be only 52°C (125°F) 50 years after waste emplacement, as compared with 120°C for the vertical orientation.

Simplification of Underground Ventilation System

The number of emplacement drifts needed for horizontal emplacement is considerably less than the number needed for vertical emplacement. This reduces the requirements for ventilation stoppages, airlocks, regulators, and other air control features. Air quantities are also reduced with horizontal emplacement, which reduces initial capital equipment costs and long-term operational costs.

Figures 23 and 24 show the ventilation schematics for vertical and horizontal emplacement, respectively. Comparison of the figures dramatically illustrates the simplification claimed. An example of the simplification is that the number of stoppages and bulkheads is reduced by as much as 70%.

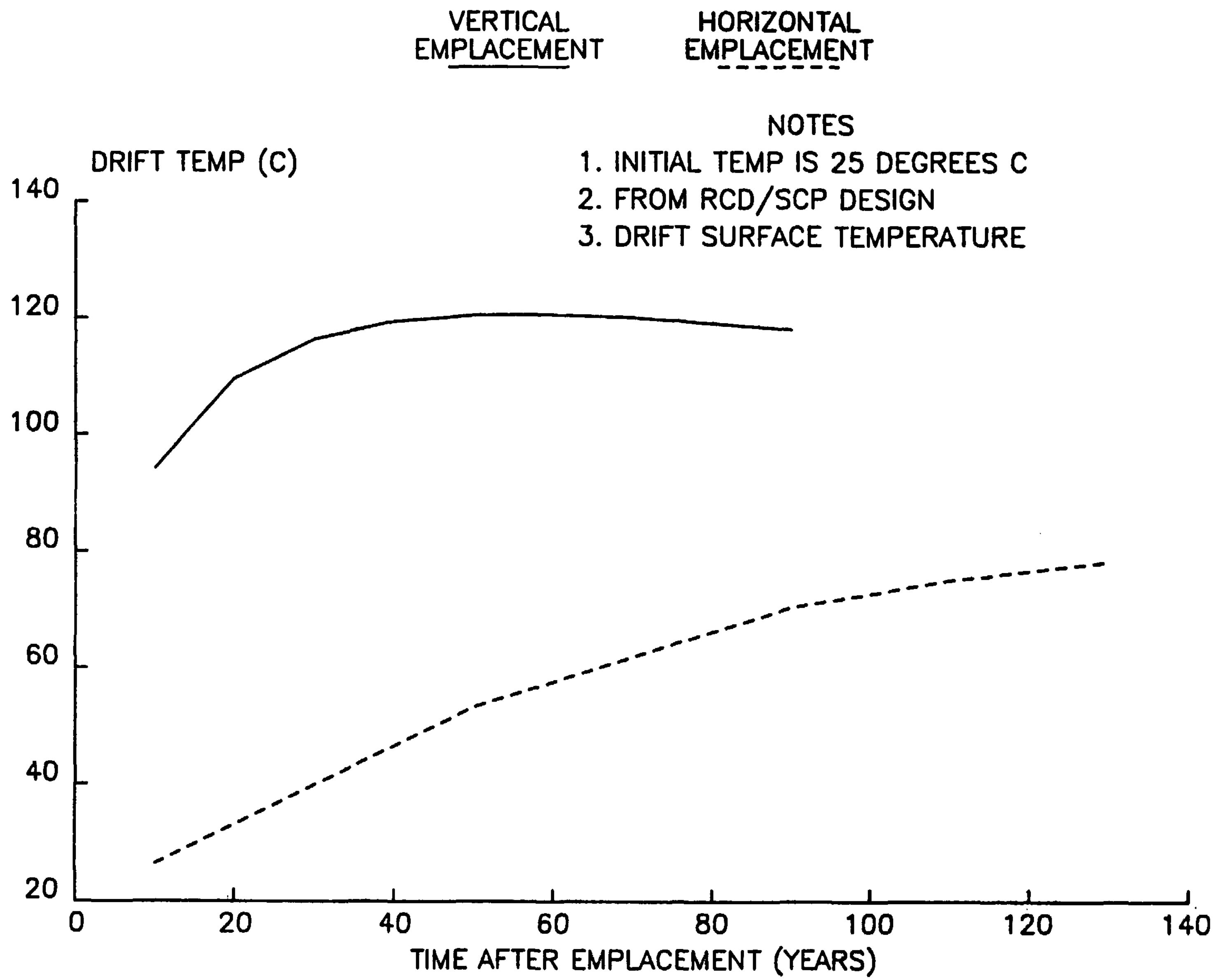


Fig. 22 - Comparison of drift temperatures for vertical and horizontal emplacement

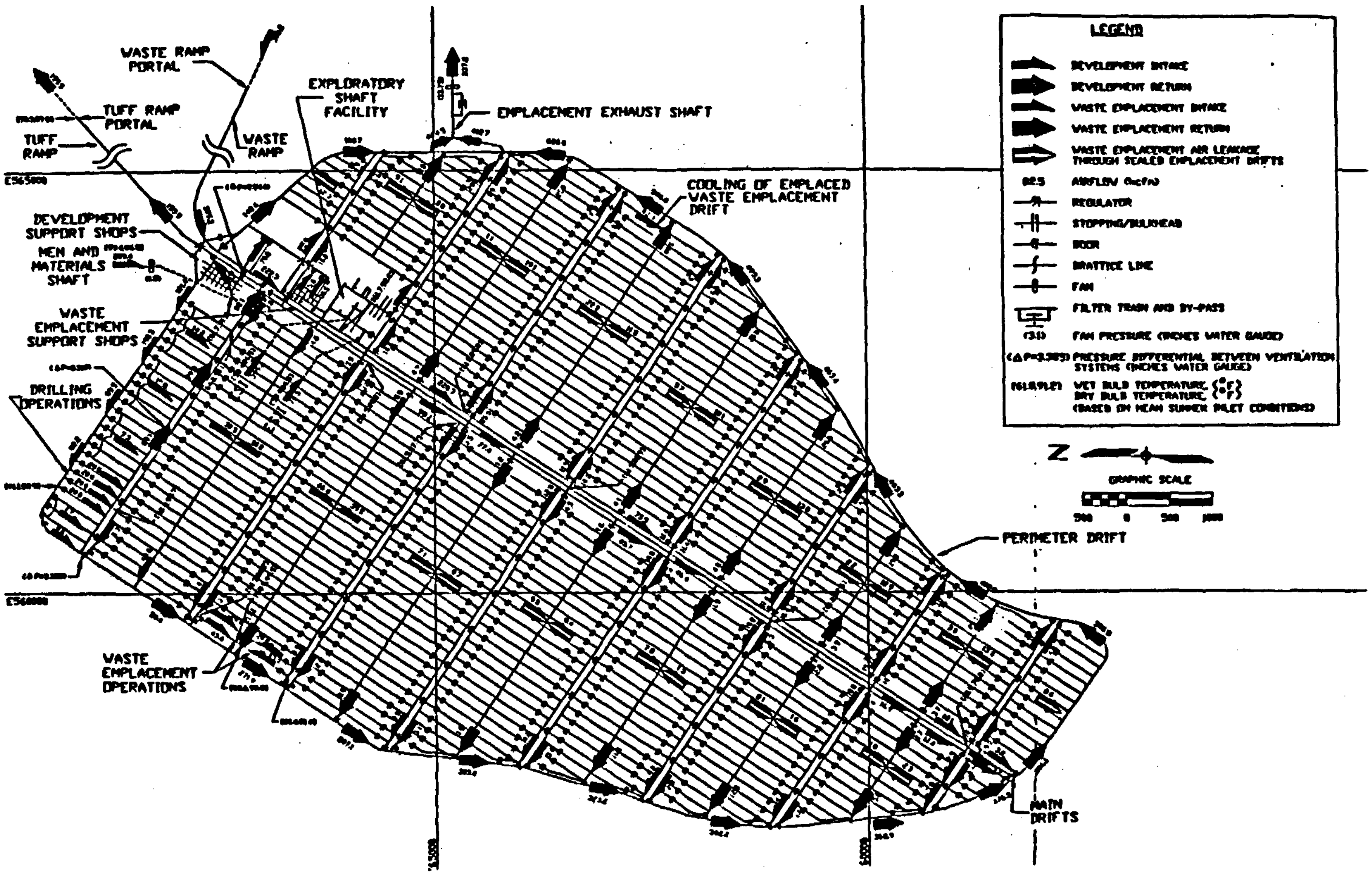


Fig. 23 - Drift ventilation layout for vertical emplacement

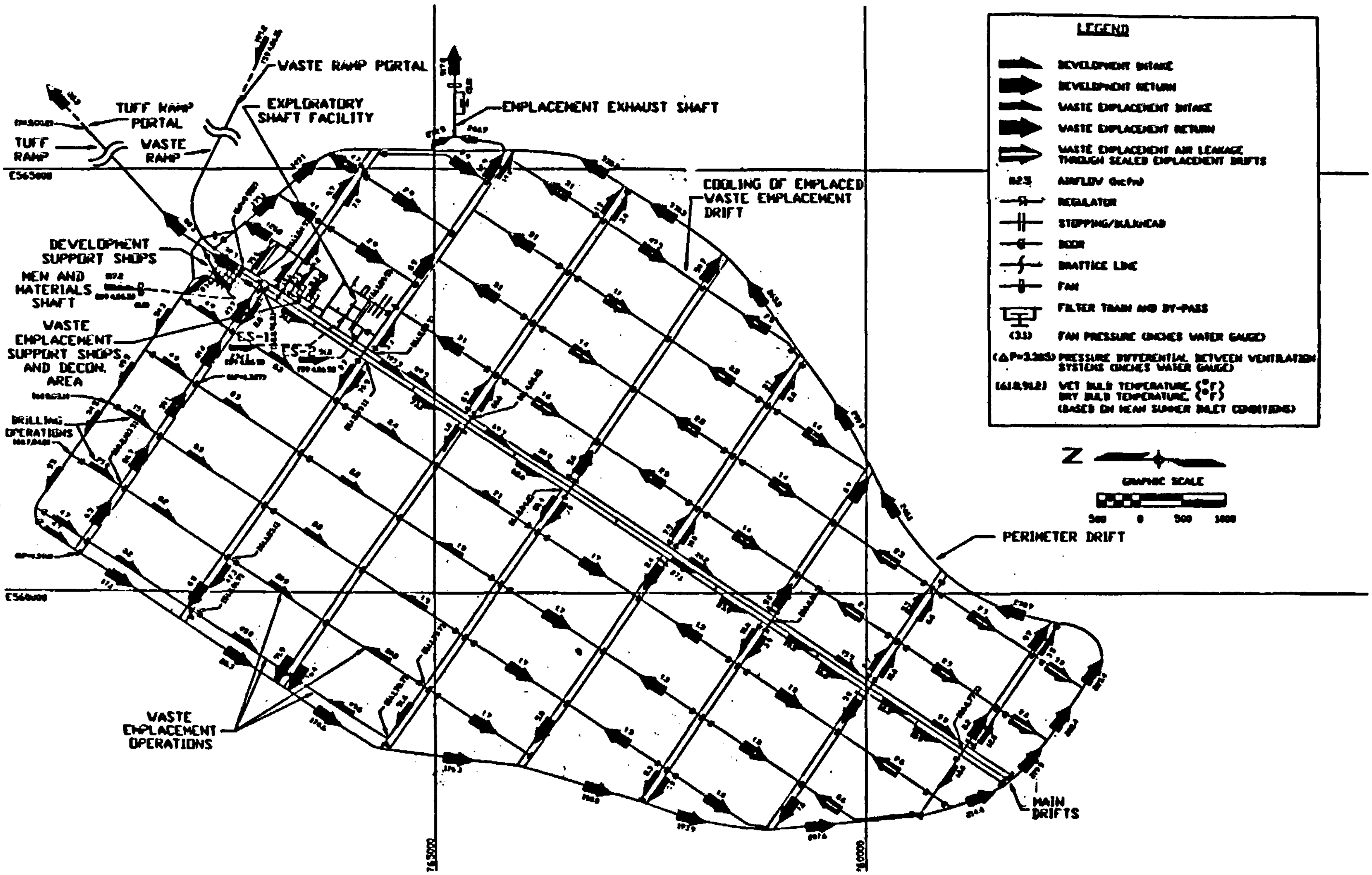


Fig. 24 - Drift ventilation layout for horizontal emplacement

Decreased Size of Surface Muck Pile

Vertical emplacement requires 14,356,900 tons of material to be mined, whereas horizontal emplacement requires only 5,305,400 tons of mining (SAND84-2641, previously cited). Although the repository may be backfilled with mined material after waste emplacement operations are complete, volumetric expansion of the material during mining will prevent return of all the material back underground. The considerable difference in mined quantities between the two emplacement configurations has a major impact on the size of the mined material storage and disposal pile on the surface and, consequently, the visual and environmental impact of the repository. These mined quantities are tabulated in Section 2.2.2.

Safety Advantages

The smaller number of borehole preparations and closures required for horizontal emplacement will result in a smaller radiation dose to underground emplacement workers, e.g., for vertical emplacement, there will be 15 times as many shield plug installations as there will be for horizontal emplacement (based on the current design that places 15 waste packages in a single horizontal emplacement hole). Furthermore, radiation levels in the drifts should be lower with horizontal emplacement due to the greater standoff of the waste packages.

The amount of mining required to support horizontal emplacement is considerably less than that required for vertical emplacement (see mining quantities and crew sizes presented in Section 2.2.2). This reduction in mining crew size reduces the total personnel exposure to the hazards associated with mining.

Performance Advantages

There are a number of potential repository performance advantages that may be realized if horizontal emplacement is used. At this point these potential advantages have been identified only to substantiate that horizontal emplacement is not detrimental to operational or long-term repository performance when compared with vertical emplacement. Examples of potential performance advantages are:

1) The waste package is further isolated from repository construction features such as borehole collars and drift support systems that may utilize materials such as concretes or grouts. This advantage is related to the possibility for modification of groundwater chemistry. This scenario is currently being actively assessed by the NNWSI project.

2) In the unlikely event that a drift floods with water, flood waters would have to reach higher levels in order for the water to enter a waste emplacement borehole and contact the waste packages.

3) The emplacement drifts for horizontal emplacement are more stable than the drifts necessary for vertical emplacement because of the drift shapes required in each configuration, the vertical jointing of the host rock formation, and the anticipated thermal stresses.

