Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-006 Rev: 2

WBS No. 1.2.6.4	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	R.L. Coppage	R. Coppage	Sr. Mine Engr	8-9-9
CHECKER:	M.J. Esp	Mark J. Esp	Sr. Mine. Engr	8-9-9
APPROVAL - LDE:	B.T. Stanley	Bruce T. Stanley	Ld. Mining Eng.	8-9-9
APPROVAL - SCDM:	B.R. Chytrowski	B.R. Chytrowski	SCDM	8-9-91
QA CONCURRENCE:	PAUL B. HALE	Paul B Hale	Sr QA Specialist	8-9-9

SUBJECT: ESF ACCESSES - SHAFT

TITLE: PRELIMINARY SIZING OF OPTIONAL SHAFT

QAG Reference: RSN-GR-013, Rev. 0

1. PURPOSE: The purpose of this analysis is to develop a recommendation for the cross section diameter of the optional shaft which might be required to support the site characterization program of the ESF project. Revision 1 responds to Management review comments generated on June 3 through 5, 1991. Revision 2 responds to Technical Review Comments generated in June 1991.

2. METHOD: The following steps will be taken in this analysis:

   - Review all test requirements
   - Develop sizing criteria for testing requirements
   - Make shaft cross section layouts which satisfy testing space requirements
   - Discuss merits of various configurations
   - State conclusions reached from discussion
   - State recommendation

3. INPUTS: Refer to DOE letter, Gertz to Bullock, re. Authorization for conducting a design study to develop a reference Exploratory Studies Facility (ESF) design to be used as input to Title I Design Summary Report, dated February 22, 1991.

   3.1 YMP/CC-0013, ESFDR, Rev. 5/31/91, issued 5/31/91, Section 1.2.6.4: FR 1; PC 1c i, ii, iv, 1i i; C Ai, B i, ii, iii.

4. CODES AND STANDARDS: None applicable

5. ASSUMPTIONS: The following assumptions are applicable:

   5.1 The required usable shaft diameter is independent of excavation and lining/support methods.

   5.2 The shaft will not be used for the hoisting of materials and muck, and since it may be constructed very late in the program, the shaft will not be used for personnel hoisting except for scientific access.

9112020061 - Part 3

5.3 The shaft will not have a ventilation function in the ESF construction.

5.4 The previous Title I test equipment and configuration of the tests will apply to this analysis.

5.5 The smallest shaft diameter which fulfills the required functions is the preferred size.

5.6 Except where absolutely required, testing should be carried out in the shaft without the necessity of excavating alcoves.

5.7 All assumptions are to be included in the approved BFD.

NOTE: None of the above assumptions are required to be verified. Assumptions 5.1, 5.2, 5.3, 5.4, and 5.6 are used throughout the Analysis Development. Assumption 5.5 is used in the Recommendation p. 10 of 12.

6. REFERENCE MATERIAL: The following reference material was used in the preparation of this analysis:

- ESF SDRD Title II Vol. 2 Appendix B, Rev. 2, issued 10/24/90
- ESF Title I Drawing Package for Various Test Related Items, (FSN to DOE) accepted 12/13/88

7. COMPUTER CODES USED: None

8. UNITS: English

9. ANALYSIS:

9.1 Scope: This analysis will make a preliminary recommendation for the cross section diameter of an optional shaft which may be constructed for site characterization/performance assessment testing purposes.

9.2 Approach:

- List the ESF functional requirements of the shaft
- Determine the space required for the performance of the functions
- Propose shaft cross section configurations which will fulfill the spacial requirements
- Discuss the relative merits of each configuration
- Develop conclusions from the discussion
- State a preliminary recommendation for the shaft cross section diameter

9.3 Shaft Functional Requirements: Ref. 3.1

- To safely and efficiently facilitate the conveyance of personnel from the surface to designated test areas along the shaft alignment
- Provide exposure of the rock mass to scientific investigation
- Provide a space for a platform to support testing activity such as core drilling, and equipment such as Data Acquisition Stations and core drills

9.4 Equipment space requirements to perform functions:

9.4.1 Provide a safe and stable means of transport for men and materials: In order to fulfill this requirement an enclosed hoisting compartment with continuous guides should be provided. The number of persons that will be hoisted in this compartment is unknown. However, enough space should be provided to permit the lowering of drilling equipment which is 3.5 ft x 3.5 ft in cross section. This requirement then forces the hoisting compartment to be 5.0 ft x 5.0 ft in cross section when space for clearance and the guides is provided. A 5.0 ft x 5.0 ft cross section will allow the use of a man cage with a 4.0 ft x 4.0 ft floor to be used thus allowing approximately 8 persons to be hoisted per deck.

9.4.2 Exposure of the rock mass: In Title I the shaft was laid out with a 12 ft diameter. Because of hoisting compartment and utilities space provisions approximately 50% of the shaft perimeter was unavailable for investigation. The shaft that is being considered here should be of such size and arrangement that most or all of the perimeter is accessible to the investigators.

9.4.3 Provide a safe platform for scientific activity: The shaft should have a cross section of sufficient size to allow safe and convenient entry and egress to the hoisting compartment. In addition, drilling and other test related activity should be carried on in enough space so that rotating machinery may be operated with reasonable safety and convenience.

9.5 Alternative shaft cross section layouts: Two variables are apparent for consideration:

9.5.1 Placement of the shaft hoisting compartment with respect to the shaft axis. The options will be either in the center of the cross section or at the edge of the section.

9.5.2 Cross section diameter - The cross section diameter must be of a size to permit safe and efficient test activity. The test activity includes drilling, equipment installation, taking measurements, and data processing. The data processing equipment is referred to as IDS. The diameter is influenced by several factors, these factors are:

- Drilling equipment layout and size: For the purposes of this analysis equipment with greater capacity than the minimum perhaps required will be considered. Assume a unit similar to a Longyear LM 37 (see Appendix A) will be used to drill the holes. This drill has the capability to drill 230 feet of HQ size hole which is more than was anticipated in Title I.

- Test equipment size: It is assumed that no equipment larger than the drilling equipment will be required. The IDS equipment is 3 ft x 3 ft cross section, its size is not a determinant since it may be located on a different level than the actual test activity.

- Vent tube: Past studies indicate that a 42 inch diameter vent duct (tube) will supply sufficient air to support any anticipated activity in the shaft.

- Utility lines: Pipes and electrical equipment. Water, compressed air, and a waste water pump column will be installed during shaft construction and will be left in place. Several power and communications cables will also be present. This equipment will be placed at or very near the hoisting compartment and will have minimal impact on the shaft diameter.

9.6 Alternative shaft cross section layouts: Figures 1, 2, 3, and 4 in the following pages show the alternative layouts of the shaft cross sections using the variables cited above.

9.7 Discussion of the shaft alternative layouts:

9.7.1 General comments:

Some spacial difficulties can be overcome by relocating the IDS equipment to another deck. The drill power module will throw off enough heat to reduce worker effectiveness and may very well be better off on another deck either above or below the testing level. A section of the vent duct can be temporarily removed when necessary to permit access to the shaft wall portion that it hides.