4) Construction blast over-break (i.e. propagation of fractures into surrounding media during drift blasting operations) has a greater potential for creating a preferential path for groundwater movement past the containers in the vertical configuration since the containers would be placed closer to and directly under the drift. The potential significance of this factor is not known at the present time.

2.2.2 Cost Advantages

Cost Savings Based on the Two-Stage Repository Concept

The report "Two-Stage Repository Development at Yucca Mountain: An Engineering Feasibility Study," SAND84-1351, illustrates the cost benefits that result from horizontal emplacement. The following is a summary of the cost benefits indicated by this report. The costs are listed for the more significant cost accounts used in the report:

TABLE 1. MAJOR COSTS OF VERTICAL AND HORIZONTAL EMPLACEMENT (SAND84-1351)

Vertical Emplacement

	Costs (Millions)			
Cost Account	Engr & Const	Operation	Decomm	Total
Transfer & Emplacement	99.6	1,138.2	0	$1,237.8
Corridors	113.0	383.0	0	$ 496.0
				$1,733.8

Horizontal Emplacement

	Costs (Millions)			
Cost Account	Engr & Const	Operation	Decomm	Total
Transfer & Emplacement	81.0	635.9	0	$716.9
Corridors	76.9	39.7	0	$116.6
				$833.5

This represents a cost savings of $900,000,000 based on these accounts alone. The total repository cost from this report is $7,013,604,000 for vertical emplacement and $5,924,215,000 for horizontal emplacement ... thus the total difference is $1,089,215,000. This comparison does not include the higher development costs associated with horizontal equipment; however, this cost differential is expected to be only a very small percentage of the differences cited above.

The major item impacting the difference in cost for vertical and horizontal emplacement is the quantity of mining required. This quantity affects crew sizes, equipment requirements, and material requirements. A summary comparison of the differences in mined quantities and crew sizes is as follows:

TABLE 2. MINING REQUIREMENTS FOR VERTICAL AND HORIZONTAL EMPLACEMENT (SAND84-1351)

Option	Drift Length	Tons Mined	Mining Crew
Vertical Emplacement	610,740	14,356,900	305
Horizontal Emplacement	245,870	5,306,400	83

The tonnage difference is 9,050,500 tons, and the difference in crew size is 222 people.

Cost Comparison by Another Approach

Figure 25 compares the total underground-related costs for vertical and horizontal emplacement, based on different quantities of waste packages. This comparison is based on work done to support the following report:

SAND85-1580 Cost Comparison of Horizontal and Vertical Waste Emplacement Methods for a Repository in Tuff," SAND85-1580 (draft)

The comparison is based on: (1) horizontal emplacement using 300 foot-long emplacement boreholes and a 100 foot standoff from the wall of the emplacement drift to the last waste package emplaced; and (2) a vertical emplacement configuration as defined in SAND84-2641, previously cited. The potential savings using horizontal emplacement by this comparison can be as much as $800 million for the approximately 40,000 waste packages of spent fuel, defense high-level waste (DHLW), and West Valley high-level waste (WVHLV) that could be received.

Figure 26 presents the results of an analysis done in SAND85-1580 to choose the length of borehole to be used. From this figure, it is obvious that the most significant part of the cost savings is achieved with horizontal borehole lengths of 300 to 400 feet; therefore, there is little incentive to employ longer and more difficult to drill horizontal emplacement holes.

Other Areas of Cost Savings

Cost savings will be realized using horizontal emplacement in areas other than mining; some of the other areas are:

o Borehole drilling - Horizontal emplacement would reduce the amount of borehole drilling, the labor required for drilling, and the quantitiy of rock material removed. For vertical emplacement, each individual borehole would require a standoff distance from the waste package to the floor of the emplacement drift; with horizontal emplacement, a single standoff distance would be required for up to 15 waste packages. The number of borehole drill set-ups would be less for horizontal emplacement by a factor equal to the number of waste packages in each horizontal borehole.

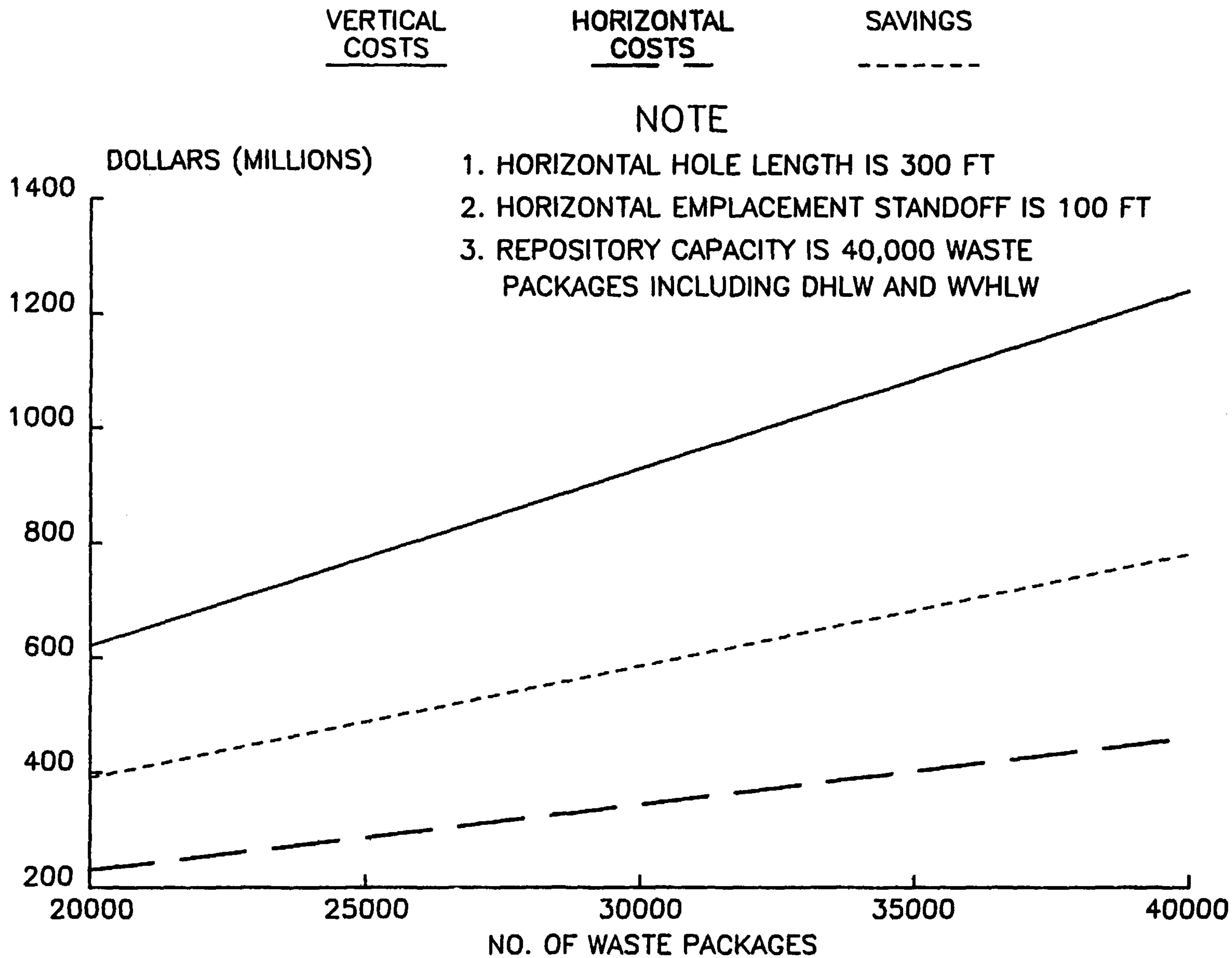


Fig. 25 - Emplacement costs and savings as a function of number of emplaced waste packages

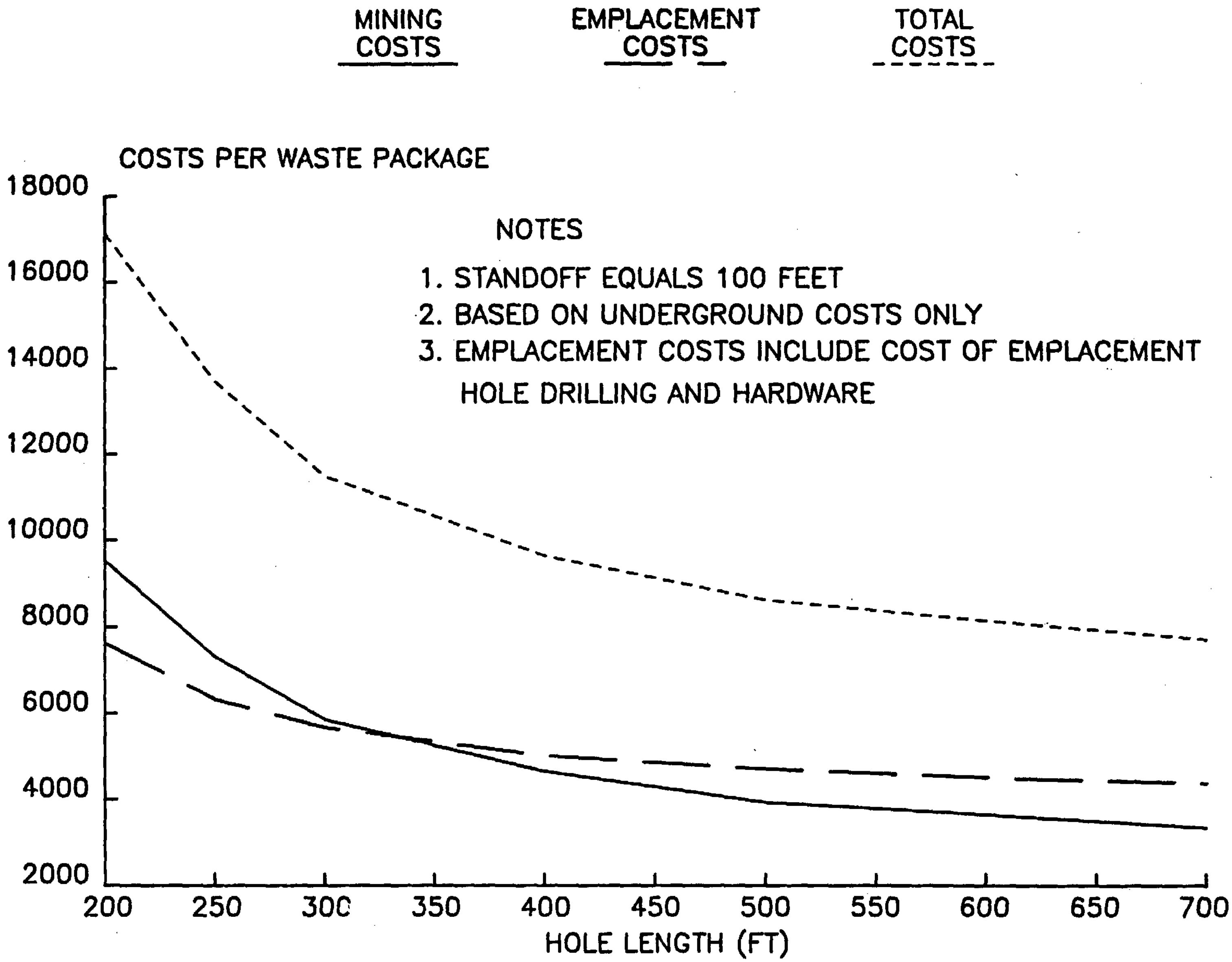


Fig. 26 - Cost per waste package as a function of horizontal borehole length

o Borehole hardware - Fewer shield plugs, borehole covers, monitoring instruments, and site preparations are required for horizontal emplacement. The cost of these and other items would be amortized over a greater number of waste packages in horizontal boreholes. With vertical emplacement, each borehole and waste package will require this hardware.

o Support labor - The ancillary tasks necessary to prepare and close an emplacement borehole require considerable labor. These tasks include the installation of the shielding closure, transporter guides, shield plug, and borehole cover. In the current tuff repository concept for horizontal emplacement, a minimum of 15 waste packages are emplaced in each borehole. In the vertical concept, only one waste package is placed in each borehole. This difference results in 15 times as many hole preparations and closures for vertical emplacement.

2.3 Potential Disadvantages of Horizontal Emplacement

2.3.1 Technical Disadvantages

Equipment Development

The horizontal emplacement equipment has not been constructed and demonstrated. Conceptual designs have been completed, and the concepts appear to be feasible, as discussed in Section 3. Questions about the adequacy of these concepts will exist until demonstrations are completed; however this disadvantage is not totally exclusive to horizontal emplacement. The demonstrations of vertical emplacement in Project Salt Vault and Climax demonstrated concept feasibility, but not to the level of detail required prior to license application. Selected proof-of-princple demonstrations will be required for either configuration, regardless of the configuration selected. Furthermore, systems needed for off-normal waste retrieval in both configurations are similar in complexity, and the need to demonstrate feasibility would exist with either configuration.

The development and demonstration costs will be higher for horizontal emplacement in that there are additional requirements for mechanisms; e.g., in horizontal emplacement a means must be devised to push the waste package into the disposal borehole, whereas in vertical emplacement gravity performs this function. The facility for horizontal emplacement equipment demonstration will be more extensive and costly due to the size required to replicate the emplacement borehole and emplacement drift.

The cost advantages for horizontal emplacement are predicated on the use of long emplacement holes that will contain a large number of waste packages. The ability to drill and line these holes has not yet been demonstrated; this is the most significant development that must be accomplished before a final decision for horizontal emplacement can be made.

Respository Performance

Horizontal and vertical emplacement present different physical configurations to model and analyze. Without extensive and detailed modeling and analysis, it is not possible to predict whether one configuration is superior to the other with respect to repository performance; however, bounding-type analyses and probabilistic-type analyses have been done, using conservative assumptions, to assess the magnitude of potential releases (SAND84-1492, "Preliminary Bounds on the Expected Postclosure Performance of the Yucca Mountain Repository Site, Southern Nevada" and SAND85-2701, "Preliminary Estimate of Groundwater Travel Time and Radionuclide Transport at the Yucca Mountain Repository Site"). These results lead one to conclude that there is little probability of a significant release consequence due to emplacement configuration.

Because the horizontal boreholes will be drilled blind, there is concern about the potential for the existence of faults through the boreholes. If the faults are considered potentially active and capable of displacements greater than a few centimeters, it would be conceivable that waste packages might become bound in the hole and thereby present a problem for retrievability. Flowpath modification due to fault movement also presents potential concerns. At this time, fault motion effects warrant further investigation to consider the potential for occurrence, the impact of their occurrence, and the likelihood that they might be undetected during access and perimeter drift construction.

With the horizontal concept, a concern exists that the metal in the liner could alter the water chemistry, resulting in accelerated waste package corrosion and/or waste form leaching. The potential for problems can be reduced or eliminated through the use of sacrificial materials and the proper selection of the liner material. It should be noted that the vertical configuration also includes a significant amount of shield plug and liner material above the waste package. It is unclear as to whether or not a quantifiable advantage or disadvantage exists (relative to the emplacement option decision) for the material compatibility considerations.

Retrievability

Based on the number of concepts presented for horizontal off-normal retrieval equipment versus the number of concepts presented for vertical off-normal retrieval equipment, it might be concluded that off-normal retrieval is more uncertain with the horizontal configuration. Comparisons between the configurations with respect to retrievability cannot be accurately made, however, until the off-normal conditions for each configuration are further evaluated to determine their credibility and probability of occurrence and until the development and demonstration needs are explicitly defined.

2.3.2 Cost Disadvantages

The development costs for the equipment to construct the emplacement boreholes and to emplace and retrieve the waste will be higher for the horizontal emplacement concept. It is anticipated, however, that these costs will represent only a small fraction of the potential savings associated with the horizontal emplacement option.

3.0 FEASIBILITY OF HORIZONTAL EMPLACEMENT CONCEPTS

This section addresses the feasibility of the horizontal emplacement concepts that have been developed. Feasibility is addressed in two ways. Section 3.1 presents a description of horizontal emplacement/retrieval equipment and a discussion of the practical aspects of equipment development; and Section 3.2 discusses general theoretical and analytical considerations related to the technical feasibility of the horizontal emplacement and retrieval system.

3.1 Equipment Feasibility

Assessment of equipment feasibility is accomplished by outlining the philosophy used in equipment design, describing equipment concepts, identifying key components and their functional requirements, and discussing similarities with equipment and operations already in existence that perform similar functions in other applications.

3.1.1 Equipment Design Philosophy

The equipment developed for borehole drilling, waste emplacement, and waste retrieval have been and will be designed according to the following principles:

- Primary emphasis will be placed on reliability, at the possible expense of efficiency. This will be accomplished by keeping designs as simple as possible.

- High safety margins will be employed to minimize the risk of damaging waste packages due to equipment failure and to minimize the potential for adverse consequences due to human error.

- Hazardous operations will be controlled remotely to minimize radiation exposure and other safety risks to personnel.

- Designs will be based on existing technology where possible in order to improve reliability and keep development costs down.

- Redundancy will be designed into key systems to minimize disruption of operations due to equipment failure.

- Backup equipment will be designed to perform critical functions in the event of primary equipment failure.

- Equipment will be designed for easy access to key components for maintenance and repair.

- Emplacement equipment will be designed so that it can also be used for normal retrieval operations.

- Equipment designs for off-normal conditions will be based on credible scenarios for those conditions.

3.1.2 Borehole Drilling and Lining Machine

3.1.2.1 Equipment Description

One of the least proven operations required for the horizontal emplacement concept is drilling and lining long, horizontal boreholes accurately and efficiently. Design of a system for performing this operation has been underway for several years and is described in the following reports:

SAND83-7085 Repository Drill Hole Methods Study

SAND84-0184 Full Face Boring of Long Horizontal Holes Versus Pilot Hole Drilling and Reaming

SAND84-7103 Small Diameter Horizontal Hole Drilling--State of Technology

SAND86-7004 Design of a Machine to Bore and Line a Long Horizontal Hole in Tuff (in review)

SAND86-7209 Feasibility Studies and Conceptual Design for Placing Steel Liner in Long Horizontal Boreholes for a Prospective Nuclear Waste Repository in Tuff (in review)

A schematic of the prototype development hardware currently under consideration is shown in Figure 27. This system consists of the following components:

Inhole drill

The drill motor is located inside the borehole and drives a drill head fitted with carbide-insert roller cutters. The drill is connected to the borehole liner through a ball joint assembly that allows the drill head to be steered in order to maintain proper trajectory. Steering is accomplished by hydraulically actuating wedges that push against the liner and force the drill head into alignment with the desired trajectory. A laser guidance system is used by the operator to determine the current position of the drill head so that corrective steering action can be taken. The laser guidance system to be used has performed successfully on numerous tunnel boring machines (TBMs).

The borehole drilling system is designed to drill a hole with a deviation of less than six inches per 100 feet, with a total deviation for the entire hole of less than 12 inches. The use of a laser guidance system and the ability to directly steer the drilling head should allow this accuracy to be maintained. As a result, boreholes will be staight enough to prevent waste packages from becoming stuck as a result of hole deviation because the clearance between the 16 foot-long waste packages and the liner will be a minimum of 1.5 inches.

The drill is designed so that it can be removed from a partally completed hole for maintenance or repair.

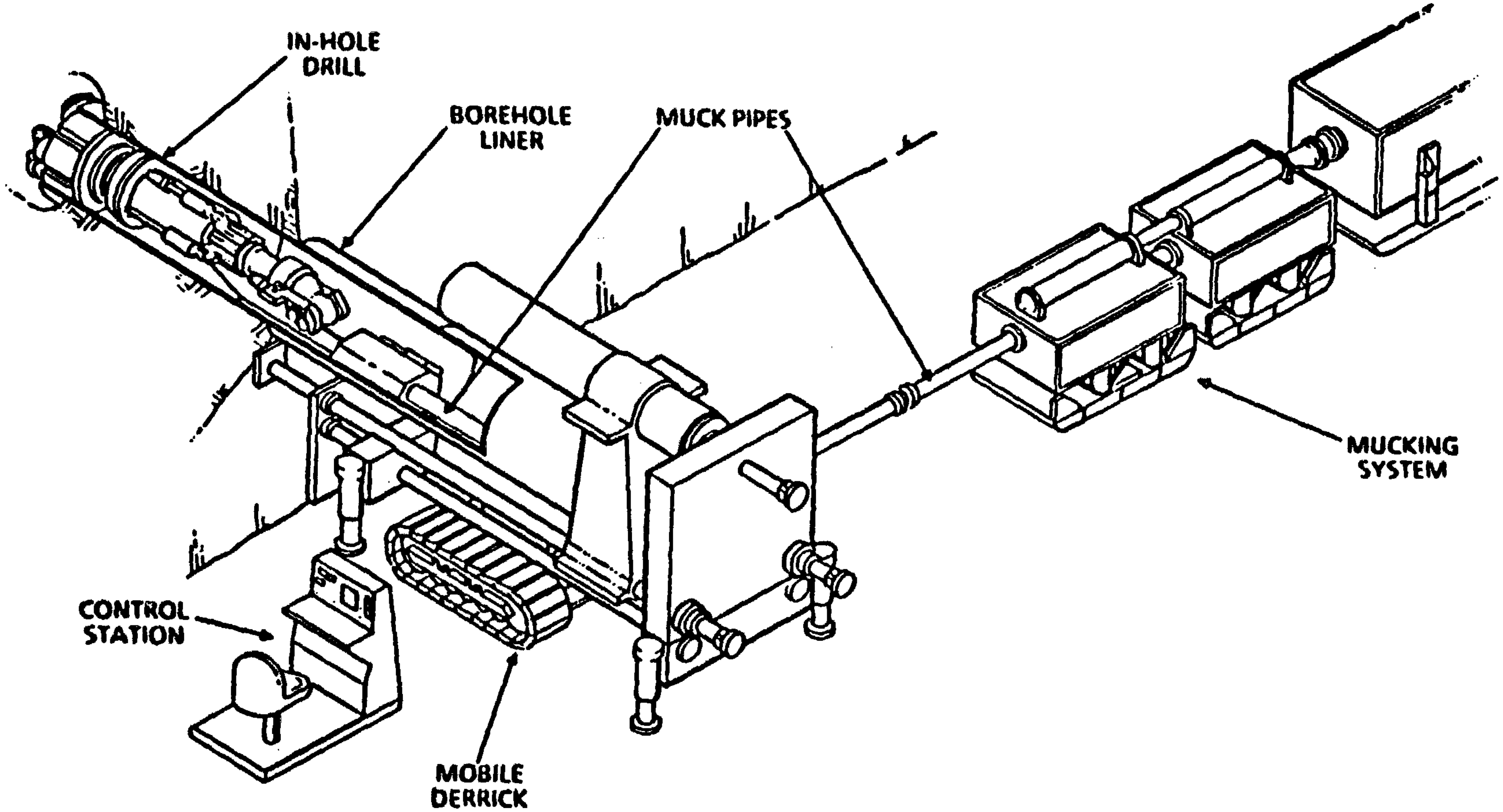


Fig. 27 - Horizontal borehole drilling and lining machine

Borehole liner

Lining of the borehole is accomplished as the hole is drilled. Thrust to the inhole drill is transmitted from the mobile derrick through the liner and ball joint assembly. The inhole drill can be removed for maintenance and upon completion of the hole by remotely uncoupling the ball joint assembly from the liner and pulling the drill assembly through the inside of the liner. The drill head diameter is smaller than the liner inside diameter, making this operation possible. By mounting the drill head eccentrically to the rotary shaft, a hole larger than the liner outside diameter can be drilled with the shaft centered; by moving the shaft to an eccentric position, the drill head is centered and can, therefore, be withdrawn.

Mobile derrick

The derrick is anchored to the walls and roof of the drift and provides thrust to the liner through a traversing head powered by large hydraulic cylinders. The traversing head also provides passage for the muck pipes that carry rock chips from the drill head to the mucking system.

Mucking system

Because of the self-imposed design goal that little or no water be introduced into the borehole for chip removal, a vacuum mucking system is employed. The system consists of vacuum pumps, muck pipes, and filter boxes. Clean air is drawn by vacuum down the inside of the liner, across the drill head where it picks up rock chips, through the muck pipes, and into the filter boxes. Primary and secondary filtering is performed to remove rock chips and fugitive dust particles prior to discharge of the air back into the drift.

3.1.2.2 Feasibility Assessment

Although this system design is a new development, it is based on existing technology. The inhole drill represents a reduction in scale of current TBMs. Drill head and cutter design as well as thrust requirements are based on extensive blind-hole drilling experience. The derrick assembly design draws heavily on extensive experience with raise drills that are currently in operation worldwide. The vacuum mucking system design is based on experience with pneumatic transport of rock cuttings in tunnel-boring, backfilling, and drilling operations.

Analysis presented in SAND86-7004, previously cited, indicates that the proposed borehole lining operation is feasible. Based on conservative assumptions for cutting forces, dead-weight friction, drilling head stabilizer friction, borehole gradient, and borehole deviation, a maximum liner installation force of 1.3 million pounds is calculated. Stress analysis based on these loads indicates that a steel liner with a wall thickness of 0.5 inch is sufficient to safely handle these loads without compressive failure or buckling. Loads on the order of those calculated are routinely handled in pipe-jacking operations in the construction industry.

3.1.3 Closure Hardware

3.1.3.1 Equipment Description

Shown in Figures 28, 29, and 30 are schematics of current design concepts for horizontal borehole closure hardware.

Borehole Shielding Closure

The borehole shielding closure serves as a radiation shield when the borehole is partially filled with waste packages. The closure is bolted to an interface plate that is mounted on a flange on the front of the borehole entry liner. The closure includes a shield collar that mates with the cask during emplacement (see Section 3.1.4.1). Ballscrew-driven closure doors are included to provide shielding that can be retracted during emplacement operations. The shielding closure is replaced with a shield plug and borehole cover when the borehole is filled to capacity; thus, the closure can be moved from borehole to borehole as emplacement operations proceed.

Shield Plug

Prior to removing the shielding closure from a given borehole, a shield plug is installed, as illustrated in Figure 29. The plug is constructed of steel or other dense material and fits into a flared section of the borehole entry liner. Emplacement of the plug is accomplished with a modified forklift employing an extending boom. Mating of the shield plug installer with the shield collar on the shielding closure is accomplished prior to retraction of the closure doors and subsequent emplacement of the plug. Shielding of the borehole entry can thus be maintained throughout the plugging operation.

Borehole Cover

Once the shield plug is installed, the shielding closure is removed and replaced with a permanent borehole cover (Figure 30). This cover secures the borehole, provides borehole identification, and retains waste package information. (See Sect. 3.1.5.1 for description of cable retrieval system.)

3.1.3.2 Feasibility Assessment

The concepts presented for the closure hardware are simple in that they employ predominantly mechanical or hydraulic designs. Similar mechanisms have been used in hot cells (NFS, AGNS, and FFTF) which involve the transfer and handling of nuclear materials. The proposed hardware is thus within the scope of available technology. Further work is required to define specific design requirements for shields to ensure radiological safety (e.g. types and thicknesses of shielding materials).