FIGURE 1

16 DIA. SHAFT CONFIGURATION

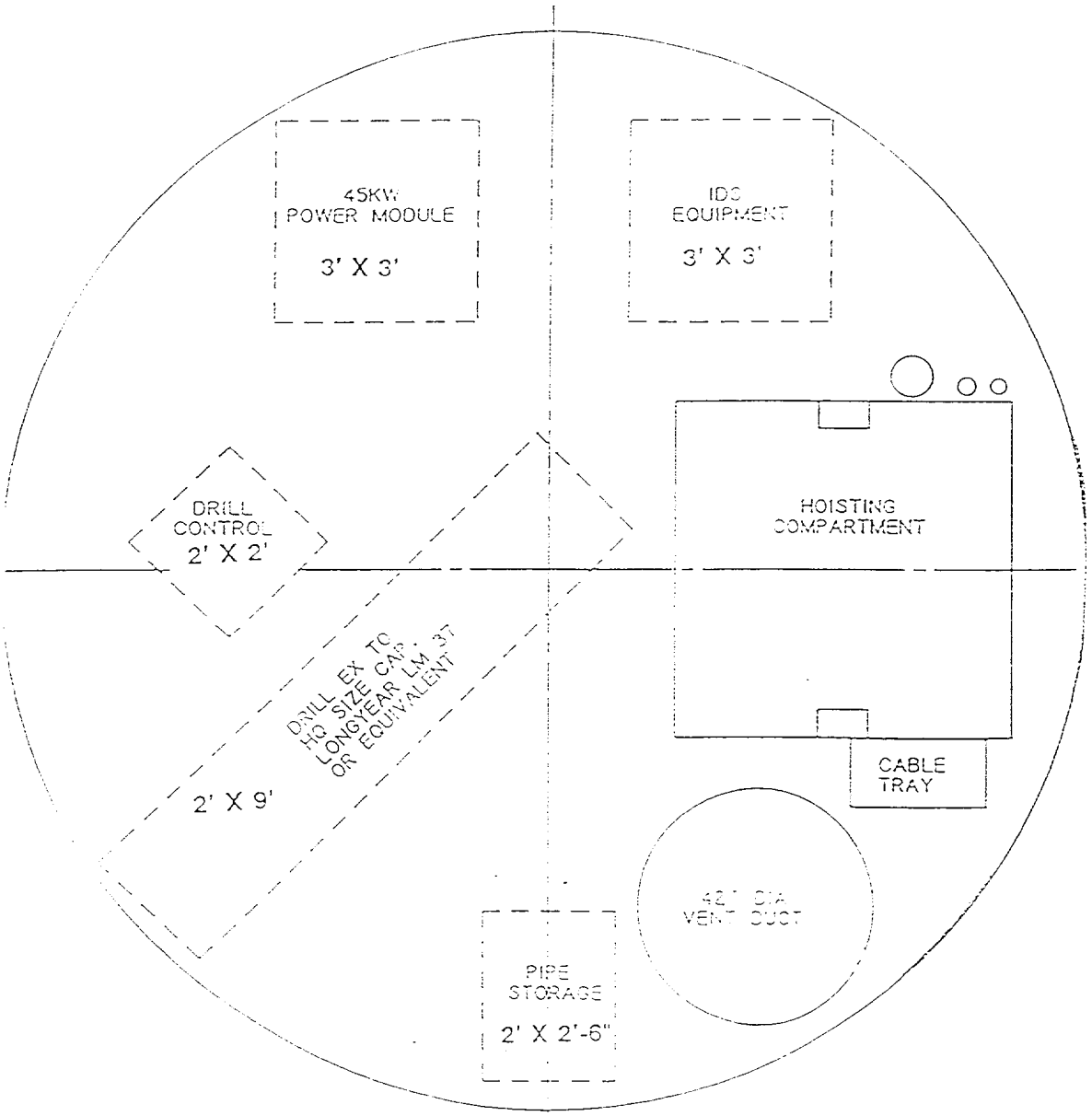


FIGURE 2

16 DIA. SHAFT CONFIGURATION

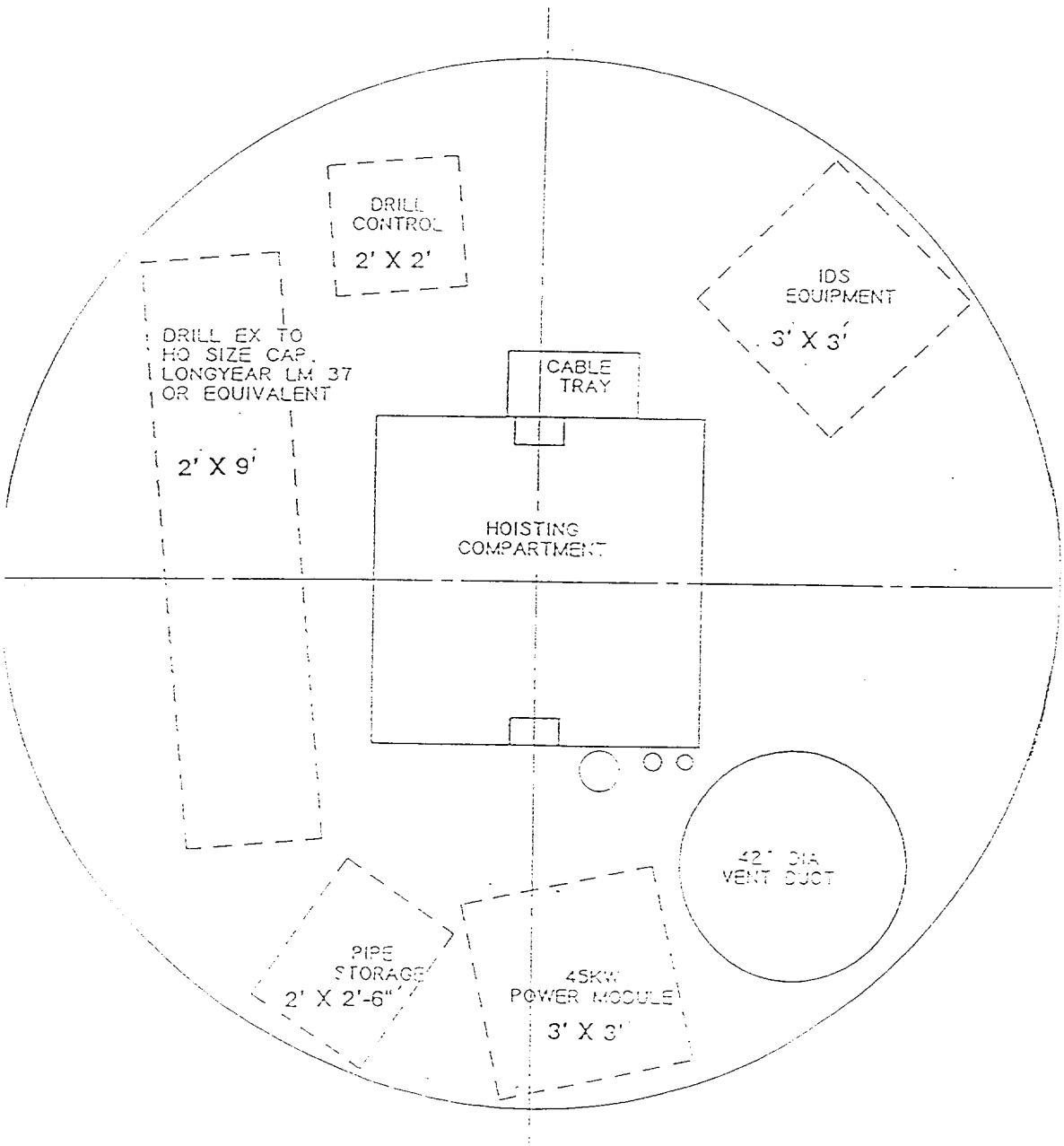


FIGURE 3

15 DIA. SHAFT CONFIGURATION

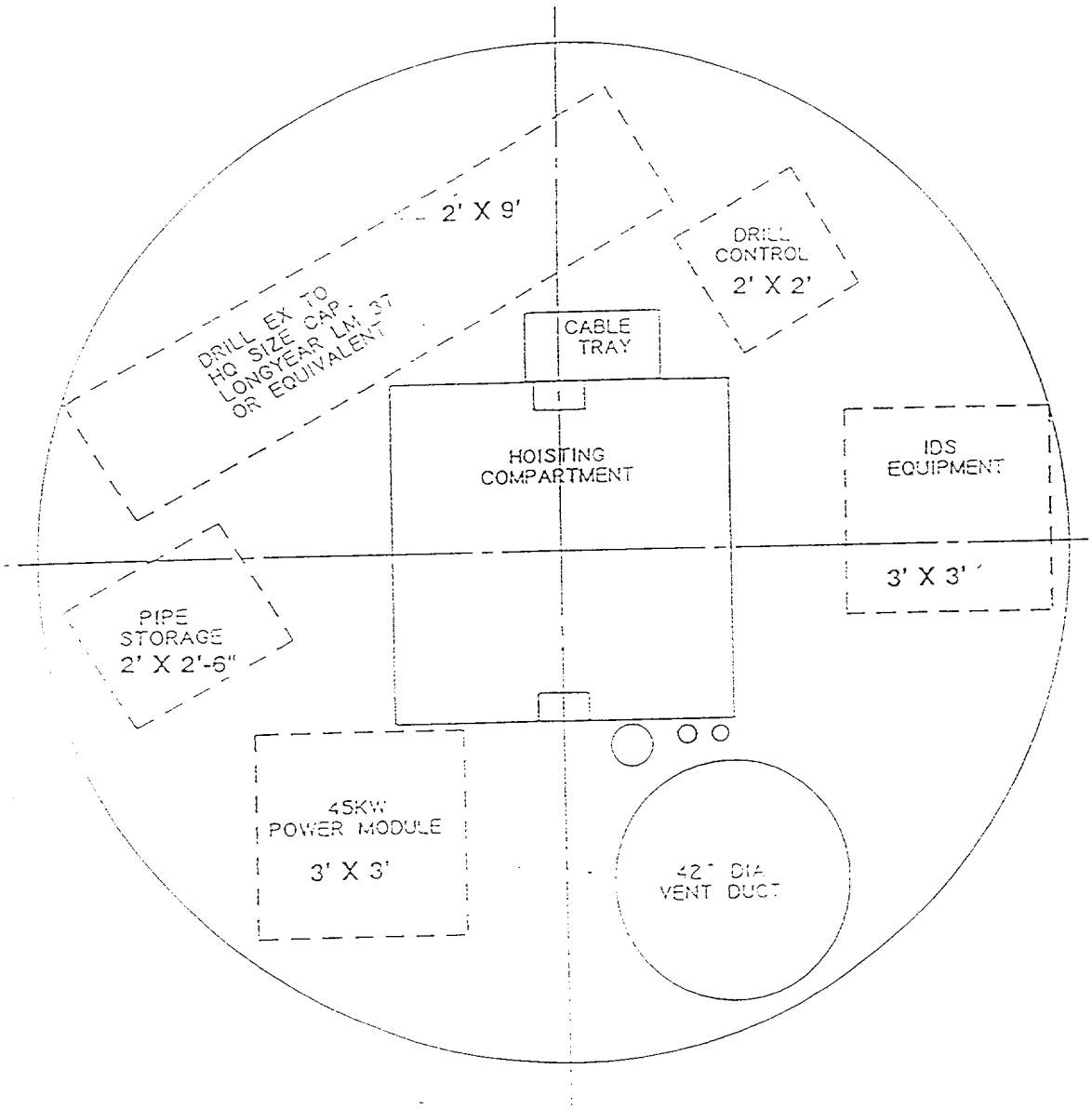
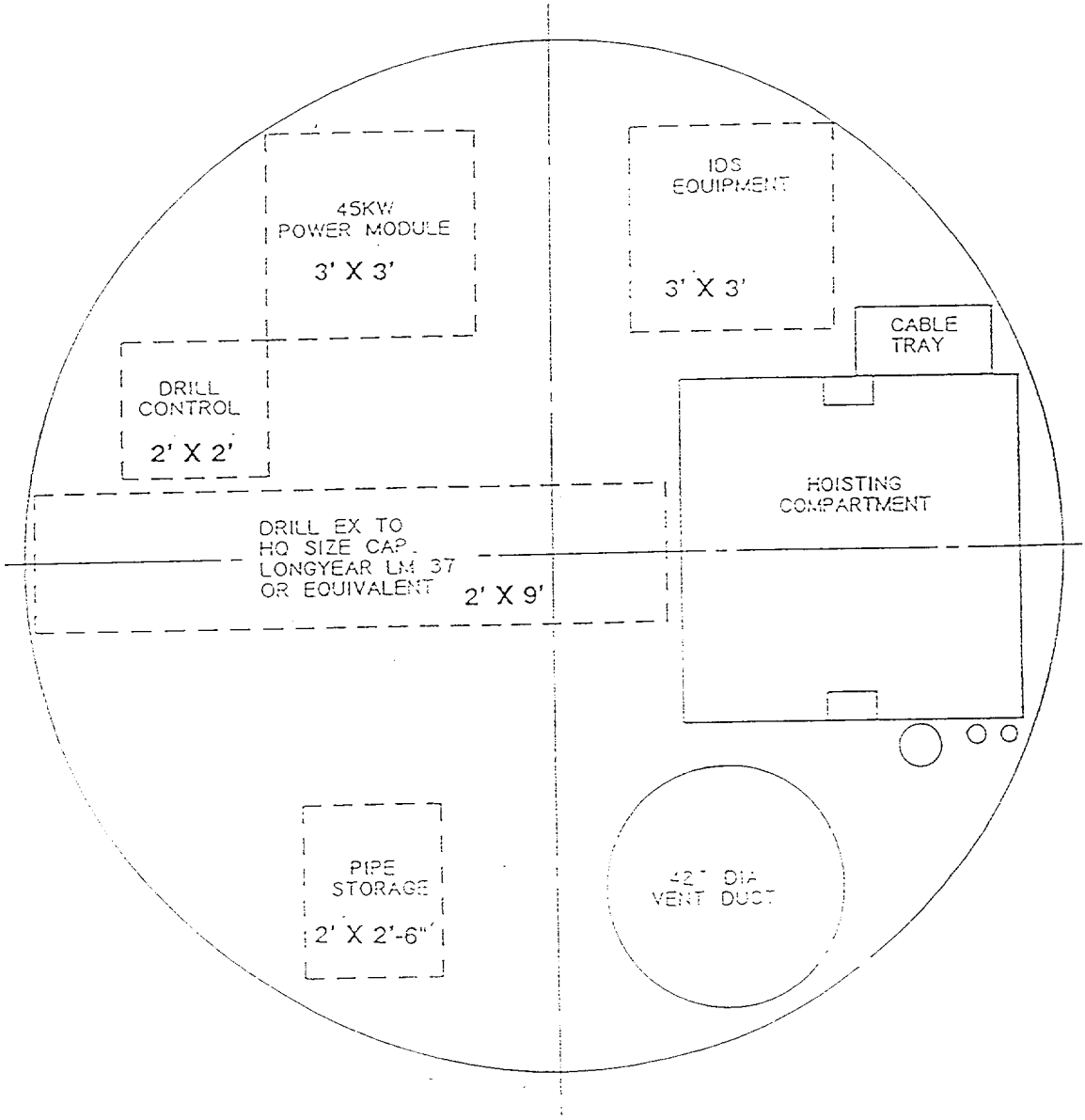


FIGURE 4

15 DIA. SHAFT CONFIGURATION



9.7.2 Figures 1 and 4

Advantage: Some holes can be drilled across the shaft centerline.

Disadvantage: Approximately 30% of the shaft perimeter is covered by the hoisting compartment.

9.7.3 Figures 2 and 3

Advantage: The entire shaft perimeter is available for investigation.

Disadvantage: Holes can't be drilled across the centerline of the shaft. It is not known at this time how significant this may be.

9.7.4 Sixteen feet diameter vs fifteen feet diameter:

- The drilling of test holes will be facilitated by the additional 1 ft of diameter in the 16 ft diameter shaft layout. A more compact version of a top head drive drill capable of doing the work required would be needed in any case if radial holes were mandated. The relative safety of the two configurations is evident as well. Tripping hazards are increased in the 15 ft diameter configuration because of the more crowded area. Several hoses and hand tools will be present on the deck although not shown.

- Various publications from time to time have made clear that the construction cost differential between a 16 ft diameter and a 15 ft diameter shaft is negligible. For this reason it can be assumed that cost is not a determinant of the cross section selection process being used here. Functional performance and safety are the primary considerations.

10. Conclusions and Recommendations:

10.1 Conclusions: The figures illustrate that fair efficiency during testing operations can be achieved in the layouts with a hoisting compartment located in the center of the shaft.

- The 15 feet diameter shaft will not support testing operations adequately because sufficient space is not available for personnel to walk and operate the equipment safely and efficiently. The 16 feet diameter shaft will provide better walkway space and reduce the probability of tripping hazards.

- In the absence of testing detail which would further define space requirements the drilling equipment space needed is assumed to have primary influence over the minimum shaft diameter that would support testing operations.

10.2 Preliminary Recommendation:

For the conceptual layout of the optional shaft use 16 feet finished diameter to support the intended testing function during ESF operations. It is recognized that this shaft, if it were constructed during ESF operations, would probably be utilized in the potential repository at some future date. The question which remains is should the shaft be constructed to repository size and specifications with respect to lining, shape, sealing requirements, etc. at this time?

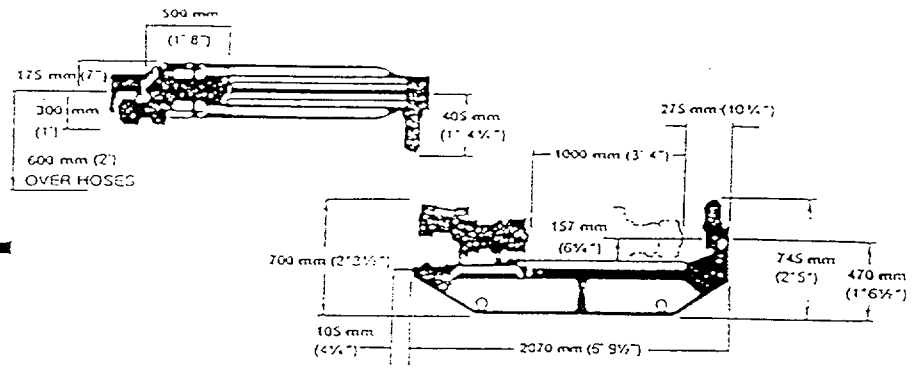
Additional analysis is required prior to answering this question.

Longyear TECH DATA

LM37 DIAMOND CORE DRILL

DIMENSIONS AND WEIGHTS

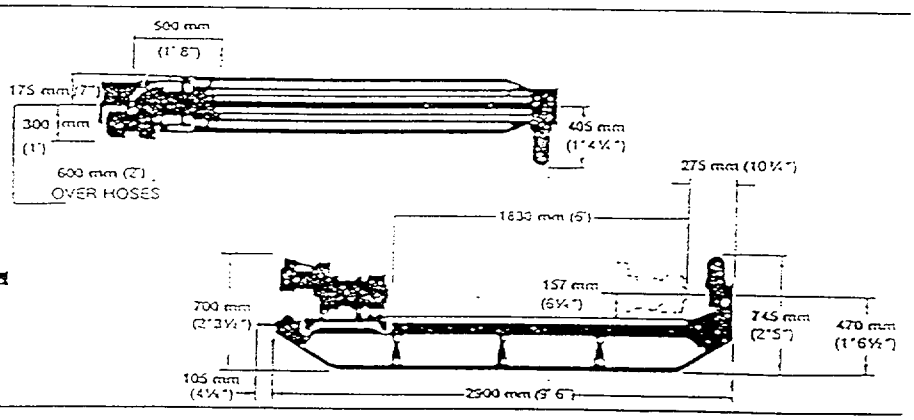
DATE	REFERENCE NUMBER	REPLACES
May 1988	LM 37/05-88	TechData LM 37/01-88



SHORT FEED FRAME

Weight 416 kg (915 lbs)

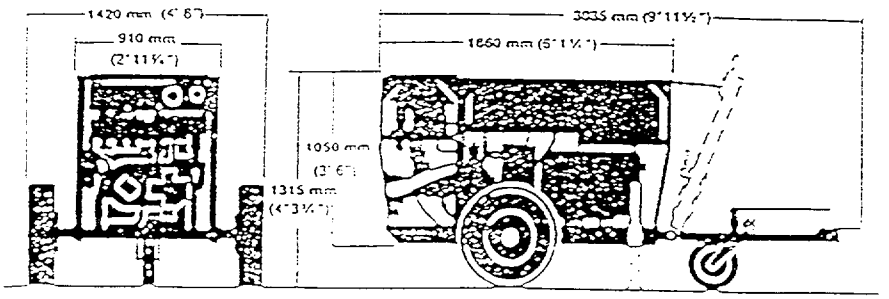
Add 50 kg (110 lbs) for version with HQ head and rod holder.