3.1.4 Waste Transporter

3.1.4.1 Equipment Description

The waste transporter consists of a vehicle fitted with a turntable and cask, as shown in Figure 31. The waste package is stored inside the

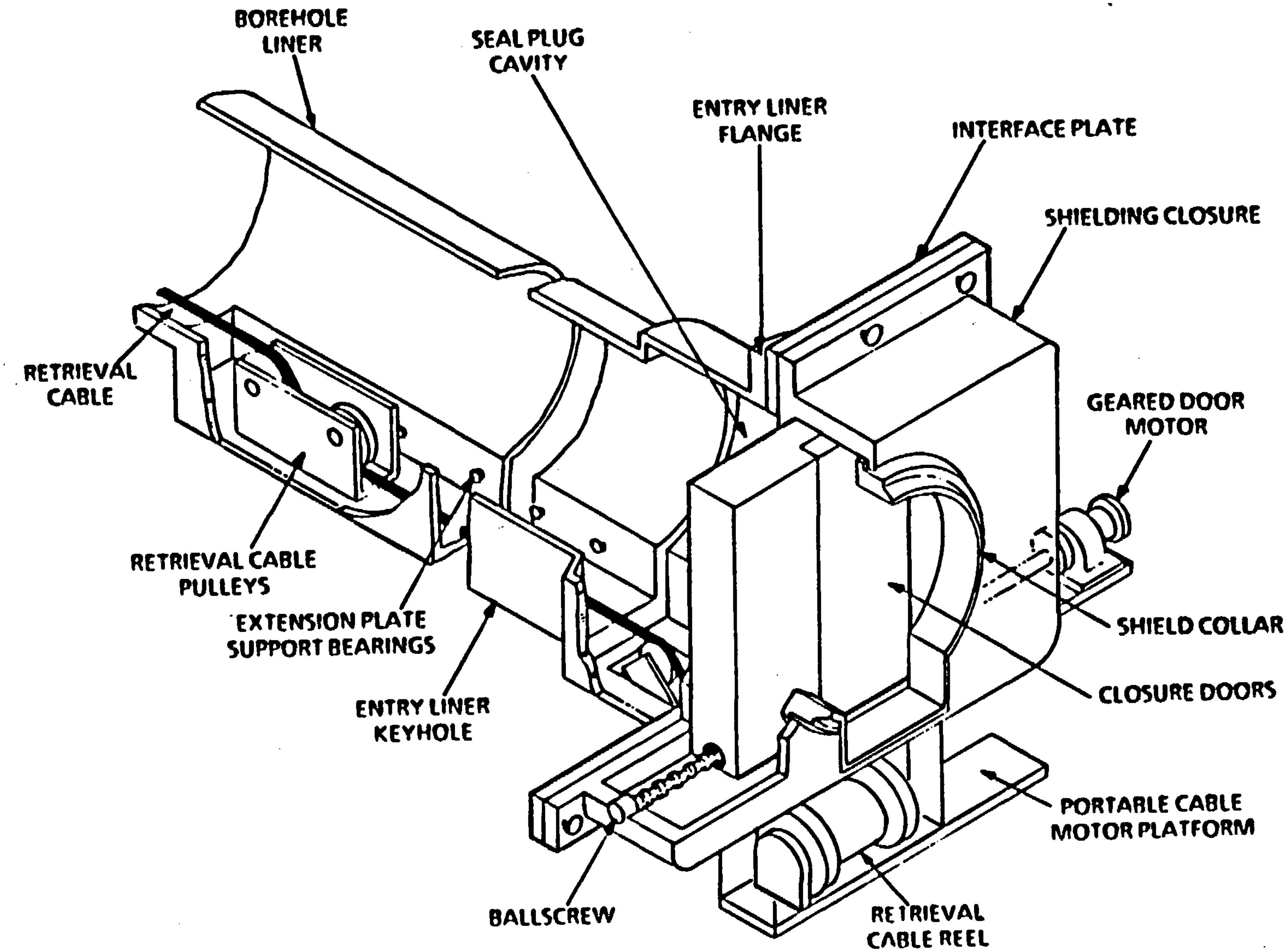


Fig. 28 - Horizontal borehole shielding closure design

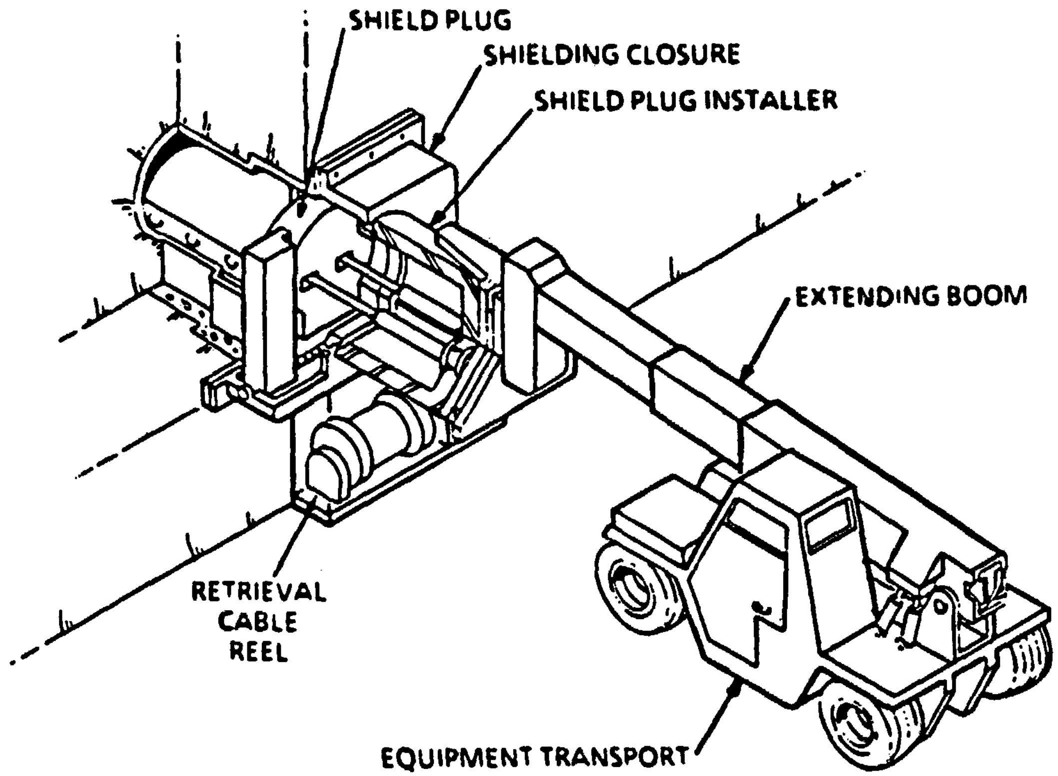


Fig. 29 - Equipment transport and shield plug installer for horizontal configuration

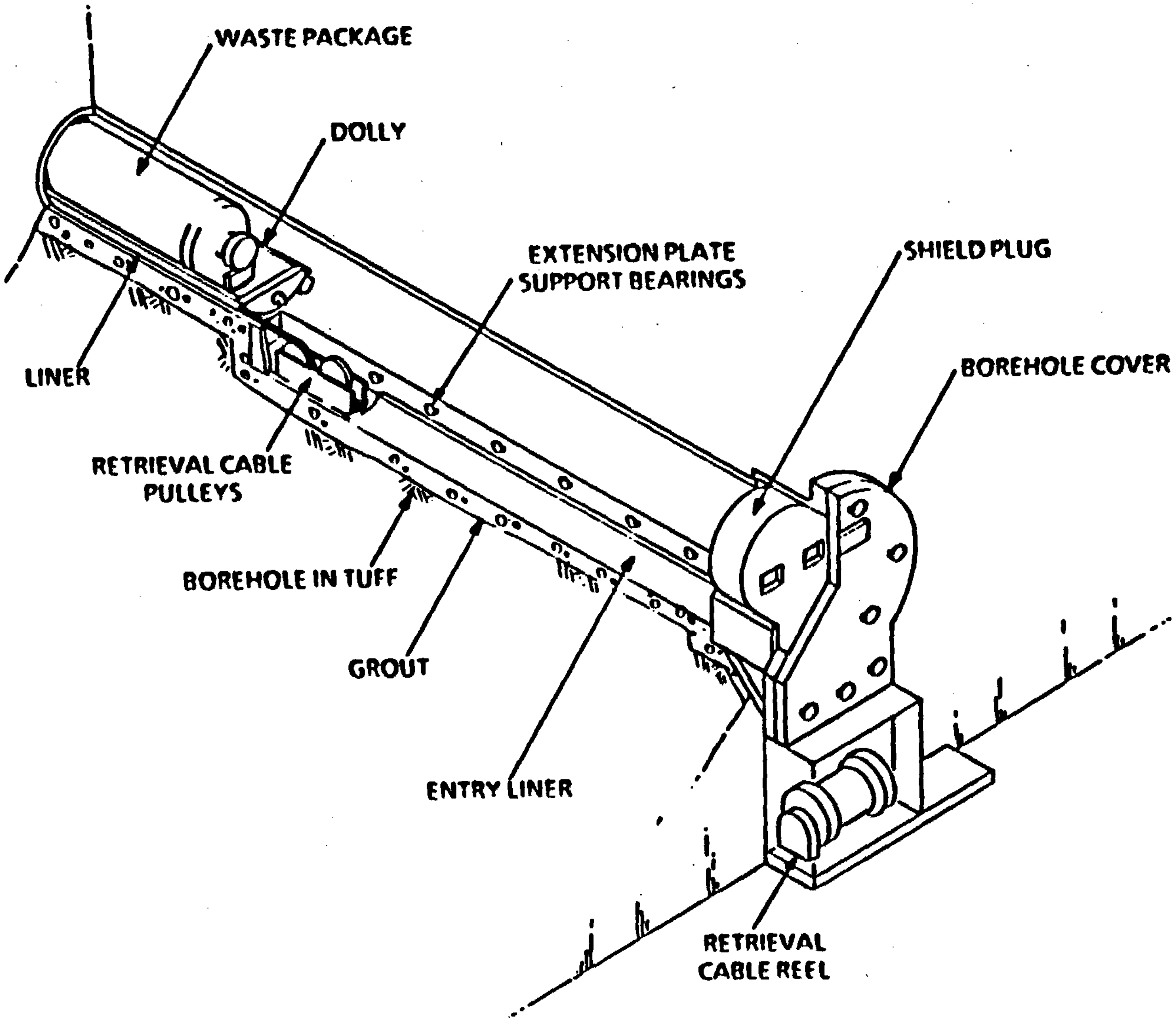


Fig. 30 - Horizontal borehole after emplacement and closure

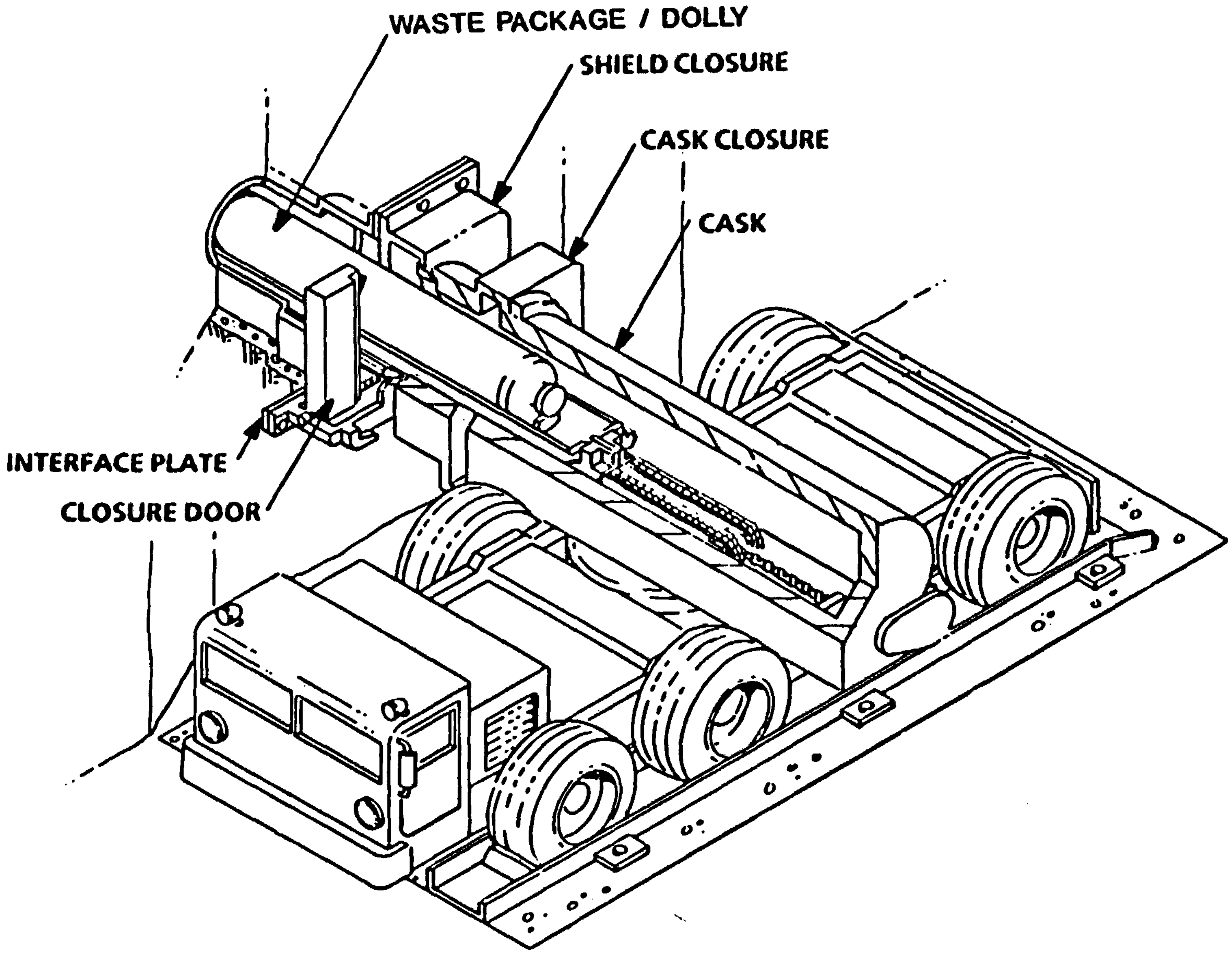


Fig. 31 - Waste transporter and emplacement/retrieval system for horizontal configuration

shielded cask as the transporter moves from the surface storage facility to the underground emplacement borehole. Several options exist for the transporter design, as discussed in detail in the following reports:

SAND83-7089 Conceptual Engineering Studies and Design for Three Different Machines for Nuclear Waste Transporting, Emplacement, and Retrieval

SAND85-7118 Feasibility Evaluation for Using Electric Drive for Nuclear Waste Transporter (in review)

Transporter Vehicle

The currently preferred transporter alternative employs a manned, rubber-tired vehicle powered by electric traction motors. The electric power is supplied by an overhead contact wire system, with storage battery power as an option for independent operation over short distances. Mechanical brakes are assisted by electric dynamic braking employing vehicle-mounted resistor grids.

In order to reduce worker radiation doses, all emplacement operations will be conducted by personnel inside the shielded cab of the transporter. The cab of the proposed transporter will seat two persons: the driver and the emplacement operator. Controls mounted inside the cab will allow the emplacement operator to operate the turntable, shield doors, and emplacement mechanism. Copious indicators, control devices, and interlocks will be employed in the control system to assure that operations are performed in correct order and that proper positioning of the cask is accomplished prior to emplacement.

Turntable

To minimize drift width requirements, the cask is mounted on a turntable, which allows the cask to be carried such that its longitudinal axis is parallel to the direction of travel. When the transporter reaches the emplacement borehole, the turntable rotates the cask 90° in a horizontal plane. A hydraulic leveling system aligns the cask with the borehole so that emplacement can be accomplished while maintaining shielding at the cask/borehole interface.

Cask

The cask serves the dual function of providing shielding for the waste package during underground transport and housing the emplacement/retrieval (E/R) mechanism described in Section 3.1.5.1. Since the cask provides primary shielding of the environs from the waste package, it will, by necessity, be massive. The cask will be designed with a cavity that mates with the shield collar on the borehole shielding closure during emplacement. Closure doors on the cask will remain closed until the cask is properly mated with the shielding closure.

3.1.4.2 Feasibility Assessment

No significant differences between vehicle design requirements for vertical and horizontal emplacement have been identified which may affect feasibility. Similar vehicles to that described above are currently in use at several surface and underground mines worldwide, although none of these are used to carry nuclear waste. Retrofitting of vehicle cabs with radiation shielding is currently done on a commercial basis, employing leaded glass and specially-formulated shielding panels that are attached to cab enclosure surfaces.

The turntable used for positioning the cask can be developed using existing technology. Similar systems capable of positioning similar-weight loads are currently in use in the machine tool industry (e.g. large milling machines). Positioning accuracy of these systems is well within the requirements of the waste transporter. Similar controls to those necessary for controlling cask positioning are currently in use in a variety of applications in, for example, the nuclear and aerospace industries.

Construction of the cask is within the capabilities of existing technology, although further work must be performed to determine specific design criteria such as types and thicknesses of shielding materials. There is essentially no difference between horizontal and vertical emplacement options as regards the feasibility of constructing the transporter cask.

3.1.5 Emplacement/Retrieval System

3.1.5.1 Equipment Description

The emplacement/retrieval (E/R) system consists of the E/R mechanism, supporting hardware, and the waste container dolly. Three reports have been written that describe some of the design concepts for the E/R system:

SAND83-7089 Conceptual Engineering Studies and Design for Three Different Machines for Nuclear Waste Transporting, Emplacement, and Retrieval

SAND84-2197 A Recommendation for Radioactive Waste Horizontal Emplacement Equipment for Tuff, Basalt, and Granite (in review)

SAND84-2640 Disposal of Radioactive Waste Packages in Horizontal Boreholes --A Description of the System, Equipment, and Procedures for Emplacement and Retrieval (in review)

<u>E/R Mechanism</u>

The current design concept for the E/R mechanism is illustrated in Figure 31. The mechanism employs a screw-driven, double-acting extension plate which pushes the waste container and dolly into the borehole during emplacement and pulls the package back into the cask during retrieval. Upon mating of the cask and opening of both sets of closure doors, the extension plate is actuated. The plate is driven out of the cask by the ballscrew, while the chain drive extends the package beyond the end of the plate and into the borehole. A cam mounted in the borehole entry liner lifts the hook on the dolly of the waste container currently being emplaced, causing it to connect with the dolly of the preceding container. A second cam releases the hook on the pusher plate from the dolly currently being emplaced, allowing the extension plate to be retracted into the cask while leaving the waste package in the borehole. Retrieval under normal conditions is accomplished by reversing this procedure.

Waste Container Dolly

The dolly is employed for several reasons. By equipping the dolly with wheels, it is possible to emplace and retrieve the waste package without sliding it along the liner. The dolly also takes all loads generated during emplacement and retrieval off the waste container, thereby lowering the possibility of damaging the container. The use of a dolly allows waste containers of different sizes to be emplaced without changing the E/R mechanism. Finally, the dolly system allows waste packages to be coupled together to form a train of waste packages in the borehole, which has certain advantages.

Coupling the dollies together is being considered in order to allow waste packages to be pulled to the retrieval position without reaching farther into the borehole than necessary. As a given waste package is retrieved, the other packages are pulled forward; thus after retrieval of the first package from the borehole, packages are always in a standard position for retrieval. This simplifies the design of the retrieval mechanism and increases the efficiency of retrieval operations.

Independent Standoff Mechanism

Consideration is being given to a mechanism, either integrated into the E/R mechanism or developed as a separate machine, for achieving standoff between the emplacement drift and the last waste container emplaced. Such a mechanism could employ hydraulic cylinders that extend sections of coupled tubing to push the containers as far inhole as needed. An automated system for coupling and uncoupling the tubing sections could be employed to allow the mechanism to operate within a totally enclosed, shielded cask. This system is attractive because it may be more cost-effective than using dummy waste packages or empty dollies to achieve standoff.

Cable Retrieval System

A concept for augmenting the described retrieval system is illustrated in Figure 32. The cable retrieval system consists of a cable which is attached to a pusher plate assembly inserted in the hole prior to waste emplacement, several pulleys to guide the cable in the entry liner region, and a motor-driven cable reel. In the event that dollies become uncoupled during the retrieval process, it would then be possible to retrieve the waste packages by retracting the cable. Such a system may also be advantageous if a waste package becomes stuck, in that higher tensile loads could be exerted on the cable than on the hooks that couple the dollies together.

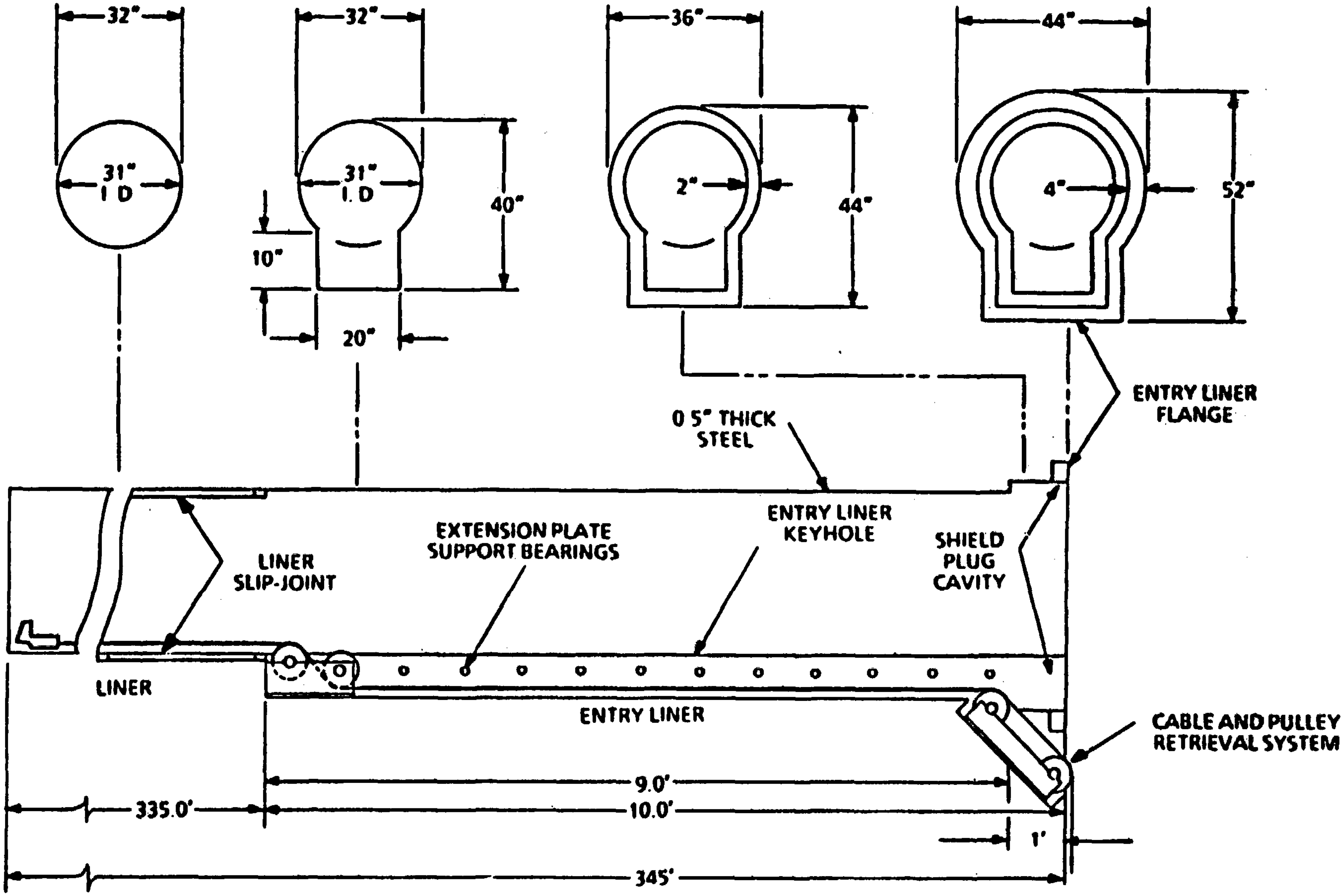


Fig. 32 - Horizontal borehole entry liner design

Retrieval Cart System

Consideration is also being given to employing uncoupled dollies, as described in Subsection 2.1.2.1.2. In this case, emplacement would be identical to that for coupled dollies, but retrieval would require a different procedure. The concept would employ a retrieval cart which is self-propelled or otherwise inserted into the borehole, a grapple system for grabbing a pull-ring on the waste container dolly, and a cable retrieval system for pulling the cart and waste container toward the borehole entrance. The cart would then release the waste container and leave it in a standard removal position for subsequent removal with the E/R mechanism previously described.

Several options exist for propelling the cart into the borehole. These include: a cart-mounted electric motor; a cart-mounted hydraulic motor; a cart-mounted air motor; and a rigid tube insertion mechanism similar to the independent standoff mechanism previously described.

The grapple system can be designed to be remotely actuated using an electric solenoid or mechanical linkage to the drive train. Alternatively, it could be designed to actuate upon contact with the pull-ring on the dolly. In any event, it must be designed so that the grapple can be uncoupled from the waste container upon reaching the standard removal system or in the event that off-normal conditions require uncoupling and subsequent off-normal retrieval operations.

3.1.5.2 Feasibility Assessment

As described above, several options exist for the waste retrieval system. Whichever concept is selected for further development, the system will be designed so that retrieval is not dependent upon the wheels of the dollies being able to roll. It is conceivable that after a long storage period, some of the wheels may develop flat spots, the bearings may seize, or some other scenario leading to increased rolling resistance may develop. The selected retrieval system will, therefore, be designed with enough pulling capacity to retrieve waste packages against sliding friction.

A one-twelfth scale working model of the E/R mechanism has been constructed and tested. This model has been used to verify that the equipment design concepts are workable and to identify changes that improve the design.

Equipment components similar to those described for the E/R system are currently in use in assembly-line manufacturing, particularly those applications that employ robotics. Differences do exist that cause special design considerations for the E/R system, but these differences do not pose significant feasibility concerns.

The radiation environment, for instance, presents no feasibility concerns, as evidenced by the components that operate in existing hot cells. A specific example of a system that operates in a high radiation environment is the Pulsed Reactor operating at Sandia National Laboratories. The auxiliary systems of this reactor include electric motors, electromagnets, and transducers such as thermocouples and proximity gages. This reactor and its predecessors have been successfully operated for years using standard, readily available components. A support system used with this reactor is a monitor network that places remotely operated television cameras inside the reactor containment building. These cameras operate for long periods of time with only minor maintenance.

The thermal environment that will exist during retrieval is another condition that presents special design considerations but does not pose significant feasibility concerns. High-temperature mechanical components are readily available in many instances. For example, roller bearings are available commercially that can operate for intermittant periods at temperatures of 175°C. This temperature capability is more than adequate for the expected conditions inside the emplacement borehole because the equipment used for retrieval will not remain in the borehole for significant periods of time. Other bearing materials such as graphite are available that are usable to temperatures far in excess of the 200°C expected in the borehole.

There are also many examples of materials and engineered systems operating at temperatures much higher than those expected inside the emplacement borehole. Some examples are : steam and gas turbines; aircraft jet engine thrust reversal systems; equipment used by the steel and aluminum forging industry; and drilling and logging equipment used in the geothermal drilling industry.

Components that cannot survive high temperatures, such as electric motors or electronic components that may be mounted on the retrieval cart to perform propulsion or borehole inspection functions, can be insulated to allow them to survive the short periods of time that they would be in the borehole. If longer periods of time inhole are required, techniques that employ Dewar-type flasks and eutectic heat sinks could be used to keep the components within their operating temperatures. These techniques have been used successfully in the geothermal industry to allow electronic components to survive in high-temperature environments (>200°C) for several hours.

3.1.6 Special Retrieval Equipment for Off-Normal Conditions

In this subsection, the equipment required for retrieving waste from horizontal boreholes under off-normal conditions is described, and the feasibility of that equipment is assessed. It should not be inferred from this discussion that this equipment will necessarily be needed or that the associated off-normal conditions will occur on a frequent basis. Similarly, it should not be inferred that retrieval from horizontal boreholes under off-normal conditions is necessarily more difficult than retrieval from vertical boreholes under off-normal conditions. The off-normal retrieval equipment for the vertical configuration shares many of the same design considerations and feasibility concerns; however, since the topic of this report is the feasibility of horizontal emplacement concepts, equipment for the vertical configuration is not explicitly discussed. Instead reference to the feasibility of vertical off-normal retrieval equipment is made where applicable in the following discussion.

3.1.6.1 Equipment Description

Initial concepts for procedures to retrieve waste from horizontal boreholes under off-normal conditions are described in the following reports:

SAND83-7089 Conceptual Engineering Studies and Design for Three Different Machines for Nuclear Waste Transporting, Emplacement, and Retrieval

SAND84-7100 Core Drill Conceptual Design Study for Retrieval of Stored Radioactive Waste (in review)

Concepts currently under consideration are presented in Subsection 2.1.2.2.2. Equipment required to perform the off-normal retrieval operations are discussed in more detail in the present subsection. In general, these concepts are not as fully developed as the concepts for emplacement and normal retrieval.

Design considerations that apply to all equipment required for these concepts pertain to the maintenance of shielding during the operations. Casks that carry the various special components that travel inhole to perform various functions must have sufficient shielding to protect operators during off-normal retrieval operations. Because of the possibility that these components would encounter contaminated material while performing those functions, the casks must be provided with shield doors to provide personnel shielding from the contaminated components during transport through the drifts. For the same reason, water-sensitive parts of the equipment components must be contained within watertight housings to allow the components to withstand decontamination operations.

<u>Horizontal Shield Plug Coring System</u>

The horizontal shield plug coring system would be used to remove a shield plug that is bound in the borehole. The system would employ a core bit coupled to a core barrel for drilling the rock surrounding the bound shield plug and removing the plug. The core bit and barrel would be carried to the borehole in a shielded cask by a transporter. Auxililary equipment needed for the coring operation includes equipment needed for cooling the bit and removing and storing rock chips generated by the coring system.

The core bit and core barrel would be rotated and thrust forward with the core drill system. Because of the limited drilling interval, it may be possible to achieve the thrusting function with a large hydraulic cylinder. Rotation of the cylinder could be accomplished with an electric or hydraulic motor mounted in the core drill cask. This motor would probably require an auxiliary cooling system.