LONG FEED FRAME

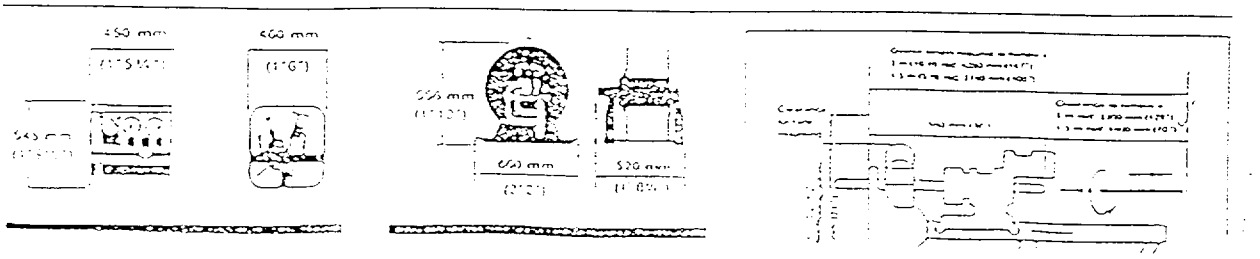
Weight 452 kg (995 lbs)

Add 50 kg (110 lbs) for version with HQ head and rod holder.



POWER PACK

1500 kg (3307 lbs)
with towing group



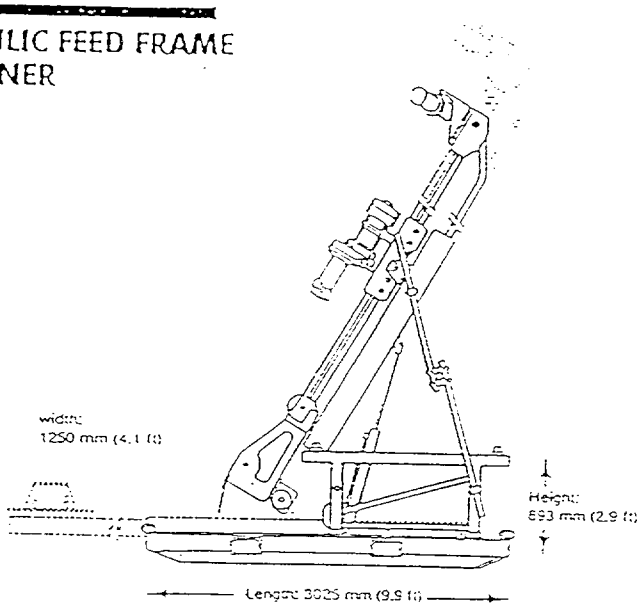
Longyear TECH DATA

LM37 DIAMOND CORE DRILL

DIMENSIONS AND WEIGHTS

DATE	REFERENCE NUMBER	REPLACES
May 1988	LM 37/05-88	TechData LM 37/01-88

HYDRAULIC FEED FRAME POSITIONER



Specifications

Inclination
Type: rotation in vertical plane; assisted by hydraulic cylinder
Angle range: 180° from vertical down to vertical up; tilt infinitely adjustable

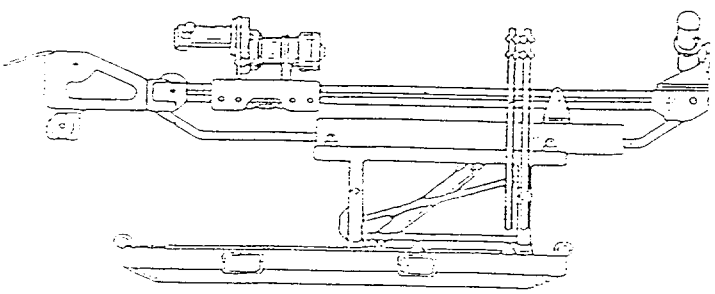
Longitudinal Extension
Type: hydraulically assisted (though drill head)
Translation: up to 1.3 m (4.3 ft); infinitely adjustable

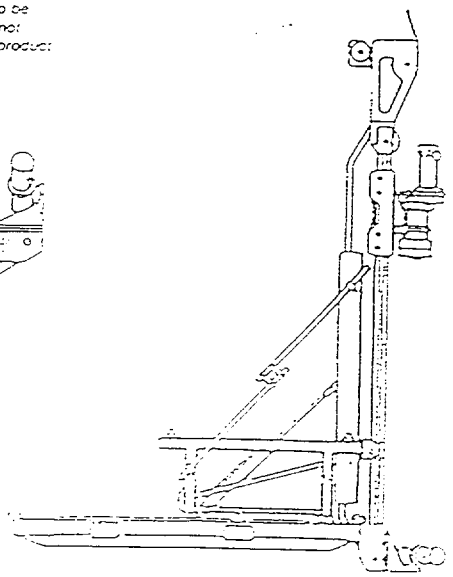
Hydraulic Hose Connections:
6m (20 ft) standard

Approximate Weights
Net: 610 kg (1340 lb)
Gross (export boxing): 640 kg (1410 lb)

Approximate Shipping
Net Volume: 3.4 m³ (120 ft³)

These drawings are meant to be representative only and are not accurate illustrations of the product to be sold





Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-007 Rev: 3

WBS No 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	R.L. Coppage	R. Coppage	SR. MINE. ENGR.	8-22-9
CHECKER:	M.J. Esp	Mark J Esp	SR. MINE ENGR.	8-22-9
APPROVAL - LDE:	B.T. Stanley	Bruce T. Stanley	Ld. Mining Engr	8-22-
APPROVAL - SCDM:	B.R. Chytrowski	B.R. Chytrowski	SCDM	8-22-9
QA CONCURRENCE:	PAUL B. HALE	Paul B Hale	SR. QA SPECIALIST	8-22-9

SUBJECT: ESF NORTH ACCESS RAMP

TITLE: PRELIMINARY TS NORTH RAMP CROSS SECTION SIZE ANALYSIS

QAG Reference: RSN-GR-013, Rev. 0

Preliminary TS North Ramp Cross Section Size Analysis

1. PURPOSE: The purpose of this study/calculation is to develop the conceptual cross-sectional excavated dimensions for the north access ramp to the Main Test Level (MTL). Revision 1 responds to Management review comments generated on June 3 through 5, 1991. Revision 2 responds to Technical Review Comments generated in June 1991. Rev. 3 responds to comments generated in August 1991.

2. METHOD: The method that will be used to develop the north ramp cross sectional dimensions will be as follows:

   2.1 Establish the functional requirements for the North access (called Waste in the SCP CDR) ramp during construction and operational phases for the ESF and repository.

   2.2 Determine appropriate vehicle dimensions, utility requirements, and required passageway clearances.

   2.3 Determine testing space requirements if any.

   2.4 Estimate ventilation pathway cross section size requirements, or various carrying capacities.

   2.5 Layout ground support/lining dimensions (make assumptions).

   2.6 Layout various ramp configurations (options) which satisfy all spacial requirements and then determine the minimum excavated cross section required. Discuss the merits of various sizes and configurations.

   2.7 State conclusions reached after analysis of the options.

2.8 State recommendation for ramp cross section dimensions and configuration.

3. ANALYSIS INPUTS:

3.1 ESFDR, Rev. 05/31/91, Sec. 1.2.6.5 Ramp Access; PC 1c.i,ii,iii,iv,v.; 1e., 1f.i,iv,; 1g., 1h.i,ii: 1i(ii), (iii), 2b.iv;2d.iii;2i.vii. CA.i, CB.ii, Section 1.2.6.5.4 PC 1c.

3.2 RIB, Chap. 2, Sec. 4, item 2, p. 3 of 6, Ver. 4, Rev. 4, 4-8-91. Ventilation Velocity Constraints.

4. CODES AND STANDARDS: The codes that will be used to determine clearances for machinery are:

30 CFR 57.9110 - July 1, 1988 edition
30 CFR 57.11001 - July 1, 1988 edition

5. ASSUMPTIONS: The assumptions listed below will be used in the analysis; none of these assumptions will be verified in this analysis.

5.1 Although the purpose of the ESF is to characterize the Yucca Mountain site and determine if the site is suitable for a repository, it is also necessary to consider the spacial requirements of a conceptual repository as well in this analysis. A guideline for all preliminary conceptual ideas, and for the alternative studies, is that the number of access penetrations from the surface to the emplacement horizon and below should be minimized. For this reason the concept of dual use; ESF and Repository, for access openings has influenced the design effort to date. This analysis will consider repository requirements as they are now known. Later developments in waste handling strategies may alter the North access ramp configuration. Assume that the ramp should be driven to the largest required size even if the largest size is dictated by repository requirements. The ramp should not have to be enlarged at a later date, since the enlargement process would cause disruptions in ventilation, and men and material movement, at the onset of repository development. This assumption is the basis for comparing the required size for both the ESF and respository functions. Therefore, this assumption applies throughout the analysis.

5.2 Construction and testing operations on the MTL and Calico Hills levels will be concurrent. This assumption has influence on the size of the ventilation return air conduit, (See p. 9 of 25).

5.3 The ramp will be constructed with a TBM and therefore will have an initial circular cross-sectional shape, (See p. 10 of 25).

5.4 The TBM will require disassembly and removal from the underground at the completion of ESF construction, (See p. 9 of 25).

5.5 All Design Input will be included in an approved Basis for Design.

5.6 Testing in the North access ramp during ESF development will consist of mapping and sampling. All other testing will be done on a non-interference basis. The waste ramp must be capable of supporting certain deferred tests. Sufficient space must be available to permit alcove excavation without long term utilities disruption, (See p. 8 of 25).

5.7 An allowance of [TBD] inches of over-excavation will be made for future ground support in the North access ramp, (See figure 3, p. 20 of 25).

6. REFERENCE MATERIAL: The following material was referred to during the preparation of this analysis.

6.1 FSN-AS-430 Rev. 2, P. 4 of 13 - Optional B7 Layout, Scenario 2.

6.2 Record of Verbal Communication, "Ventilation Duct Sizes in ESF N. Ramp Access and Calico Hills North," Jurani to Coppage 5-13-91.

6.3 ST-MN-010 Preliminary Transportation Methods Analysis Rev. 1.

6.4 PBQD letter dated 1-24-91, Harig to R. E. Finley SNL Re: Historical Information for Repository Design, with attachments.

6.5 PBQD CLTR 88-PB04 Alternative TBM Layout for the Repository (M. Grieves) 11/89.

6.6 SAND84-2641 SCP CDR Appendix R.

6.7 Personal Communication with J. Friant, Robbins Corp. Re: TBM Component Sizes.

7. COMPUTER CODES: Not applicable.

8. UNITS: The numerical units used in this analysis will be English Standard.

9. ANALYSIS: TS North Access Ramp.

9.1 Consider first the TS North Access ramp during ESF construction and operations.

9.1.1 Functional Requirements of the ramp during ESF construction and operations:

- Provide exposure of lithology and structure of the rock mass between the surface portal and the MTL for Site Characterization Testing. The opening arrangement must allow mapping and sampling and collection of perched water should it be encountered.

- Provide a conduit for excavation muck and ventilation air intake and exhaust during construction of the ramps.

- Provide a ventilation intake conduit during MTL construction after connection to the south ramp is completed.

- Provide for transport of equipment, supplies and fuels, to support subsurface construction and operations.

- Provide primary means of personnel entry and egress to the subsurface for construction and testing.

- Provide for the entry of all utilities to the underground; i.e. power, water (fire & process), communications, and compressed air.

9.1.2 Spacial Requirements for Functional Performance.

Site Characterization Testing - Sampling & Mapping

- Equipment used for sampling: Large diameter core drilling and diamond saws, the estimated space required is approximately 5′ wide x 7.5′ high x 5′ long.

- Equipment used for mapping: A scissor lift truck or Jumbo will be used which will have traveling dimensions as shown in ST-MN-010 Rev. 1 Preliminary Transportation Methods study.

- The North Ramp tests are defined or described in the ESFDR. it is assumed that adequate space will be available or can be made available with reasonable effort and with no significant disruption of subsurface operations.

Muck Conduit and Ventilation Conduit

- Refer to ST-MN-010 Rev. 1 Preliminary Transportation Methods Analysis, which defines the equipment which will be permanently installed in the north ramp during ESF construction and operations. The current recommendation is that the principal method of construction muck removal through the North access ramp will be by the use of a 36 inch wide troughed or tubular conveyor belt. The nominal cross sectional outline for this unit is shown in the referenced study. All the other equipment anticipated for use in the ESF are also sized in the referenced study.

- The ventilation exhaust duct size should be as large as commercially feasible to reduce resistance and provide ample allowance for contingencies. Seventy-two inch diameter pipe has been used in several tunnel jobs of this type, and is recommended for use here. A Preliminary Ventilation Analysis will support a recommendation for this size duct. Ref. 6.2, p. 5 of 25 of this report.

9.1.3 Transport of Equipment, Supplies and Fuels:

Refer to the ST-MN-010 Rev. 1 Appendix for the range of dimensions of the various trucks and other vehicles that could be used for this purpose during construction and operations.

9.1.4 One item which appears to have a larger dimension than any other piece of equipment contemplated for underground movement is a Calico Hills TBM Main Bearing. This item may be as large as [TBD] in diameter and 2.0′ thick. When the TBM work is completed, the TBM will be dismantled and removed through the ramp. A special transporter will be required for this job.

9.1.5 Personnel Entry and Egress:

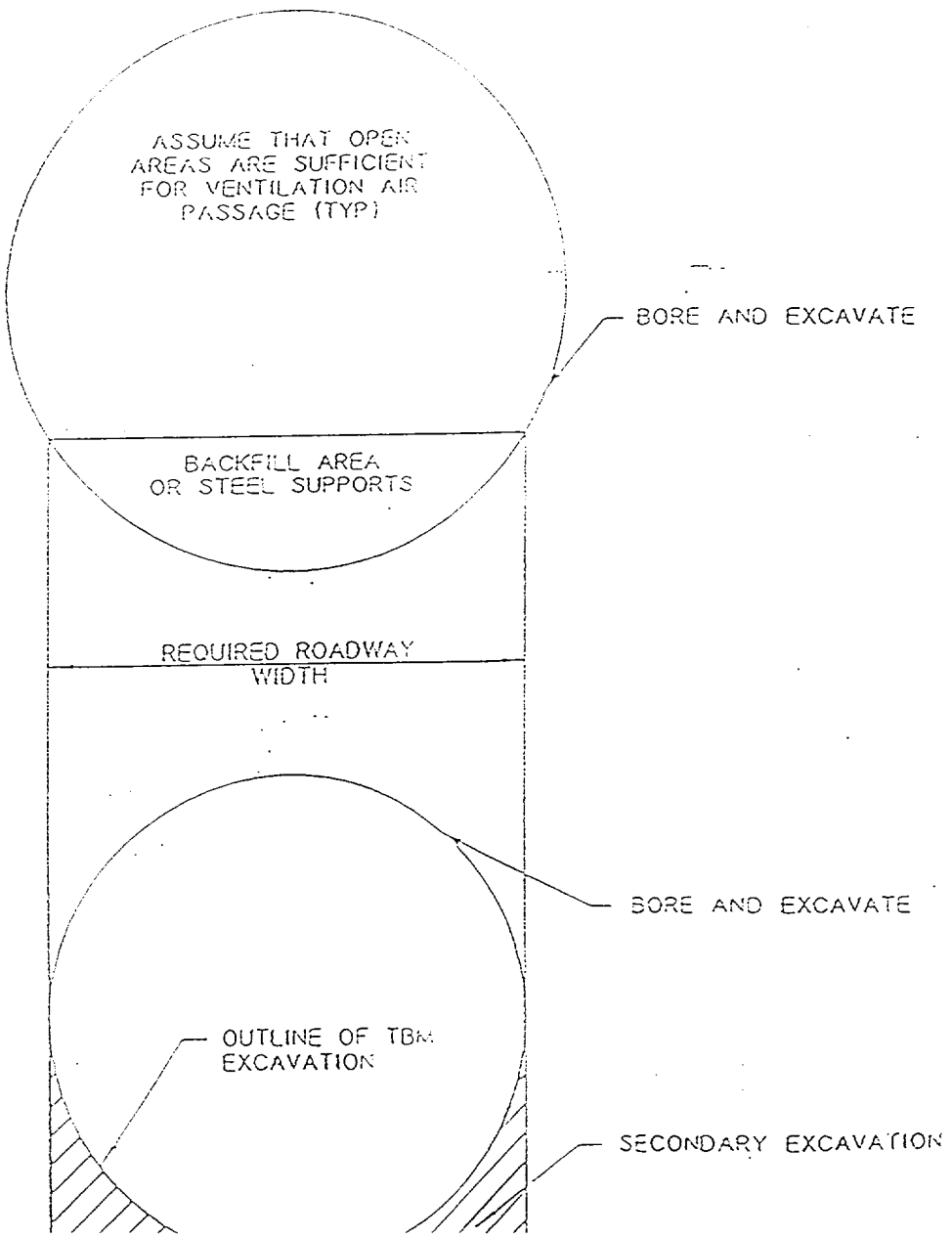
The movement of personnel by means of rubber tired vehicles will not influence the ramp cross section size, because the vehicles will be the same size as those used for materials. The personnel foot traffic will influence the ramp dimensions. In accordance with 30 CFR 57.9110, a minimum of 30 inches of clearance must be provided for foot traffic on at least one side of a vehicular roadway unless shelter holes are provided. It is preferred that this clearance be provided on both sides, however, in the case of the ramp at least one side will have a walkway of 30 inches.

9.1.6 Ramp Roadway Considerations

The use of a TBM for ramp construction produces an invert which is rounded and unsuitable for vehicular or regular foot traffic. In the case of the North access ramp a flat roadway surface is required to facilitate the anticipated testing and maintenance traffic. This can be produced in two ways: (1) Over-excavate sufficiently to permit backfilling with muck or concrete to produce a flat roadway of sufficient width or (2) after TBM boring, excavate a flat bottom of required width. Refer to Figure 1, next page, for an illustration of the configuration produced by the two methods.

FIGURE 1

TWO ROADWAY CONSTRUCTION METHODS



Each method has advantages. An analysis and selection of the optimum method applicable to the ramp is beyond the scope of this analysis. A preliminary assessment of the situation indicates that the excavate and backfill method has two construction related advantages over the two-step excavation method.

First, since the ultimate repository road width requirement is not now known because of waste transporter size uncertainty, a compacted backfill roadway could be removed easily and the final roadway constructed to the required width when needed. The second advantage is that secondary excavation would most probably require the use of explosives or a hard rock mechanical excavator. Mucking would require a LHD. Due to blasting and smoke clearing needs or complications caused by mechanical excavation, this process would be slow and disruptive of testing and TBM continuous operations. Additionally, vent tube installation and blasting protection work could also complicate and impede the ramp construction process. The conclusion at this point without a detailed analysis is that the bore and backfill method of roadway construction should be used for the purpose of this general arrangement/conceptual analysis. The method that is least impactive to the natural rock state should be selected, this would favor the backfill method of road construction.

9.1.7 Utility Entry to the Underground:

The following utility lines are presumed to be present concurrently in the ramp. These are estimated maximum sizes and numbers:

- 1 ea. 8 inch diameter fire fighting water line
- 1 ea. 4 inch diameter process water line
- 1 ea. 10 inch diameter compressed air line
- 3 ea. 3 inch diameter power conductor conduits
- 3 ea. 2 inch diameter communication conduits
- 6 ea. 2 inch diameter IDS conduits

The placement of the utilities will have negligible impact on the ramp size, especially in view of the excess space created by adoption of a circular cross section.

9.1.8 Clearances required or specified during ESF construction.

- Walkways: At least 30 inches on one side of the vehicular travel way must be provided.

- Any test area should have at least 7.5 feet of head room to allow operation of a core drill or a rock sawing operation.

- At least 1 foot of clearance should be allowed between the vehicular travelway and a barrier separating the test area from the travel way to allow for vehicle safety.

- There should be an allowance of 1 foot of clearance (minimum) between the ventilation pipe bottom and the top of the vehicles passing beneath for safety reasons.

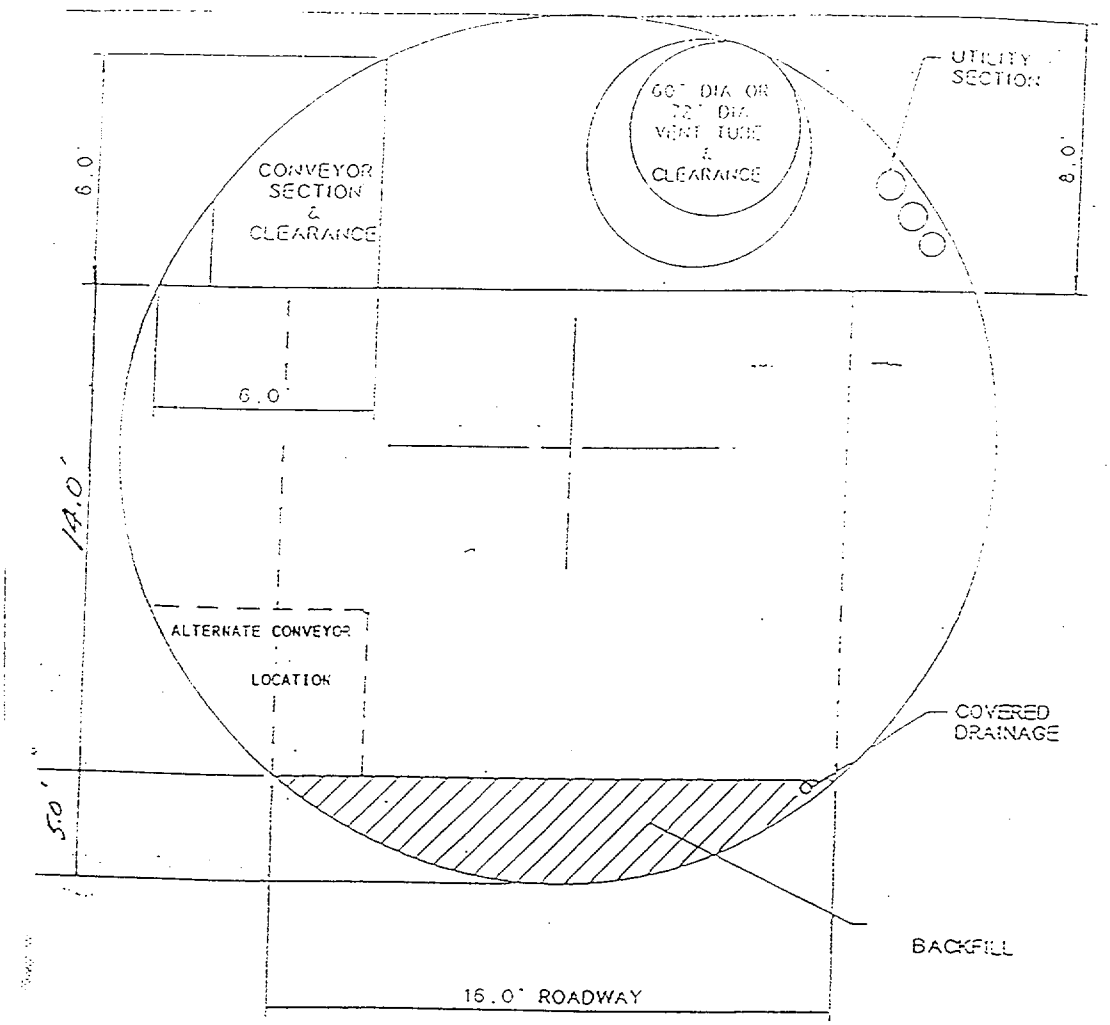
9.1.9 Typical Preliminary Layout of the Waste Ramp Cross Section during construction. (See Figure 2)

Inspection of this Figure leads to the following conclusions:

The primary, top to bottom air flow obstructions are the vent tube, conveyor and utilities. The flat bottom requirement for wheeled equipment passage and testing operations adds significantly to the size of the excavated opening which must be created.

FIGURE 2

TS NORTH RAMP ACCESS
GENERAL ARRANGEMENT 25' DIAMETER
DURING ESF OPERATIONS



TYPICAL 25' DIA RAMP/DRIFT
WITH 16'x14' HIGH
CLEARANCE FOR TRANSPORTION

9.1.10 The maximum area available for ventilation airflow is calculated as follows:

- Excavated area = 491 ft^2
- Obstructions to airflow:
- Flat bottom fill = 32 ft^2
- Permanent equipment obstructions :

  conveyor = 6 ft x 4 ft (approx): = 24 ft^2

  vent tube (72 in. diameter): = 28 ft^2

  total area equipment: = 52 ft^2

  - Liner deduction (12" thick): = 60 ft^2
  - Utility line area: = 2 ft^2

  TOTAL Obstruction = 146 ft^2
  - Net Area for airflow = 345 ft^2

This space will permit 517,500 cfm flow without exceeding the mandatory upper limit of 1500 fpm (Ref. 3.2, p. 2 of 25 of this report) for airspeed in walkways.

9.2 SPECIAL REQUIREMENTS DURING REPOSITORY OPERATIONS

9.2.1 Functional requirements of the waste ramp during repository emplacement operations:

- Provide fresh air flow to the operations areas
- Provide a roadway from surface to the emplacement level for waste transporter.
- Provide a secondary means of personnel egress from underground to the surface.
- Provide for entry of utilities from surface to the underground.

9.2.2 Space requirements in the waste ramp to perform its functions during repository operations:

- Fresh air flow requirements:
  Refer to SAND 84-2641, SCP CDR, Appendix R, p. R-39.
  Preliminary analyses indicate 625,000 CFM may be required depending upon emplacement strategies and development methods.