Fluid for cooling the bit and cleaning rock chips out of the borehole must flow into the cask, around the outside of the core barrel and bit body, into ports located on the face of the core bit, through passages in the core barrel and thrust cylinder, through a fluid slip-ring on the thrust cylinder, and out of the cask. Air would probably be used as the drilling fluid. The drilling fluid system must be designed with the possibility that contaminated material may be drilled. As a result, the drilling fluid must either be contained within a shielded flow system outside of the cask and recycled or else filtered and decontaminated. Rock chips would have to be stored in a shielded container for transport to the surface and subsequent disposal.

The vertical shield plug coring system described in Subsection 2.1.2.2.1 has similar design considerations to those presented here.

Dolly Uncoupling System

The dolly uncoupling system would employ a mechanism for disconnecting hooks between waste container dollies in a horizontal borehole under off-normal conditions so that blocked or bound waste containers could be removed. The mechanism would be carried to the borehole in a shielded cask by a transporter. An extension mechanism would be used to push the uncoupling mechanism to the dolly couplings and to retract the mechanism back into the cask.

The uncoupling mechanism must be designed to slide beneath the dollies along the floor of the liner. The extension mechanism could use hydraulic cylinders and sections of coupled tubing to push the uncoupling mechanism to the dolly couplings. An automated system for coupling the tubing sections together could be used to achieve any extension into the borehole that may be necessary.

When the uncoupling mechanism is held stationary at a dolly coupling and actuated, it must self-align with the dolly hook and extend a bar in order to lift the hook to its uncoupled position. This action could be powered with compressed air conveyed from a compressor outside the cask through the coupled tubing.

An alternative to this system is to uncouple each dolly with the retrieval cart prior to grabbing the dolly pull-ring and pulling the waste container to the borehole entrance. The retrieval cart could use a remotely controlled mechanism to slide beneath the dolly and unhook the coupling at the rear of the dolly; or the dolly could be designed to uncouple from the front.

Horizontal Borehole Inspection System

The horizontal borehole inspection system would employ an inspection module that could be mounted on the retrieval cart described in Subsection 3.1.5.1 and carried into the borehole to provide data needed to assess the condition of the borehole and waste container under off-normal conditions. Instrumentation and equipment contained in the inspection module may include a video camera, lights, a temperature probe, a radiation probe, and a gas sampler.

Liner Repair System

The liner repair system would employ a liner expander and repair liner that would be inserted in a horizontal borehole under off-normal conditions to open and line a collapsed or severely deformed section of liner in the standoff region of the borehole. The system would be carried to the borehole in a shielded cask by a transporter. A liner expander extension mechanism would be used to insert the expander and repair liner to the damaged section.

The liner expander extension mechanism could use hydraulic cylinders and sections of coupled tubing to push the liner expander into the borehole. An automated system for coupling the tubing sections together could be used to achieve any extension into the borehole that may be necessary. Similarly, hydraulic cylinders could be used to push the sections of repair liner into the borehole. It may be necessary to join the sections of repair liner together with full or partial welds, in which case an automated system for welding and cutting the liner sections inside the cask would be necessary.

The liner expander must be capable of being inserted into a relatively small-diameter section of damaged liner and expanded to a larger diameter while exerting significant radial forces in several directions perpendicular to the axis of the liner. The design of the expander could be similar to that of a scissor jack, except that webbing would be required in several radial planes rather than one. Opening of the expander could be accomplished with hydraulic fluid or compressed air conveyed from a pump or compressor outside the cask through the coupled tubing used to insert the expander into the borehole. By dividing the coupled tubing internally into two flow paths, it would be possible to reverse the fluid flow in order to reduce the diameter of the expander.

If the liner repair operation were successful in a given borehole, it would be necessary to cut the repair liner at a point inside the borehole so that the excess liner could be withdrawn into the shielded cask in order to close the borehole shielding closure doors. This operation could be done with liner cutters that extend radially from the feet of the expander. By retracting the expander fully into the cask, a flow valve could be switched to a different mode such that fluid flow through the coupled tubing would then cause extension and retraction of the liner cutters. Cutter extension, combined with rotation of the coupled tubing, could then be used to cut the repair liner.

Borehole Reaming System

The borehole reaming system would be used to ream a section of horizontal borehole so that subsequent coring operations could remove a bound waste container under off-normal conditions. The system would employ a reaming bit and drill system carried to the borehole in a shielded cask by a transporter. Auxiliary equipment needed for the reaming operation includes equipment needed for cooling the bit and removing and storing rock chips generated by the reaming system.

The reaming bit would be designed with a conical center that uses the lined borehole as a pilot hole, and it must be large enough to ream the borehole to a size that will accomodate the core bit described in the next section. The bit must be capable of cutting both the liner and the rock surrounding the liner, and it must be designed for high-temperature operation.

The reaming bit would be rotated and thrust forward with the reaming drill system. The drill system could use hydraulic cylinders and sections of coupled tubing to provide the thrusting function. An automated system for coupling the tubing sections together could be used to achieve any extension into the borehole that may be necessary to drill to a bound waste container. Rotation of the coupled tubing could be accomplished with an electric or hydraulic motor mounted in the core drill cask. This motor would probably require an auxiliary cooling system.

The drilling fluid system for cooling the bit and cleaning rock chips out of the borehole has similar design considerations to those described earlier for the horizontal shield plug coring system.

Horizontal Coring System

The horizontal coring system would be used for removing bound waste containers from horizontal boreholes under severe off-normal conditions. The system would employ a core bit coupled to a core barrel for drilling the rock surrounding the waste container and removing the container. The core bit and barrel would be carried to the borehole in a shielded cask by a transporter. Auxiliary equipment needed for the coring operations includes equipment needed for cooling the bit and removing and storing rock chips generated by the coring system.

The core bit, core barrel, and drilling fluid system used in the horizontal coring system have similar design considerations to those described earlier for the horizontal shield plug coring system. An additional consideration is that the core bit must have cutters mounted inside its inner wall that can be hydraulically actuated to extend radially inward and cut through the liner from the outer surface inward. The hydraulic system for actuating the cutters could use a hydraulic pump mounted outside the cask, a fluid slip ring mounted on the drill pipe, and hydraulic lines carried inside the drill pipe.

A system for pushing the core out of the core barrel would be needed in order to transfer the waste container core from the core barrel to the surface storage vault. This could be accomplished with a circular plate located in the top of the core barrel which is pushed out of the core barrel with a pair of hydraulic rams.

The system for providing rotation and thrust to the core bit has similar design consideration to those described earlier for the borehole reaming system.

The vertical coring system described in Subsection 2.1.2.2.1 has similar design considerations to those presented here.

Shielded Drill System

The shielded drill system would be used to provide access to the side of a horizontal borehole for auxiliary liner cutting operations using the horizontal liner cutting system and subsequent removal of a bound waste container using the horizontal coring system. The shielded drill system would employ a rock bit for drilling a hole from an auxiliary drift to the emplacement borehole liner. The drill system would be carried into the auxiliary drift in a shielded cask by a transporter. Auxiliary equipment needed for the drilling operations includes equipment needed for cooling the bit and removing and storing rock chips generated by the drilling system.

The drill bit in this system would be required to cut only rock. It must be large enough in diameter to drill a hole that will accomodate the auxiliary liner cutter described below. Otherwise, the drill bit and system for providing rotation and thrust to the bit have similar design considerations to those described earlier for the borehole reaming system.

The drilling fluid system for cooling the bit and cleaning rock chips out of the borehole has design considerations similar to those described earlier for the horizontal shield plug coring system.

<u>Horizontal Liner Cutting System</u>

The horizontal liner cutting system would be used to cut the borehole liner from the side using an auxiliary borehole, followed by subsequent removal of a bound waste container using the horizontal coring system. The liner cutting system would be carried to the auxiliary borehole inside a shielded cask by a transporter. A liner cutter extension mechanism would be used to insert the cutting disk into the auxiliary borehole and retract it back into the cask when the cutting operation is complete.

The liner cutting disk must cut primarily the steel liner, but it must also be capable of cutting a portion of the rock surrounding the liner. The disk might employ diamond or carbide cutters and must be designed for a high-temperature environment. Air cooling of the cutters may be necessary, but because of the small volume of material removed during the cutting operation, no chip removal system would be needed. In general, the diameter of the cutting disk must be slightly greater than twice that of the borehole liner.

The liner cutter extension system has design considerations similar to those described earlier for the dolly uncoupling system. In general, however, the liner cutter extension system must employ coupled tubes that are stiffer and stronger than those of the dolly uncoupling system.

3.1.6.2 Feasibility Assessment

The feasibility of the presented systems is uncertain due to the complexity of the required equipment. Individual components of the systems, however, are judged to be feasible, based on existing technology. Considerations related to this assessment include:

o Reaming bits currently in existence are routinely used to enlarge boreholes in the petroleum drilling industry. Drill bits have been used under high-temperature conditions for many years in the geothermal drilling industry.

o Coring systems are also widely used by the petroleum and scientific drilling industries, although the core diameters are generally much smaller than those required here. The feasibility of the required coring systems for waste retrieval, however, is strengthened by the complexity of some of the existing systems, for example those used to retrieve cores by wireline from boreholes drilled into the ocean floor several miles below the surface.

o Casing cutters and underreamers used in the petroleum drilling industry lend credence to the proposed method for cutting the borehole liner.

o The required mucking system appears feasible, based on the success of pneumatic transport of rock chips and the existence of high-efficiency particulate air (HEPA) filters.

o High-temperature components are availble for some of the equipment, and insulation can be used where necessary to allow conventional components to operate in the high-temperature borehole, as previously discussed.

o Automated drill rigs capable of pipe-handling and remote operation have been built and tested with success in the petroleum drilling industry.

In summary, there is no indication in the present assessment that the proposed special retrieval equipment is infeasible, although the presence of radiation makes the development of equipment and procedures more uncertain. Further work is required to develop the concepts more fully and to more accurately determine the need for the equipment. The feasibility considerations presented here also apply, in general, to the equipment needed for off-normal retrieval from vertical boreholes.

3.2 Technical Feasibility

In this subsection, general horizontal emplacement/retrieval system technical feasibility concerns are addressed. Technical feasibility has been assessed by a combination of calculations, engineering analysis, and comparison with existing working systems. Total rigor has not always been possible to date, and additional analyses are planned in certain areas; however, results to date build confidence in the technical feasibility of horizontal emplacement.

3.2.1 Long-Term Access to the Emplacement Boreholes

The design of the underground openings that are used for access to the emplaced waste is done using a combination of two approaches, namely, the application of experience-based design methods and the application of analytical techniques to supplement and verify the results of the experience-based methods.

The experienced-based methods are founded on a rock mass classification system where the formation in which the opening is to be developed is classified using numerous classification parameters. The net rock mass classification for the rock is then compared with a library of experience data to compare how openings have previously performed in rock of similar classification. These methods have been successfully employed for many years in the design of many underground openings. The shortcoming of these methods is that they do not contain parameters which take into consideration the temperature increase that is expected in the rock at a repository. Certain adjustments to these methods to include the effects of temperature have been proposed but have not yet been verified. These techniques are applicable to both drifts (large openings) and boreholes. When applied to repository-sized openings in Yucca Mountain, both rock mass classification systems used indicate that usable openings can be constructed using relatively minimal ground support. The evaluations also indicate that conditions similar to those anticipated at Yucca Mountain exist in the Grouse Canyon tuff at G-Tunnel, where stable openings have been constructed using only roof bolt and wire mesh support. These evaluations are detailed in the following report:

SAND82-2034 Rock Mass Classification of Candidate Repository Units at Yucca Mountain, Nye County, Nevada

Construction feasibility for the emplacement drifts is therefore established.

Analytical approaches have been applied to predict the stresses and displacements that will exist near drifts and boreholes for up to 100 years after waste emplacement. Numerous stability analyses are synopsized in the SCP-CDR, based upon at least 21 supporting NNWSI references and appendices in the CDR report. Perhaps the most directly applicable reference is:

SAND86-7005 Reference Analyses of the Design of Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff (in review).

The above report documents stress analyses of drift stability for both horizontal and vertical emplacment, with and without continuous drift ventilation, for up to 100 years after waste emplacement. Higher stresses occur for the unventilated cases. With horizontal emplacement the highest stresses are noted in the drift crown; these stresses range from 31 MPa (ventilated) to 36 MPa (unventilated). These values are well below the average laboratory value of compressive strength of 150.8 MPa. Even if a 50% reduction factor is applied to the laboratory value of strength to account for rock mass effects (scale, fractures, etc.), the minimum safety factor at any point is still 2.1. Based upon these (and other supporting) calculations, it appears feasible to expect that stable openings in the Topapah Springs tuff can be developed which can withstand the excavation and thermally-induced loads for the preclosure operating life.

Drift useability will also be assured by conducting a rigorous program of drift maintenance. Periodic inspection of drifts will be performed to identify any stability problems, and prompt corrective action will be taken, such as addition of roof bolts or the use of structural roof supports if necessary. Monitoring of selected drift sections will be done to provide data on rock movement, air quality, and drift temperatures. Documentation of geotechnical data obtained during mining, borehole drilling, and emplacement will be conducted to provide information which may be needed to ensure drift stability. Review of this documentation will also be necessary for pre-retrieval assessment of repository stability and development of a retrieval plan, should retrieval be mandated.

3.2.2 Long-Term Stability of the Emplacement Boreholes

One key to maintaining the retrieval option is to assure that the emplacement boreholes remain open. Drawing upon the experience gained in the petroleum and geothermal drilling industries, a viable way to keep the boreholes open is with the use of steel liner. This approach has been adopted for the horizontal emplacement envelope.

The liner will be used solely for maintainence of the retrieval option and is not being relied upon to serve any waste isolation function. Design considerations for the liner include stresses caused by rock loading due to localized sloughing of rocks in the top and possibly sides of the emplacement boreholes, thermal effects, the potential for degradation by corrosion, and compatibility with other materials in the emplacement envelope.

Upon completion of the drilling process and removal of the inhole drill, liner stresses should decrease significantly because of the fact that the drilled borehole is larger than the outside diameter of the liner. Residual compressive stresses will remain because of friction against the borehole wall, but these stresses are not expected to be significant. Rock fall may impose concentrated and distributed loads over portions of the liner; however, preliminary analysis indicates that liner stresses in a 0.5 inch-thick liner should not exceed 2500 psi in such cases, well below the failure stress of steel. Stresses caused by the weight of the waste packages and the liner itself are of the same order of magnitude.