  625,000 CFM/1500fpm = 417 ft^2

  If the maximum allowable velocity in the waste ramp is 1500 F.P.M. more ventilation requirement studies will be conducted as repository design develops. The volume requirements may change and thus impact the ramp cross section dimension. For the present the quantities shown above will suffice.

- Waste transporter space requirement: Refer to Section 6.4 of this report for the latest waste transporter cross sectional dimensions:

  15 ft wide x 13 ft high (not verified)

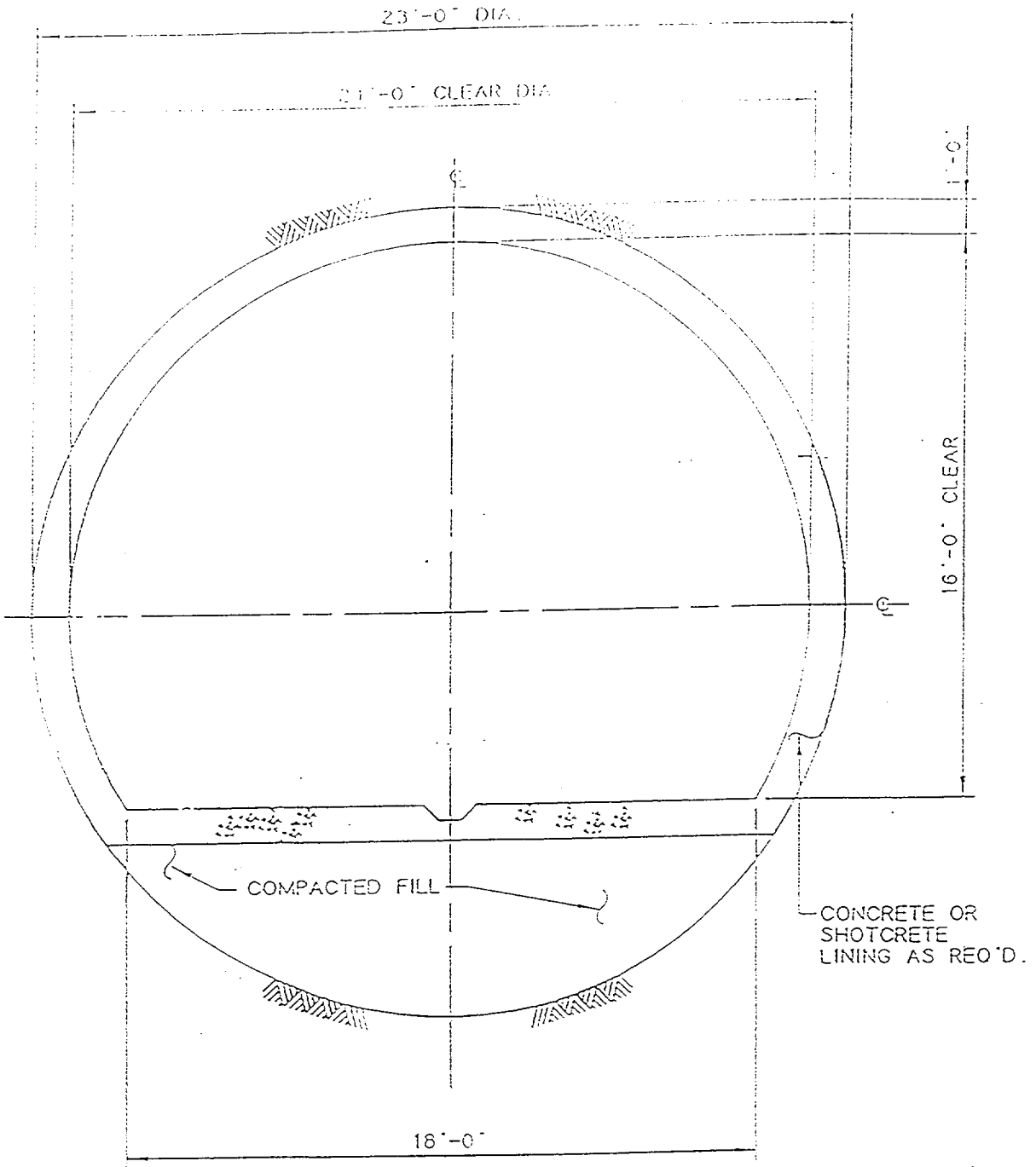
- Personnel egress transporters are assumed to be smaller than the waste transporter. A 30 inch wide walkway minimum must be provided outside of the vehicle passageway or safety alcoves must be provided at appropriate intervals.

9.2.3 Refer to Figure 3 for a proposed North access ramp configuration during the repository operations as presented in Section 6.4 of this report.

This configuration does not provide the required space:

Area available for functions	=	281.6ft^2
Area required for air flow	=	417.0ft^2
Additional space required	=	135.4ft^2

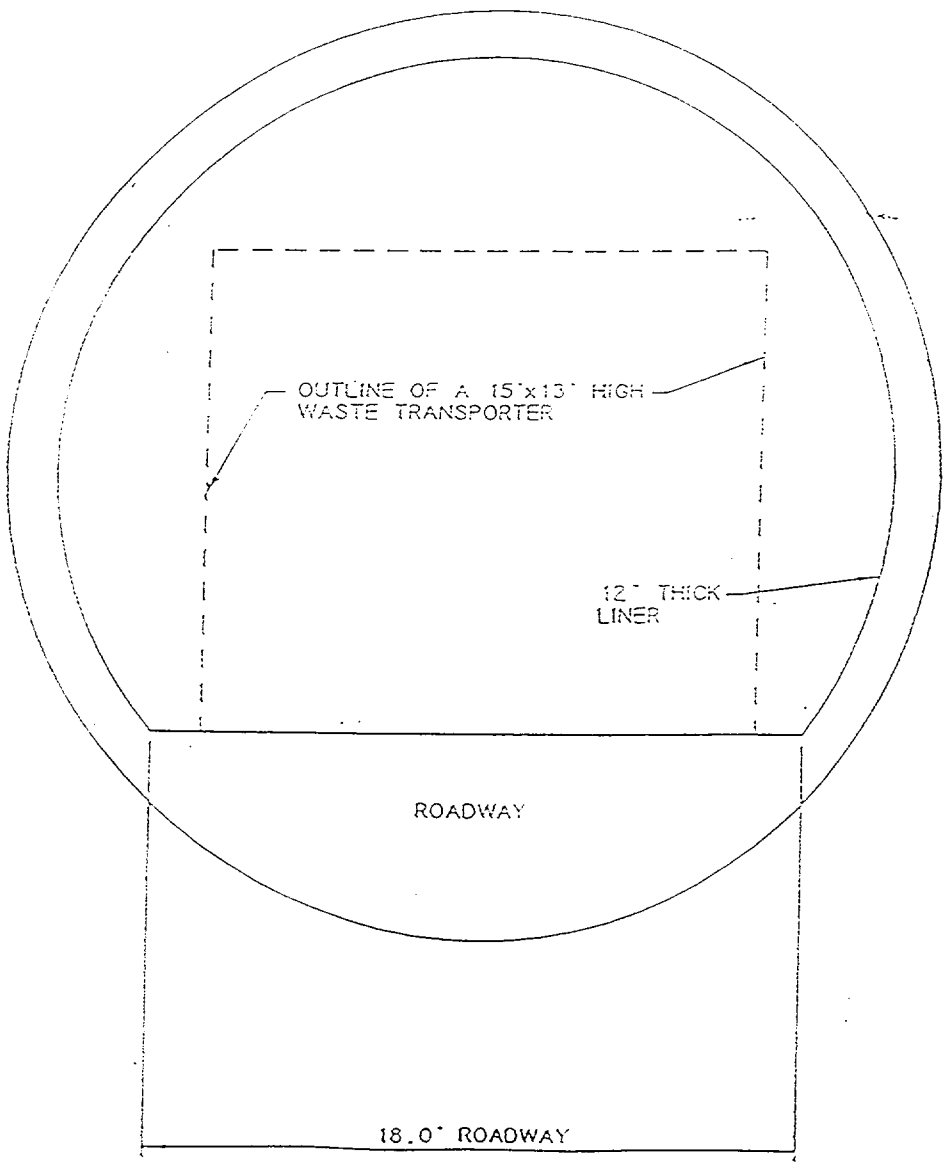
9.2.4 Subsequent to the development of the SCP CDR cross section, particularly during the alternative studies, it became clear that the repository requirements for the ventilation and waste transportation functions could and probably would increase. It was proposed for the alternative studies that a cross section similar to Figure 4 should be used for planning purposes at this time:



SCP-CDR WASTE RAMP

FIGURE 4

TS NORTH 25' DIA. RAMP EXCAVATION SUPPORTING REPOSITORY OPERATIONS



This cross section allows for the passage of approximately 541,000 CFM ventilation intake during repository operations which more closely matches some repository estimates. This layout barely provides adequate clearance for the latest waste transporter (15 ft. wide) version. The addition of more bottom fill and roadway paving could provide more roadway width causing greater air flow velocity. At present, the transporter width requirements are not completely defined and will change with time, therefore this layout will suffice for the present analysis.

9.2.5 Special requirements at the time of this analysis
One special requirement is apparent:

Upon completion of drifting on the TS level it will be necessary to disassemble the TBM(s) for removal through one of the ramps. Personal Communication with a major TBM manufacturer indicates that the largest component for a 25 ft. diameter TBM that would be used to drive the Calico Hills ramp that would be moved through existing openings would be a main bearing with outside dimensions of approximately 12′ diameter by 2.0′ thick. This piece could be easily moved through the North access ramp if it is bored 25 ft. in diameter.

10.0 CONCLUSIONS:

10.1 Conclusions applicable to the TS North access ramp during the ESF construction period:

If the assumptions made with regard to maximum equipment size and test space allocations are correct then a minimum of 16 ft. x 14 ft. (Refer to Figure 2) is required to permit efficient ESF construction and testing operations. Large Jumbos, LHDS, and drills were considered. Smaller equipment could be used, however, the mine plan, schedules, and opening sizes indicate that larger sizes of commercial excavation equipment will be more efficient and therefore will better support the schedules. These assertions are supported in ST-MN-010 Rev. 1. The test space allocation is highly speculative and not strongly supported by test plans because (1) The test plans are not well defined now, and (2) the testing activities are sporadic and may occasionally be done in the ramp cross section without resorting to alcove construction. Space for drill equipment and walkways will be essential in several areas, as well as a barrier to reduce the

hazard of collision by moving vehicles with people and test related fixtures. For the purposes of this analysis a reduction in the equipment sizes is not preferred.

Vent tube size reduction may increase the air flow velocity in the tube above that which is recommended practice. Since fan power requirements vary as the velocity cubed, vent tube size reduction could be an undesirable choice when power supply costs and other factors are considered. The conclusion is that the 25 ft. diameter ramp cross section will permit the use of efficient equipment sizes and permit most test activities to be carried out.

10.2 Conclusions applicable to the TS North access ramp during repository operations.

The possible ventilation requirements for repository operations indicate that a 25 ft. diameter waste ramp would fulfill the ventilation function better than a smaller diameter. Since the waste transporter may require 15 feet of roadway width, 25 feet is again required, as shown in Figure 4.

Uncertainties with respect to waste transporter size, ESF excavation schedules, repository ventilation requirements and ground support requirements (liner thickness) lead to the conclusion that a conservative approach should be taken to ensure that enough space is provided for the efficient performance of the functional requirements. The adoption of a 25 ft. excavated diameter ramp exhibits a conservative approach to providing functional space in the ramp using the available information.

10.3 Recommendation: Excavate the TS North ramp to a 25 ft. diameter size from the portal to the MTL level intersection.

This recommendation is in conflict with the RIB Chap 2, Sec. 4, item 1, p. 2 of 3, version 4, Rev. 4, which states that the waste ramp should have an excavated diameter of 21 feet. After review of this analysis and more definitive information regarding repository requirements is developed, a change in the RIB should be made if a 25 ft. diameter ramp is required.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-008 Rev: 2

WBS No. 1.2.6.4.3	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	R.L. Coppage	R. Coppage	SR. MING. ENGR.	8-9-91
CHECKER:	M.J. Esp	Mark J Esp	SR. MING. ENGR.	8-9-91
APPROVAL - LDE:	B.T. Stanley	Bruce T. Stanley	Ld. Mining Engr.	8-9-91
APPROVAL - SCDM:	B.R. Chytrowski	B.R. Chytrowski	SCDM	8-9-91
QA CONCURRENCE:	PAUL B. HALE	Paul B. Hale	Sr QA Specialist	8-9-91

SUBJECT: ESF ACCESSES

TITLE: CALICO HILLS NORTH RAMP SIZING STUDY

QAG Reference: RSN-GR-013, Rev. 0

1.0 PURPOSE: The purpose of this analysis is to make a preliminary recommendation for the diameter of the Calico Hills North Access Ramp. Revision 1 responds to Management review comments generated on June 3 through 5, 1991. Revision 2 responds to Technical Review Comments generated in June 1991.

2.0 METHOD: The following procedure will be followed in this analysis:

- List the Design Requirements for the ramp.
- List the functional requirements of the ramp as developed in the Alternative Studies.
- Refer to the Transportation Methods Analysis to determine the size and placement of equipment in the ramp cross-sectional space.
- Develop possible cross-sectional general arrangements which meet the basic requirements.
- Discuss the merits of the various options as to how well each fulfills the functions assigned to the ramp.
- List the conclusions that may be drawn from the discussion of the merits of each option.
- Based on the conclusions reached, make a preliminary recommendation for the ramp diameter.

3.0 DESIGN INPUTS: The following ESFDR sections are pertinent to the sizing of the Calico Hills North Access ramp: The reference is YMP/CC-0013, ESFDR, Rev. 05-31-91, 1.2.6.5

PC 1c.i,ii,iii,iv,v.; 1e., 1f.i,iv,; 1g., 1h.i,ii; 1i(ii),(iii), 2b.iv;2d.iii;2i.vii. CA.i, CB.ii
Section 1.2.6.5 .4 PC 1c

4.0 CODES AND STANDARDS: 30 CFR 57.9110. July 1,1988 ed.

NOTE: Compliance with 30 CFR 57 is one of the primary criteria governing this analysis.

5.0 REFERENCE MATERIAL:

5.1 ST-MN-010, Rev. 1, 6-14-91, Jurani, Preliminary Transportation Methods Analysis.

5.2. Record of Verbal Communication, Jurani to Coppage, 5-13-91, "Ventilation Duct Sizes in ESF N. Ramp Access and Calico Hills North Access Ramp."

5.3. FSN-AS-430, Rev. 2, Alternative Studies, Option B-7, Scen. 2. (Option 30).

5.4. ESF Test Planning Package 91-5, Preliminary ESF Test Planning package for support of Pre-Title II, ESF Design Studies.

5.5 Letter from Tamondong to Grenia 7-23-91, regarding Change in Calico Hills N/S ramp size. IC 1625

5.6 YMP-025-2-MING-MI49 and 50, rev. A.

5.7 RSN ST-MN-030, and 031. Rev. 0

6.0 ASSUMPTIONS: The following assumptions have been used in the development of this analysis: No verification of these assumptions is required.

6.1. The ramp diameter should not be larger than is necessary to permit safe and efficient performance of its function (p. 10 of 12 of this report). Supports all statements in the Conclusions and Recommendations).

6.2. All Design Input will be included in an approved Basis for

6.3 Any testing activity which would impede the advance of the TBM excavation process will either be postponed or will be done in alcoves created on a non-interference basis. Tests will be performed at locations and times to be determined by the test PI based upon field observations. Refer to reference 5.4 above. Assume that no space for testing is required in the typical ramp cross section and that alcoves will be constructed as needed. (Supports Concl. no. 2, p. 11 of 12).

7.0 COMPUTER PROGRAM:

Not applicable.

8.0 UNITS: English Standard

9.0 ANALYSIS - Scope: The scope of this analysis is to:

1. State the functional requirements of the Calico Hills North ramp;
2. Refer to analyses which indicate the space required to accommodate equipment and fixtures which support the functional activity;
3. Develop alternative layouts of the ramp cross-section;
4. Select the layout which best suits the functional requirements and constraints.

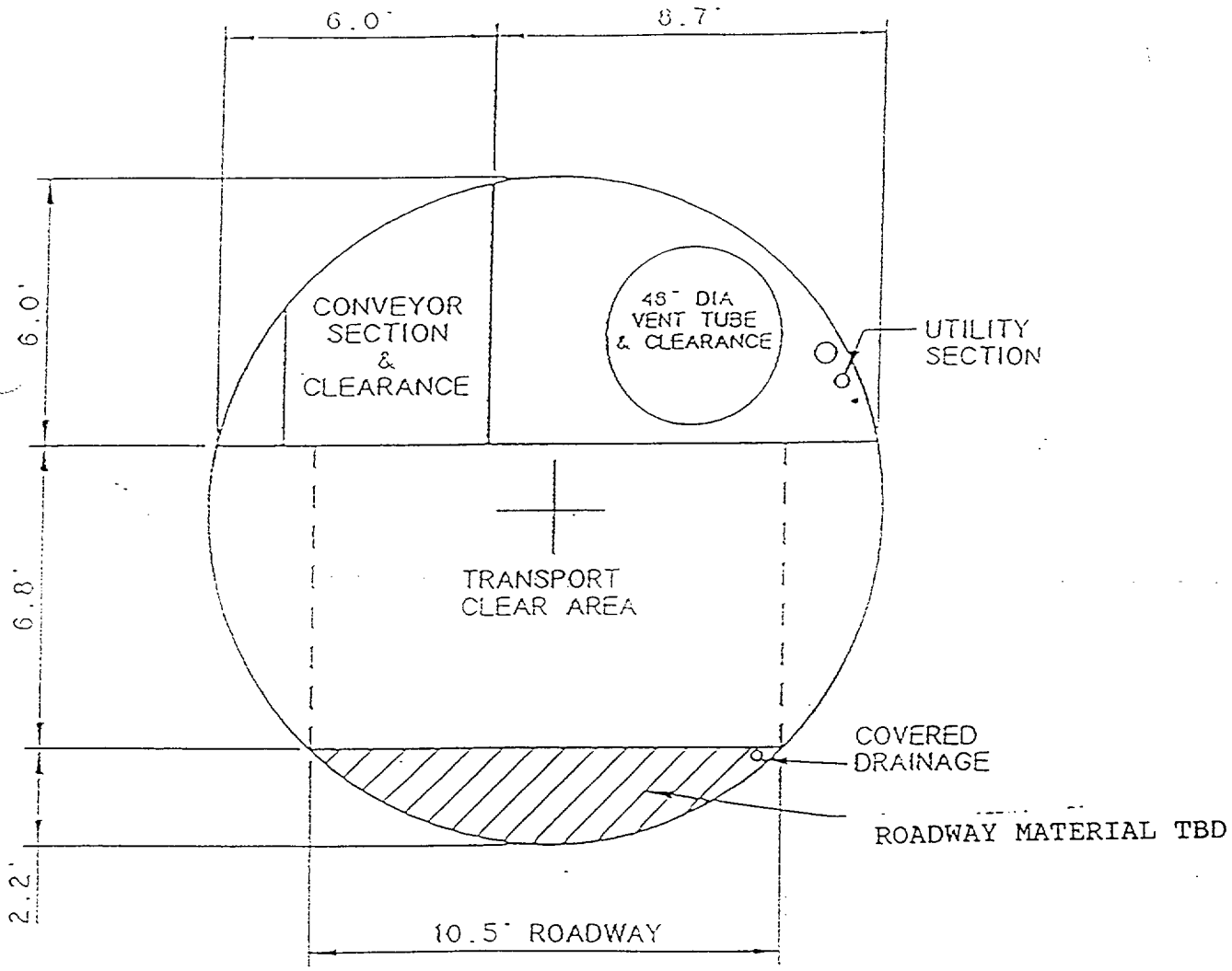
9.1 Functional Requirements: The following are the presently known functions of the Calico Hills North Access ramp:

1. To provide an access for personnel and equipment to the Calico Hills level from the TS North Access Ramp;
2. To provide exposure of the rock mass that lies between the MTL and the Calico Hills Level for scientific examination and evaluation;
3. To provide a pathway for ventilation airflow to support construction and testing operations in the Ramp and on the Calico Hills Level.

9.2 Refer to ST-MN-010, "Transportation Methods Analysis," which presents the cross-sectional dimensions of the equipment that could be used in the Calico Hills operations. The largest sizes of the appropriate equipment should be used to develop the cross section layout for the sake of conservatism and flexibility of operations scheduling.

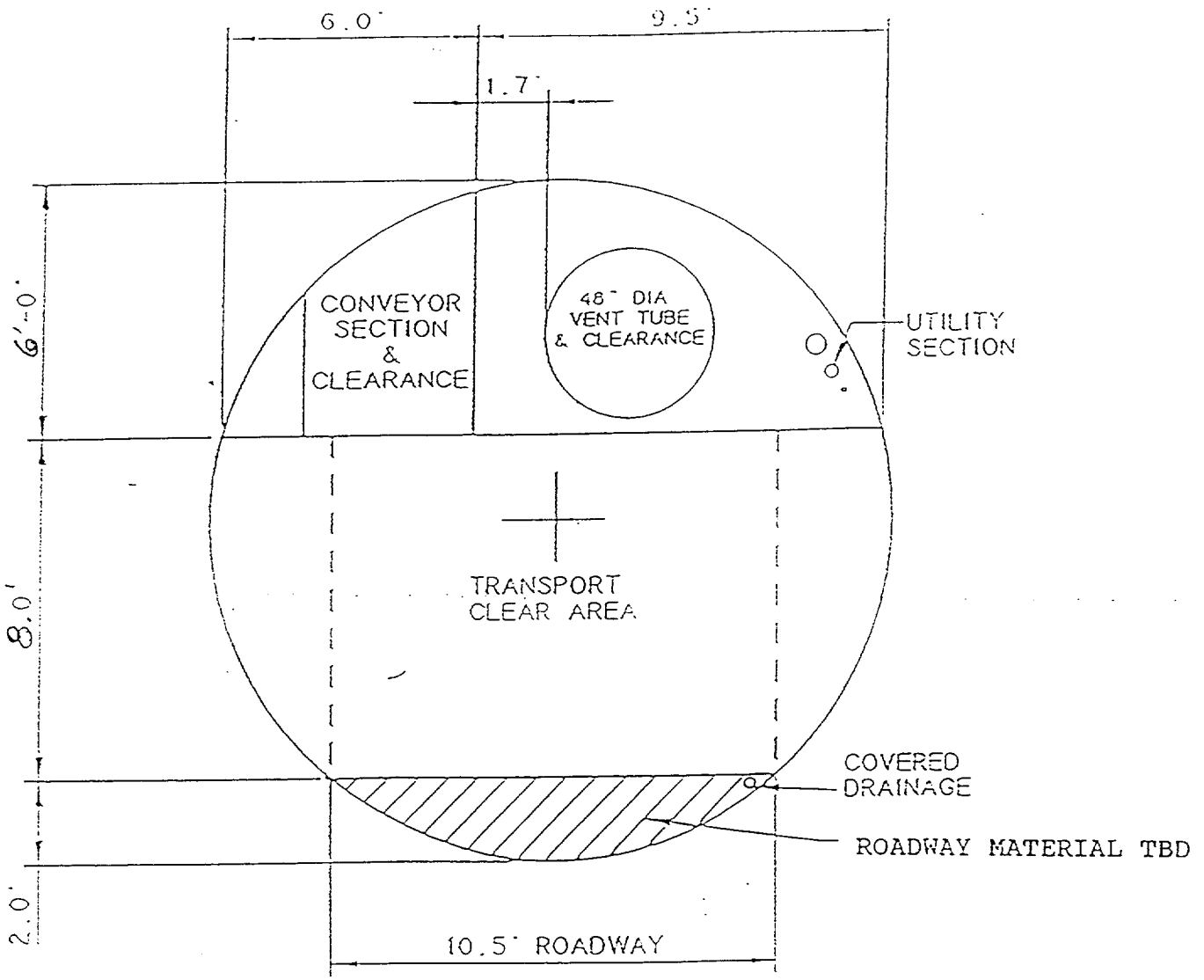
9.3 Refer to Record of Verbal Communication, Jurani to Coppage, 5-13-91, regarding Ventilation Duct Sizes which details the size of the ventilation duct required during the ramp construction.