Thermal stresses in the liner are a potential concern, but preliminary analysis indicates that these stresses will not be excessive if the liner and borehole are properly designed. Because of the significant thermal output of spent fuel, temperatures in the emplacement boreholes will reach elevated levels. The predicted borehole wall temperatures without lining are shown in Figure 33. (The thermal conductivity of steel is much greater than that of tuff, so the presence of a liner should not significantly affect the predicted temperatures.) With a maximum temperature of 215°C, a 350 ft-long liner will expand longitudinally approximately 0.8 foot if unconstrained. If completely constrained, longitudinal stresses in the liner would exceed 60 kpsi, which could be above the strength of the liner material used. Factors that could cause partial or complete restraint of the liner include excessive friction against the borehole wall due to a crooked borehole and drag at the welded joint between liner sections due to misalignment during the joining process. As a result, design criteria will be established to guarantee that the borehole is sufficiently straight and that liner sections are accurately aligned before welding.

Other provisions will also be made in the emplacement envelope design to permit the liner to expand longitudinally. These provisions include a gap between the inhole end of the liner and the end of the borehole, a slip-joint at the entrance of the liner, and the use of no grout or cements to fix the liner to the borehole wall. (The slip-joint feature is illustrated in Figure 32.) Similar provisions for thermal expansion are used with success in geothermal wells, where several thousand feet of production tubing are sometimes fixed only at the bottom of the well and allowed to

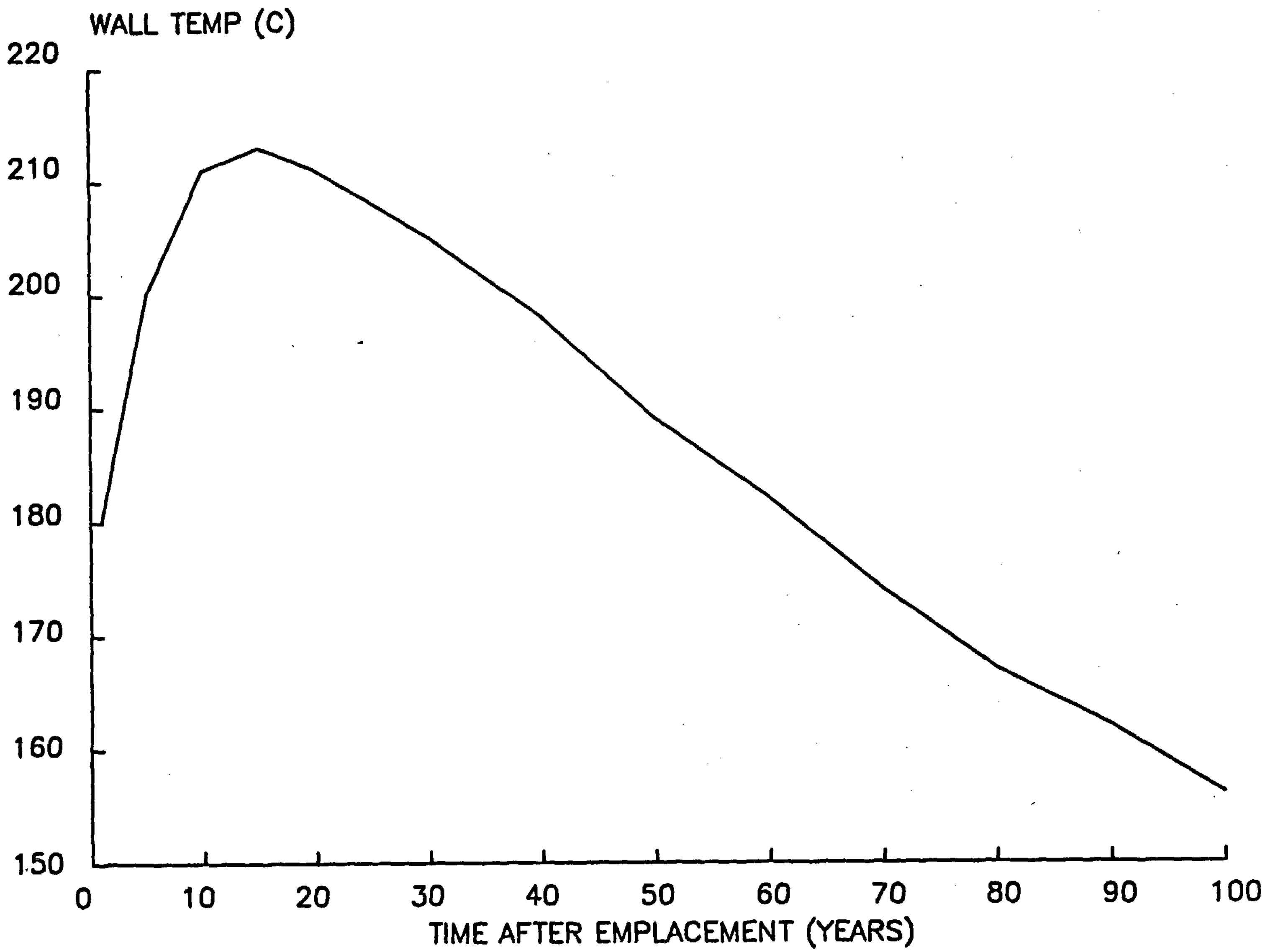


Fig. 33 - Borehole wall temperature for horizontal emplacement

expand vertically without buckling in similar thermal environments. Only one cycle of liner expansion will occur; therefore, there is no potential for fatigue due to expansion/contraction cycling.

Preliminary analysis indicates that unconfined radial expansion of the liner due to thermal effects should be insignificant, with less than 0.1 inch increase in liner diameter. To help prevent excessive stresses as a result of this expansion and to permit easier liner installation, the borehole drilling system is designed to drill a borehole 37 inches in diameter, with a liner outside diameter of only 36 inches. Unless the borehole is significantly crooked, there should be no significant radial stresses due to thermal expansion. Analyses are continuing, however, in order to more fully assess the potential for localized radial buckling under such conditions and to establish criteria for borehole straightness.

No significant liquid water is anticipated to contact the waste packages or liner at the Yucca Mountain site. As seen in Figure 33, the borehole wall temperature is above the boiling point of water for a period of time much greater than the retrievability period, a maximum of 84 years after emplacement. As a result, corrosion of the liner is not expected to be significant during the retrievability period. Initial investigations indicate that surface corrosion rates should be less than 0.002 inch/year for mild steel, and stresses on such a corroded liner should still remain below the yield stress of the liner material. As described in Section 4, however, this issue will be studied further. The use of sacrificial materials or corrosion-resistant liner materials is a design option if further study shows corrosion to be a problem.

A potential exists for water condensate to form in the borehole entry region because of the lower temperatures that would result in that region. This potential problem will be studied to determine possible implications and solutions.

In view of the preliminary results cited, employment of a liner appears to be a feasible approach to maintaining borehole stability and ensuring a favorable borehole condition for retrieval. Further work will be done, however, to verify and document these results.

3.2.3 Emplacement Dynamics

Emplacement of waste packages in the horizontal configuration according to current concepts requires transmittal of compressive loading along a train of coupled or uncoupled dollies. At issue is the dynamic behavior of the train under these conditions. The potential for corkscrewing of the dolly train exists and may require the use of a rail or channel in the liner to guide the train or modification of the dolly design to place the waste package center of gravity below the centerline of the borehole.

A potential also exists for misalignment of the dollies and buckling of the dolly train; however, preliminary assessment indicates that these should not be problems because the diametral clearance between the waste package and the liner is much smaller than the diameter of the waste package. There is thus not much room for lateral displacement that would result in significant misalignment. Furthermore, the weight of the waste package and the circular borehole geometry should produce forces during emplacement that result in self-alignment of adjacent packages and reduce the potential for eccentric loading. Finally, rolling resistance of the wheeled dollies during emplacement will be small compared with the weight of the package, thereby reducing compressive loads on the cart train that could lead to buckling. Further work is necessary to determine the accuracy of this assessment.

3.2.4 Synergistic Effects

The ability to emplace and retrieve waste from a horizontal borehole is dependent upon the borehole liner. As noted in Subsection 3.2.2, anticipated conditions should not pose liner failure concerns if the liner and borehole are properly designed. In the present subsection, synergistic effects on the liner caused by combinations of conditions are addressed.

Partially Filled Emplacement Borehole

The emplacement borehole is normally only partially filled with radioactive waste since a portion of the borehole is left vacant to provide a standoff distance between the last container emplaced and the emplacement drift. If the number of waste containers in the borehole is less than the design capacity, the performance of the borehole liner will not be adversely affected. This conclusion is based on the following comparisons between a borehole that is loaded to the design capacity and one that is not filled to capacity: (1) the total liner expansion will be less for a partially filled borehole, and thus the thermal expansion-induced stress in the liner will be lower; (2) the thermal stress in the rock surrounding the borehole adjacent to emplaced waste containers will be essentially the same in both cases; and (3) partial filling does not alter the symmetry of the loads applied to the liner and therefore does not increase the potential for liner buckling.

Partially Filled Emplacement Borehole, Elevated Temperatures, High Radiation, and Earthquake- or UNE-Induced Ground Motion

The only difference in this combination of circumstances from the above is the introduction of ground motion. No damage to the emplacement borehole or the borehole liner is expected (assuming no fault motion within the borehole) because the wavelength for ground motion is very large compared to the cross-sectional dimension of the borehole. The seismic effect on the liner will be a transient, wholebody acceleration and displacement but no shearing or offset. This conclusion is substantiated by numerous examples of subsurface structures that have survived earthquakes without damage. The California Aqueduct is one of many examples of underground structures that have withstood an earthquake. This strucure was located near the epicenter of the 1971 San Francisco earthquake and suffered no structural damage as a result of the earthquake. A Lawrence Livermore Laboratory report, "Effects of Earthquakes on Underground Facilities: Literature Review and Discussion" (D.W. Carpenter and D.H. Chung, 1985), summarizes the historical performance of underground facilities subjected to seismic loading. In general, this report concludes that openings in competant rock much larger than the horizontal emplacement boreholes survive earthquakes with minimal damage.

Earthquake Occurring During Emplacement Operations

This combination of events may impose significant loads on the interface between the transporter cask and the emplacement borehole. This loading will be independent of other factors such as borehole filling, radiation, and temperature. To accomodate the load, it will be necessary to design the interface with strength sufficient to withstand the imposed loads. It will also be necessary to design the transporter with reaction supports adequate to ensure that the waste transporter moves in harmony with the ground motion. In addition, the E/R system will be designed so that any adverse effects resulting from ground movement during emplacement or retrieval can be rapidly mitigated.

Water Intrusion into a Filled Borehole

It is currently planned that waste will not be emplaced in boreholes where water inflow is detected. Water inflow after emplacement could possibly occur, however, if a perched reservoir is replenished by precipitation and subsequently recreates a dripping fracture that intersects the emplacement borehole. If such a combination of circumstances occurs, it will present no significant hazard during retrieval because the water will be vaporized as it encounters the boiling temperature isotherm around the borehole and will subsequently be driven into the rock or down the annulus between the liner and the borehole wall until it cools and condenses. This does not alter the design basis for the liner environment because the design basis already includes the presence of water vapor.

Conclusion

Two points should be made regarding this discussion. The first is that this discussion is not intended to lend credibility to the synergistic scenarios presented. The second point is that the synergistic effects are not unique to horizontal emplacement; they are also present for vertical emplacement and must be considered in design for either emplacement configuration.

In summary, it is concluded that no significant adverse conditions will develop with the horizontal emplacement configuration due to synergistic effects.

4.0 EMPLACEMENT EQUIPMENT DEVELOPMENT PLANS

4.1 Schedule for Emplacement Orientation Decision

Prior to license application, a decision must be made to emplace waste either vertically or horizontally. Figure 34 shows the schedule for that decision in relation to activities planned in the equipment development program. Prior to the decision, emphasis will be placed on designing and evaluating the feasibility of horizontal emplacement equipment and retrieval equipment for both horizontal and vertical configurations for off-normal conditions. During this period, further work will not be done on vertical emplacement equipment for the following reasons: (1) vertical emplacement equipment has been developed before at the Project Salt Vault and Climax facilities; (2) adequate time exists between the decision and license application to develop vertical emplacement equipment for proof-of-principle demonstrations if the vertical orientation is selected; and (3) feasible concepts for vertical emplacement equipment have already been developed, as discussed in the following reports:

SAND84-1010 Disposal of Canistered Waste in Vertical Boreholes--A Description of the System, Equipment, and Procedure for Emplacement and Retrieval (in review)

SAND84-2275 NNWSI Repository Worker Radiation Exposure for Vertical Emplacement and Retrieval of Spent Fuel (in review)

In the case of horizontal emplacement, concepts have also been developed and appear feasible, as described in Section 3; but certain key components are sufficiently complex that feasibility must be demonstrated in a more rigorous fashion prior to the emplacement orientation decision. Similarly, off-normal retrieval equipment for either configuration has not been designed or demonstrated; therefore more work on the off-normal retrieval concepts presented in this report is warranted prior to the emplacement orientation decision.

The orientation decision will be based on comparison of the configurations on several issues:

- long-term waste isolation performance
- safety of operating personnel and the general public
- retrievability
- thermal and mechanical effects on the repository
- equipment feasibility
- cost

Since key components of the horizontal emplacement equipment and the horizontal and vertical off-normal retrieval equipment require demonstration to prove feasibility, the program outlined in the following section is proposed for immediate start-up.