CALICO HILLS RAMP SIZE
OPTION 1



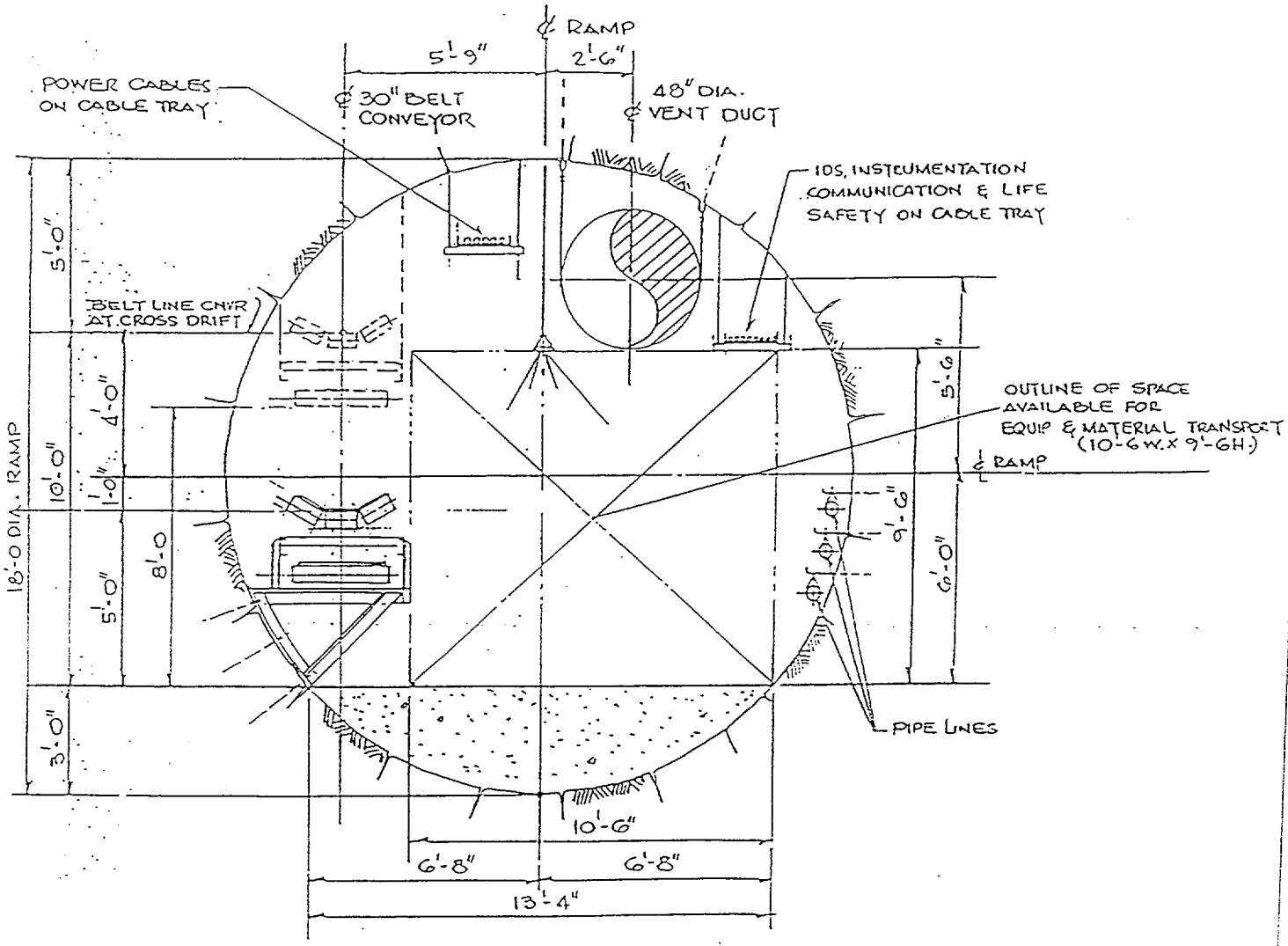
TYPICAL 15' DIA RAMP/DRIFT
WITH 10.5'x6.8' HIGH CLEARANCE
FOR TRANSPORTATION

CALICO HILLS RAMP SIZE
OPTION 2



TYPICAL 16' DIA RAMP/DRIFT
WITH 10.5'x8.0' HIGH CLEARANCE
FOR TRANSPORTATION

CALICO HILLS RAMP SIZE OPTION 3



TYPICAL 18'-0" DIA. RAMP CROSS-SECTION

9.4 The Alternative Studies program selected Option 30 for a Basis of Design. One of the important features was the use of TBM Excavation for the Calico Hills access ramp. This method produces a round cross-sectional shape which has some influence upon the ultimate size of the excavation because of the need to provide a flat roadway resulting in wasted space from utilizing equipment with basically rectangular cross-section in a circular shaped space.

9.5 The Ref. 5.5 letter recommends that the conveyor used for muck removal should be located below the springline of the ramp excavation.

9.6 The preceding Figures illustrate how various equipment items and fixtures could be arranged in three different sized cross-sections: Discussion of alternative ramp cross section arrangements:

9.6.1 General statements: (1) Placement of the conveyor in the back of the drift or ramp is a key feature in the cross-sectional arrangement in options 1 & 2. The placement of the conveyor off the roadway level reduces the roadway width requirement and thus influences the entire diameter. (2) Alcoves may be constructed at various locations in the ramp. The placement of the conveyor and ventilation equipment near the back of the drift would facilitate this construction. However, it is possible to raise the conveyor and utilities at selected locations to allow the construction of alcoves. Refer to reference No. 5.6 for an illustration of a typical alcove construction sequence. The sizing of the typical

ramp cross-section is not dependent upon side excavation requirements since the enlargement requirements are localized.

(3) The roadway width of 10.5 ft is based upon the anticipated equipment sizes and walkway width requirements.

9.6.2 Functional Requirements:

1. Access for personnel and equipment: The arrangements shown in Options 2 and 3, meet this functional requirement if the appropriate equipment fleet as described in ST-MN-010 is utilized. The arrangement shown in Option 1 has restricted headroom for transport of a roadheader or other similar continuous mechanical excavator, which is anticipated for use in the non-welded CH rock.

2. Rock mass exposure: Since mapping should be done ahead of installation of the permanent equipment shown in the Figures, there is very little difference in the ability of the three arrangements to perform this function.

3. Ventilation: The ventilation air volume required to support the Calico Hills construction and testing is 115,000 cfm (ref. 5.7). The option #1 cross section forces the required air volume to reach a velocity which exceeds industry guidelines. This volume of air flowing in the option #2 cross section effective area produces an approximate air velocity of 750 ft per minute. The same volume of air flowing in the option 3 cross section produce: an approximate air velocity of 516 ft per minute. These velocities are within industry guidelines. However, the lower anticipated velocity in option 3 is a favorable factor from the stand point of less airborne dust hazard and lower power consumption.

9.7 Optimization:

1. The arrangement shown in Option 1 restricts flexibility to excavate openings off the ramp. In addition, the headroom is restricted at the intersection of a lateral or alcove with the ramp. Option 1 will have ventilation air velocity exceeding recommended standards. This Option is less than optimum size.
2. The arrangement shown in Option 2 shows increased headroom which would facilitate the movement of the contemplated mechanical excavator and would permit sufficient clearance of the conveyor when excavating an alcove to minimize interference with the advancing TBM.

Headroom at the intersection is improved to a degree which permits normal operation of any of the contemplated equipment through the intersection.

4. The arrangement shown in option 3 reflects design review comment resolutions which call for placing the conveyor on or below the excavation spring line. This arrangement increases the required excavation diameter since the roadway width should remain constant at 10.5 ft.

10. CONCLUSIONS AND RECOMMENDATIONS:

10.1 Conclusions: The foregoing discussion and the references cited lead to the following preliminary conclusions:

1. The ventilation, muck handling, and transportation equipment space requirements are the primary determinants for the ramp diameter because any restrictions on equipment size or operations will degrade system performance.
2. The flexibility to develop lateral drifts and alcoves is a secondary determinant because there are 4 test locations planned on the Calico Hills North Access Ramp. (refer to Test Planning Package 91-5). These openings may be partially constructed prior to the permanent furnishings of the ramp.

3. Examination of the alternative ramp layouts using 15 ft., 16 ft., and 18 ft. diameters indicates that an 18 ft. diameter is the smallest size that completely satisfies the stated requirements for the ramp cross-sectional diameter including the requirement for conveyor location on or below the springline.

10.2 Recommendation: On a preliminary basis, adopt an 18 ft. diameter for the cross-section of the Calico Hills North Access ramp. The question of Calico Hills access size will be revisited during later design efforts.

PRELIMINARY UNDERGROUND

TRANSPORTATION METHODS

ANALYSIS

ST-MN-010
Rev. 3
August 20, 1991

RAYTHEON SERVICES NEVADA
101 Convention Center Dr., P250
Las Vegas, Nevada 89109

For comments and information, call 794-7991

Romeo S. Jurani
Senior Mining Engineer

Raytheon Services Nevada	DESIGN ANALYSIS Number: ST-MN-010 Rev: 3 Page 1 of 70

WBS No. 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	ROMEO S. JURANI	Jurani	Sr. Mining Engr.	8/20/91
CHECKER:	MARK J. ESP	Mark J Esp	Sr. Mining Engr.	8/20/91
APPROVAL - LDE:	BRUCE T. STANLEY	Bruce T. Stanley	Lead Mining Engr.	8/22/91
APPROVAL - SCDM:	BOLEK R. CHYTROWSKI	B. R. Chytrowski	Site Characterization Design Manager	8/22/91
QA CONCURRENCE:	PAUL HALE	Paul B Hale PAUL B. HALE	QA Rep.	8-22-91

SUBJECT: ESF Transportation

TITLE: Preliminary Underground Transportation Methods Analysis

QAG Reference: RSN-GR-013, Rev. 0

---

1. PURPOSE: To study the methods of underground transportation applicable to the Yucca Mountain Project Exploratory Studies Facility (ESF) and subsequently to recommend the transportation method to be used in the ESF construction and operation. Revision 1 was issued to incorporate the Management Review comments. Revision 2 was issued to incorporate the first Technical Review comments. Revision 3 is issued to incorporate the second Technical Review comments.

2. METHOD: General mining plan and construction strategy including mining methods are established. All available underground mining industry transportation methods are examined and applied to suit the ESF construction, operation and scientific activities. This includes the haulage system for bulk movement of muck from mostly mechanical mining and partly from drill and blast mining methods; and the transportation for personnel, material and supply, service and utility. Specific criteria applicable to the design of the ESF are correlated and the appropriate transportation is recommended.

3. DESIGN OR STUDY INPUT:

   3.1. Instruction Letter of DOE's Carl P. Gertz to Richard Bullock : Authorization for Conducting a Design Study to Develop a Reference Exploratory Shaft Facility (ESF) Design to be used as input to Title I Design Summary Report, EDD:EHP-2080, stamped February 22, 1991.

3.2. YMP/CC-0013 (ESFDR) Rev. 5/31/91 issued May 31, 1991

- Section 1.2.6.0: PC.1d.i, ii, and iii.
- Section 1.2.6.7.9: FR.1; and PC.1b, and 1c.

3.3. YMP/CC-0002 (RIB) Ver. 4, Rev. 4, issued April 8, 1991

- Chapter 1, Section 2, Item 1.

4. CODES AND STANDARDS:

- 30 CFR 57, Revised July 1, 1988

5. REFERENCE MATERIAL:

Refer to Section 12.0, pages 64-65 of the analysis.

6. ASSUMPTIONS:

6.1. It is assumed that all input will be included in the approved Basis For Design (BFD)

6.2. For the purpose of general arrangement concept, the assumptions used are common mining engineering practices and are not subject to verification.

7. COMPUTER PROGRAM USED: Not Applicable

8. UNITS USED: English

9. ANALYSIS:

Refer to pages 3 through 70 of the analysis.

10. CONCLUSION/RECOMMENDATION:

Refer to Section 11, pages 61 - 63 of the analysis.

PRELIMINARY UNDERGROUND

TRANSPORTATION METHODS

ANALYSIS

ST-MN-010
Rev. 3
August 20, 1991

RAYTHEON SERVICES NEVADA
101 Convention Center Dr., P250
Las Vegas, Nevada 89109

For comments and information, call 794-7991

Romeo S. Jurani
Senior Mining Engineer

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INTRODUCTION

The selection of an underground transportation system for the Exploratory Studies Facility (ESF) requires an integrated study of factors such as tonnage, distance, haulage grade, product size, number of excavation areas, planned developments, safety, capital cost, operational and maintenance costs.

There are a number of transportation methods available to the mining industry that can be applied to the ESF. The ESF general mining plan and construction strategy, concurrent with site characterization requirements, have unique features that can only be suited with a specific transportation system.

The applicability of common mining industry haulage practices, such as rail, rubber-tired, and conveyors, is to be studied to fit the needs of the ESF. The rock handling capacity from mechanical mining methods, the ventilation distribution and air quantity available during development, and the various transportation needs to support construction, personnel and scientific activities, are to be analyzed.

With safety aspects considered, the study will conclude and recommend a combination of transportation systems that satisfies the needs of the ESF.

1.0. GENERAL MINING CONSTRUCTION AND STRATEGY

1.1. TWO RAMP ENTRY BY MECHANIZED MINING

The ESF general mining plan is to develop a testing facility which has two accesses, one to the north and the other to the south of the proposed repository block[2,7]. The north and south entries are both 25 ft diameter[4,7] and are called Topopah Spring (TS) North Ramp[1] and Topopah Spring South Ramp respectively. Both ramps will be connected through the TS Main Test Level (MTL).

An internal access to the Calico Hills (CH) level will branch from both TS north and TS south ramps[7]. Figure 1.1, General Mechanical Mining Plan shows the conceptual idea. The CH north[6] and south accesses are 18 ft diameter ramps connected at the CH level.

To minimize rock disturbance of the entry openings, all ramps are developed with Tunnel Boring Machines (TBM)[5,7].

1.2. DEVELOPMENT OF TEST ALCOVES, TEST DRIFTS, LATERALS, AND REFUGE

Mechanical mining methods, such as by mobile miner and roadheader, will be used to develop some test alcoves and drifts, special cutouts for vehicle passing and turns, laterals, and refuge chambers. Drill and blast methods may also be used in the construction process when needed.