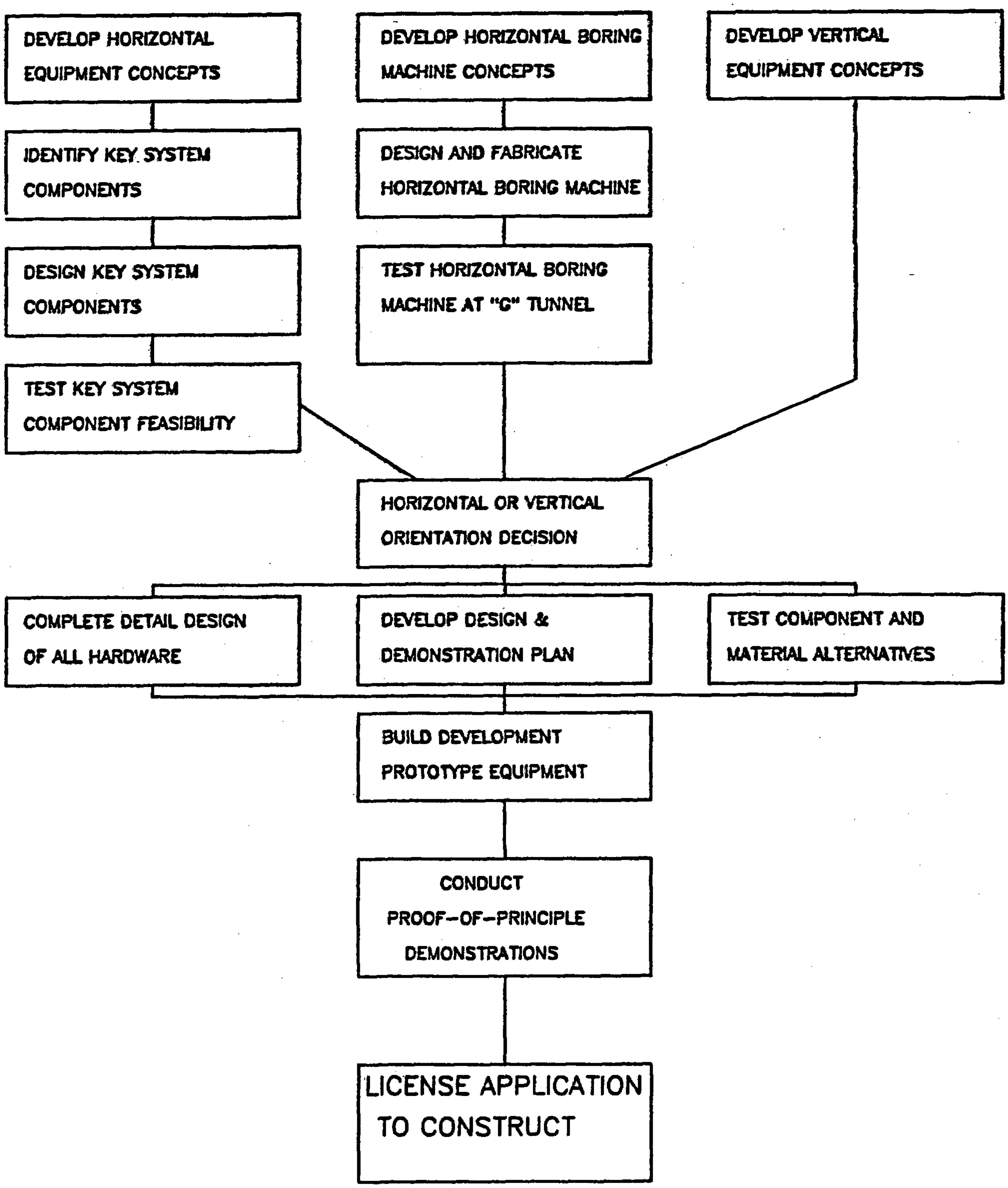


Fig. 34 - Equipment development plan

4.2 Planned Activities in the Equipment Program Prior to Orientation Decision

The proposed development program for the horizontal emplacement equipment and horizontal and vertical off-normal retrieval equipment considers the equipment to consist of five relatively distinct systems: horizontal boring and lining machine; emplacement envelope; waste transporter; emplacement/retrieval system for normal conditions; and special retrieval systems for off-normal conditions. The following subsections describe the work proposed for each system prior to the orientation decision.

4.2.1 Development of Emplacement Borehole Drilling and Lining System

In order for the horizontal emplacement orientation to be judged feasible, the feasibility of drilling and lining long, horizontal boreholes must be proven. For this purpose, the boring machine described in Section 3.1.2 will be fabricated and tested. Planned activities prior to the emplacement orientation decision include:

DPBM fabrication - The development prototype boring machine (DPBM) designed by The Robbins Co. under contract to Sandia will be fabricated. Contract negotiations are complete, and start-up is awaiting approval to proceed. Plans call for fabrication to be complete by late-1987.

DPBM acceptance tests - Tests will be conducted with the DPBM in a rock quarry upon completion of the fabrication phase. The purpose of these tests is to assess the ability of the system to drill and line a horizontal borehole in hard rock. Steering, rock-chip removal, reinstallation, and other system functions will be tested, and any required design modifications will be identified and completed.

G-Tunnel Tests - Performance tests of the DPBM will be conducted in the G-Tunnel test facility at the Nevada Test Site in mid-1988. General system performance, drilling rate, and the ability to drill and line straight boreholes will be assessed. The results will be used to determine the feasibility of achieving an adequate borehole production rate at the quality level required in the repository. If the horizontal configuration is selected, further tests will be conducted in the Exploratory Shaft Facility in order to provide site-specific data needed to optimize the drill and estimate borehole production rates for the repository.

4.2.2 Design of Waste Emplacement Envelope

Emplacement envelope hardware consists of the borehole liner, shielding closure, shield plug, and permanent emplacement borehole cover. The key items under this activity that must be resolved prior to the orientation decision are horizontal borehole stability and liner survivability. Tasks planned under this activity include:

Liner stress analysis - Detailed analysis of horizontal liner stresses caused by thermal expansion and possible rock-fall will be conducted and documented. The results will be used to determine the potential for liner collapse and to recommend a liner wall thickness.

Corrosion studies - Studies will be performed to determine the corrosion environment of the horizontal liner (thermal, chemical, etc.), to establish the operative corrosion mechanism(s), and to determine probable corrosion rates. The results will be used to assess liner survivability over the retrieval period to determine the possible need for sacrificial materials or a corrosion resistant liner. The potential for water condensation in the borehole entry region will be determined, and possible corrosive effects will be assessed.

Waste emplacement envelope design - The borehole entry liner, liner slip-joint, and closure hardware will be designed in order to provide data necessary for designing the E/R mechanism (Section 4.2.4). Shielding analysis will be be performed, based on source-term calculations for the waste containers, in order to identify criteria for closure hardware shielding design.

4.2.3 Design of Underground Transport Equipment

As noted in Section 3.1.4, emplacement orientation is unlikely to significantly affect transporter vehicle design. Certain functions required of the transporter, however, are significantly different between the two orientation options. As a result, tasks under this activity prior to the emplacement decision will concentrate on designing key components of the transport equipment in order to identify potential obstacles to development and to provide design data needed in other areas of repository design.

Vehicle design - Vehicle configuration affects underground drift design because of vehicle height, width, and turning radius requirements. These parameters depend on loads and, possibly, emplacement orientation. Studies will, therefore, be conducted to establish vehicle design requirements prior to the orientation decision and to identify possible commercial equipment that could be adapted to fit these requirements.

Turntable design - The ability of the turntable to rotate and position the cask is important because it affects drift width requirements. By carrying the cask parallel to the drifts, drift width can be minimized. The only alternative to rotating the cask for emplacement is turning the entire vehicle 90°, thereby requiring wider drifts and a more maneuverable vehicle. Under this task, the turntable will be designed in order to identify general criteria such as weight and dimensions and to identify any potential obstacles to development.

Cask design - The design load of the turntable is a function of the cask weight, which in turn is a function of shielding requirements. Shielding evaluations based on source-term calculations for the waste containers will be performed in order to determine general design criteria such as cask shielding materials and weight.

Emplacement control design - Concepts for emplacement control equipment will be developed prior to the orientation decision in order to prove feasibility and identify possible impacts on E/R mechanism design. Design criteria for required instrumentation, monitors, and control devices will be established.

4.2.4 Development of E/R System for Normal Conditions

The feasibility of proposed concepts for routine horizontal emplacement and retrieval should be proven prior to the emplacement orientation decision. The following tasks are judged necessary to accomplish this goal:

Emplacement dynamics studies - Further consideration of emplacement dynamics is necessary to ensure that problems such as misalignment, corkscrewing, and buckling of the dolly train will not occur. Analyses will be conducted to determine parameters related to dynamic stability. The results will be used to assess the potential for train instability and to determine the possible need for guiding hardware in the borehole liner.

E/R system design and testing - Alternative concepts for the E/R system will be studied in detail to determine preferred alternatives. These will be designed and tested, as judged necessary, to prove feasibility prior to to the emplacement orientation decision.

Dolly design - General design criteria for the waste package dollies will be identified to provide information needed for E/R system design. Preliminary cost estimates for the dollies will be made in order to provide information needed in comparing vertical and horizontal emplacement costs.

4.2.5 Development of Special Retrieval System for Off-Normal Conditions

Prior to the orientation decision, the feasibility of development equipment for horizontal and vertical off-normal retrieval conditions should be assessed in more detail:

Advanced conceptual design - Although the design requirements for this equipment depend on the results of scenario development for off-normal conditions, it is presently assumed for the sake of conservatism that horizontal and vertical off-normal retrieval systems like those described in this report would be desirable. Concepts for these system will, therefore, be developed further prior to the orientation decision in order to more accurately determine feasibility. Other concepts will be developed as required to deal with specific retrieval scenarios that are identified.

Key component testing - If further evaluation identifies any off-normal retrieval conditions that have a significant probability of occurrence, key components of the required retrieval equipment will be designed and tested, as needed, to prove feasibility.

4.2.6 Horizontal Equipment Development Tasks Deferred Until After Orientation Decision

Several development tasks specifically related to horizontal emplacement equipment will be deferred until after the orientation decision is made. These include:

- Exploratory Shaft Facility testing of DPBM
- turntable performance and reliability testing
- optimization of dolly design to minimize production costs
- studies to determine need, impact, and materials to be used in horizontal borehole grouts near the borehole entry

4.3 Planned Activites in Equipment Program After Orientation Decision

After selection of the emplacement orientation, development prototype equipment for the selected orientation will be developed and tested. This equipment will be designed based on results from key component testing described above and will be fabricated for the purpose of demonstrating proof-of-principle. Figure 34 illustrates the approach to be used in this phase of the program. In general, the development prototype hardware for each system will consist only of those components necessary to demonstrate proof-of-principle for the systems. Testing will be conducted under conditions that simulate pertinent emplacement and retrieval conditions. A surface test facility is under consideration for this purpose. Since program direction is currently uncertain, further planning for development prototype equipment fabrication and testing is deferred until the orientation decision is made. The results of the demonstrations will be used as a basis for design and fabrication of prototype equipment for repository operations and as a basis for feasibility considerations to be included in licence application.

5.0 SUMMARY

Concepts have been developed for emplacing high-level nuclear waste in both vertical and horizontal orientations at the proposed Yucca Mountain repository. Data have been presented which indicate that horizontal emplacement has significant technical and cost advantages over vertical emplacement and relatively few potential disadvantages. Cost savings of over $1 billion are predicted for the horizontal orientation, primarily as a result of lower mining volumes and associated costs.

Concepts for vertical and horizontal emplacement equipment appear to be technically feasible, and no significant differences in repository performance have been identified. Results have been discussed which indicate that stable underground openings can be developed and maintained with either emplacement orientation. Horizontal emplacement equipment feasibility has been assessed by comparing the concepts with existing equipment and operations used to perform similar functions in other applications in the petroleum, scientific drilling, mining, nuclear, and aerospace industries. None of the concepts that have been developed require technology beyond current limits; thus equipment needed to perform the required horizontal emplacement functions are judged feasible. Because the horizontal emplacement equipment is more complex than that required for vertical emplacement, however, further work prior to the emplacement orientation decision is needed to prove the feasibility of horizontal emplacement equipment.

The equipment development program outlined in this report is designed to require a minimum expenditure of funds prior to the orientation decision. This program, prior to the decision, focuses on development tasks deemed necessary to demonstrate the feasibility of drilling and lining long horizontal holes and the feasibility of emplacing and retrieving waste in the horizontal orientation. Once the decision is made, a more extensive development program will be required to demonstrate proof-of-principle, regardless of the orientation selected.

Sufficient information does not currently exist for selecting an emplacement option. Based on the potential advantages and the consistent use of reasonably available technology, there is, however, sufficient justification for the horizontal emplacement option to warrant further investigation. It is, therefore, recommended that approval be given to proceed immediately with the proposed program.

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K. Street, Jr.
Lawrence Livermore National
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Post Office Box 808
Mail Stop L-209
Livermore, CA 94550

L. D. Ramspott (2)
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Lawrence Livermore National
Laboratory
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Mail Stop L-204
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D. T. Oakley (2)
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Los Alamos National Laboratory
N-5, Mail Stop J521
P.O. Box 1663
Los Alamos, NM 87545

L. R. Hayes (2)
Technical Project Officer for NNWSI
U.S. Geological Survey
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J. A. Cross, Manager
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R. R. Loux, Jr., Executive Director (3)
Nuclear Waste Project Office
State of Nevada
Evergreen Center, Suite 252
1802 North Carson Street
Carson City, NV 89701

John Fordham
Desert Research Institute
Water Resources Center
Post Office Box 60220
Reno, NV 89506

Dr. Martin Mifflin
Desert Research Institute
Water Resources Center
Suite 1
2505 Chandler Avenue
Las Vegas, NV 89120

Department of Comprehensive
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Henderson, NV 89015

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International Corporation
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Golden, CO 80401

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E. P. Binnall
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Building 50B/4235
Lawrence Berkeley Laboratory
Berkeley, CA 94720

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Eric Anderson
Mountain West Research-Southwest, Inc.
398 South Mill Avenue, Suite 300
Tempe, AZ 85281

Judy Foremaster (5)
City of Caliente
Post Office Box 158
Caliente, NV 89008

J. P. Pedalino
Technical Project Officer for NNWSI
Holmes & Narver, Inc.
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Las Vegas, NV 89109

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Washington, DC 20585

J. R. Rollo
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for Engineering Geology
U.S. Geological Survey
106 National Center
12201 Sunrise Valley Drive
Reston, VA 22092

Vincent Gong
Technical Project Officer for NNWSI
Reynolds Electrical & Engineering
Co., Inc.
Mail Stop 615
Post Office Box 98521
Las Vegas, NV 89193-8521

S. H. Kale (RW-20)
Office of Civilian Radioactive
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U.S. Department of Energy
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Washington, DC 20585

J. H. Anttonen, Assistant Manager
for Commercial Nuclear Waste
Basalt Waste Isolation Project
Office
U. S. Department of Energy
P.O. Box 550
Richland, WA 99352

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Office of Civilian Radioactive
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R. L. Bullock
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Prof. S. W. Dickson
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Mackay School of Mines
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Reno, Nevada 89557

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L. Jardine
Project Manager
Bechtel National, Inc.
P.O. Box 3965
San Francisco, CA 94119

D. Harig
Project Manager
Parsons Brinckerhoff Quade & Douglas, Inc.
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