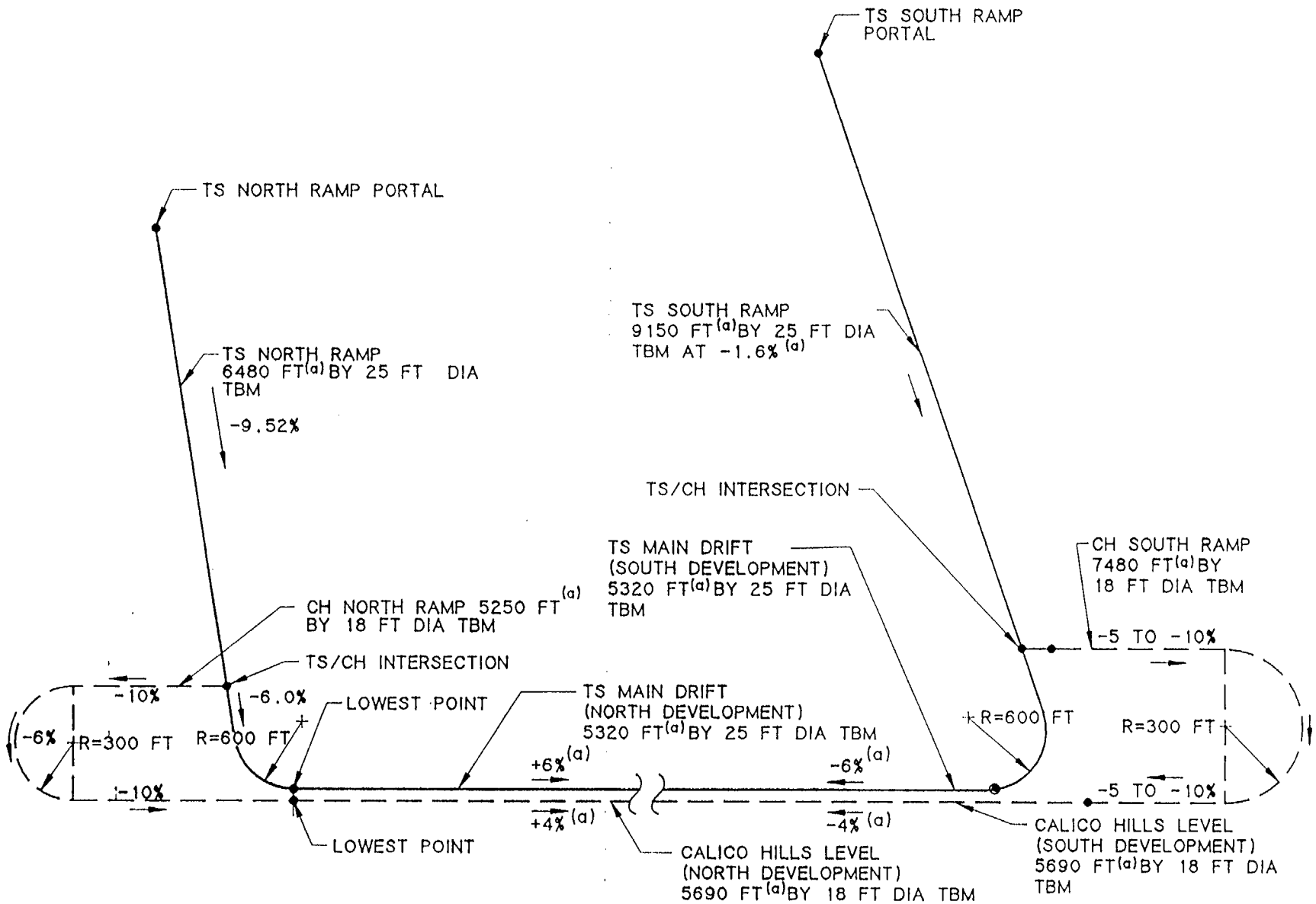


FIGURE 1.1 GENERAL MECHANICAL MINING PLAN

NOT TO SCALE
(a) APPROXIMATE SLOPE DISTANCE AND HAULAGE GRADE

Muck handling from these developments, including locally articulated loading stations into the main haulage system, is discussed. In excavating the ESF, consideration is given to prioritizing activities to get to Calico Hills as quickly as possible. However, the development of test alcoves, test drifts, and collection of samples shall receive priority, if they are of immediate necessity for characterizing Yucca Mountain to validate data which can not be obtained on a later date. Likewise, laterals, drifts, and refuge chambers required by regulations and DOE orders shall be constructed.

1.3. OPTIONAL THIRD ENTRY (SHAFT)

An optional shaft[3], about 16 ft in diameter, may be constructed as a third access to the TS level, if necessary. The shaft will be constructed at a later date, possibly after the TS north and south ramps are connected.

The underground muck handling related to the construction of the shaft will have to follow the existing haulage system developed for the two main ramp accesses.

2.0. TS NORTH AND CH NORTH RAMPS

2.1. CONSTRUCTION OF TS NORTH RAMP

The ESF TS north portal is constructed by controlled drill and blast methods until it has advanced enough to mobilize a 25 ft diameter TBM. The TBM is to be assembled at the surface near the portal and rail/skid into the north portal. After mobilization,

the TBM will bore the TS north ramp declining at 6 to 10% grade for about 6480 feet. The haulage system discussed in this study will transport the rock cuttings of the TBM.

The TBM will temporarily halt after passing the proposed TS/CH north ramp intersection, to give way for the construction of the intersection.

2.2. CONSTRUCTION OF TS/CH NORTH RAMP INTERSECTION

Construction of the initial CH north ramp and TS intersection is by drill and blast methods or by a mechanical miner. Sufficient underground space for an 18 ft diameter CH TBM mobilization will be provided. Section 6.0 has more description of the TBM mobilization.

The haulage system will be used to dispose of the broken rock from this construction.

2.3. CH NORTH RAMP DRIVE

The TBM for the CH north ramp will be assembled underground. Parts and materials shipped from the surface to the underground will have to go through the 25 ft diameter TS north ramp presumably in the presence of existing conveyor belts, ventilation tubes, air and water pipes, and electric conduits. All these utilities are to be in place and used during the construction of the TS/CH north ramp intersection.

A special transport method and space in the ramp will be provided to bring the parts and pieces of the CH TBM to its mobilization site. After assembly, the TBM will be on rail and slide to the face. Boring of CH north ramp will then be started.

2.4. SIMULTANEOUS TBM OPERATION FOR TS AND CH NORTH RAMPS.

As soon as rock disposal systems for both the TS and CH north ramps are available, both TBMs will be operated simultaneously. Figure 1.1 shows the schematic view of the ramps and the horizontal curves generally negotiated until connection of the TS and CH levels is achieved. The main haulage system appropriate for the rock transport of both TBMs in operation has to be concluded in this report.

3.0. TS SOUTH AND CH SOUTH RAMPS

The description of mining construction for the TS south and CH south ramps is the mirror image of the construction described for the TS north and CH north ramps as shown in Figure 1.1. The construction method, haulage system, and other transportation requirement of the TS south and CH south ramps are similar to the TS north and CH north ramps and need not be described again.

4.0. DETERMINATION OF HAULAGE SYSTEM FOR THE ESF

A haulage system is the main transportation mode designed for bulk handling of rock materials from TBM, mobile miner, roadheader, drill and blast, and other mining activities. The main feature of a haulage system is handling and moving rock materials from the face of production to its final destination, such as the surface, during peak construction periods on the preferred basis of instantaneous muck rates.

The selection of a mine haulage system requires an integrated study of factors such as tonnage, distance, haulage grade, product size, number of excavation areas, planned developments, safety, capital cost, operational and maintenance cost, and the mining systems.

4.1. HAULAGE SYSTEM CAPACITY

The haulage system has to be designed with enough flexibility to meet the needs of the ESF. Preliminary calculation of the TS North Ramp muck output from all mining units is shown in Appendix 4.1. In a worst case scenario, the instantaneous muck rate is 771 tons per hour (tph) coming from the following areas:

a) TS TBM Operation - 302 tph
b) TS Mobile Miner Operation - 75 tph
   (For development of test alcoves or drifts along the TS ramp or MTL, one face at a time)
c) CH TBM Operation - 169 tph

d) CH Roadheader Operation - 71 tph

(For development of test alcoves or drifts along the CH ramp of CH level, one face at a time)

e) For 25% allowance - 154 tph

(The 25% uncertainty allowance includes drill and blast, and other mining products added to have a general arrangement concept. This will be a subject of another study to satisfy Section 1.2.6.0.PC.1d.iii of the YMP/CC-0013, Rev. 5/31/91).

Figure 4.1 shows the haulage capacity plan as the instantaneous muck rate flows from the north mining faces to the surface. The TS South Ramp muck output is perceived to have the same instantaneous muck rate of 771 tph.

4.2. AVAILABLE HAULAGE VENTILATION DURING CONSTRUCTION

The size and construction sequence of the ramps and test alcoves are determined to satisfy the needs of the ESF. Preliminary indications from the ventilation analysis[14] are that the ventilation available for the ESF development before connection of the TS or CH ramps is 188,500 cfm at each portal. About 15 to 20% of this airflow may not reach the mining face because of leakages[10] along several thousand feet of ventilation tubes.

The total airflow is distributed in the following breakdown:

a) TS TBM Operation - 82,000 cfm

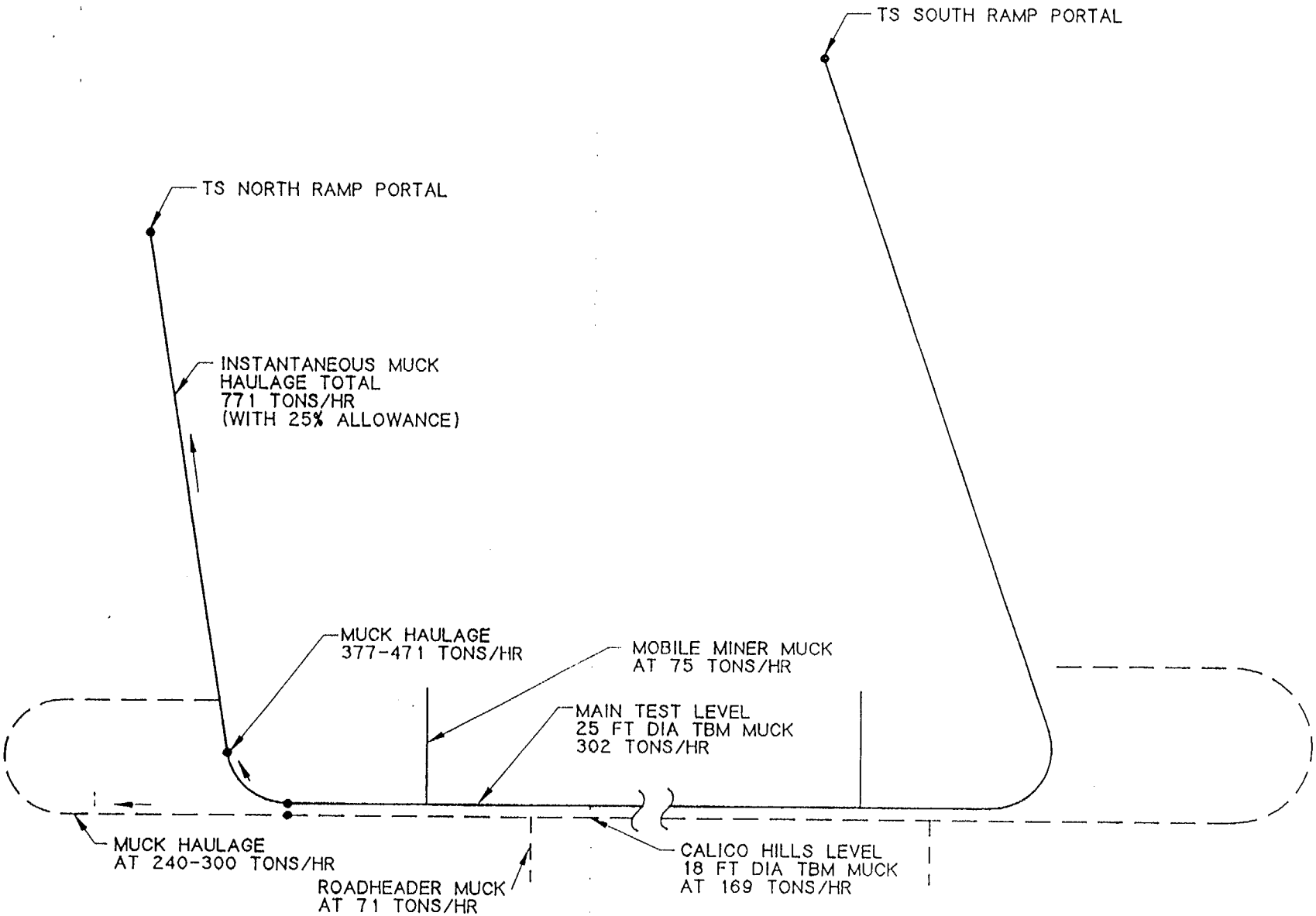


FIGURE 4.1 HAULAGE CAPACITY PLAN

NOT TO SCALE (GOOD FOR NORTH OR SOUTH RAMP DEVELOPMENT)

b) TS Mobile Miner Operation - 40,000 cfm

c) CH TBM Operation - 42,500 cfm

d) CH Roadheader Operation - 24,000 cfm

The total 188,500 cfm is a dedicated airflow to support specific mining activities. A limited number of diesel equipment may be supported by the ventilation system to comply with project requirements on ventilation of diesel equipment[12].

During ESF development, the ventilation system, which does not have flexibility to expand its capacity other than reusing the air, has an important role in the design of the haulage system.

4.3. HAULAGE OPTIONS

Most issues of the ESF mine haulage system such as tonnage, distance, haulage grade, product size, number of excavation areas, planned developments, safety, and the mining systems are briefly discussed. Capital, operating and maintenance costs will be addressed in a separate report.

The available technology of the mining industry shows that there are about seven different options that may be considered for the ESF haulage system. These are shown in simplified diagrams on Figures 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.3.6, and 4.3.7. The options are the following:

Option 1. Rail Haulage and Diesel Locomotives (Figure 4.3.1).

Option 2. Rail Haulage and Electric (Trolley) Locomotives (Figure 4.3.2).

Option 3. Monorail Haulage and Electric Cable Hoist (Figure 4.3.3).

Option 4. Rubber-Tired (Trackless) Haulage and Diesel Vehicles (Figure 4.3.4).

Option 5. Rubber-Tired (Trackless) Haulage and Electric (Trolley) Vehicles (Figure 4.3.5).

Option 6. Conveyor Haulage and Rubber-Tired (Trackless) Diesel or Battery-Powered Vehicles (Figure 4.3.6).

Option 7. Conveyor Haulage and Rubber-Tired Electric (Trolley) Vehicles (Figure 4.3.7).

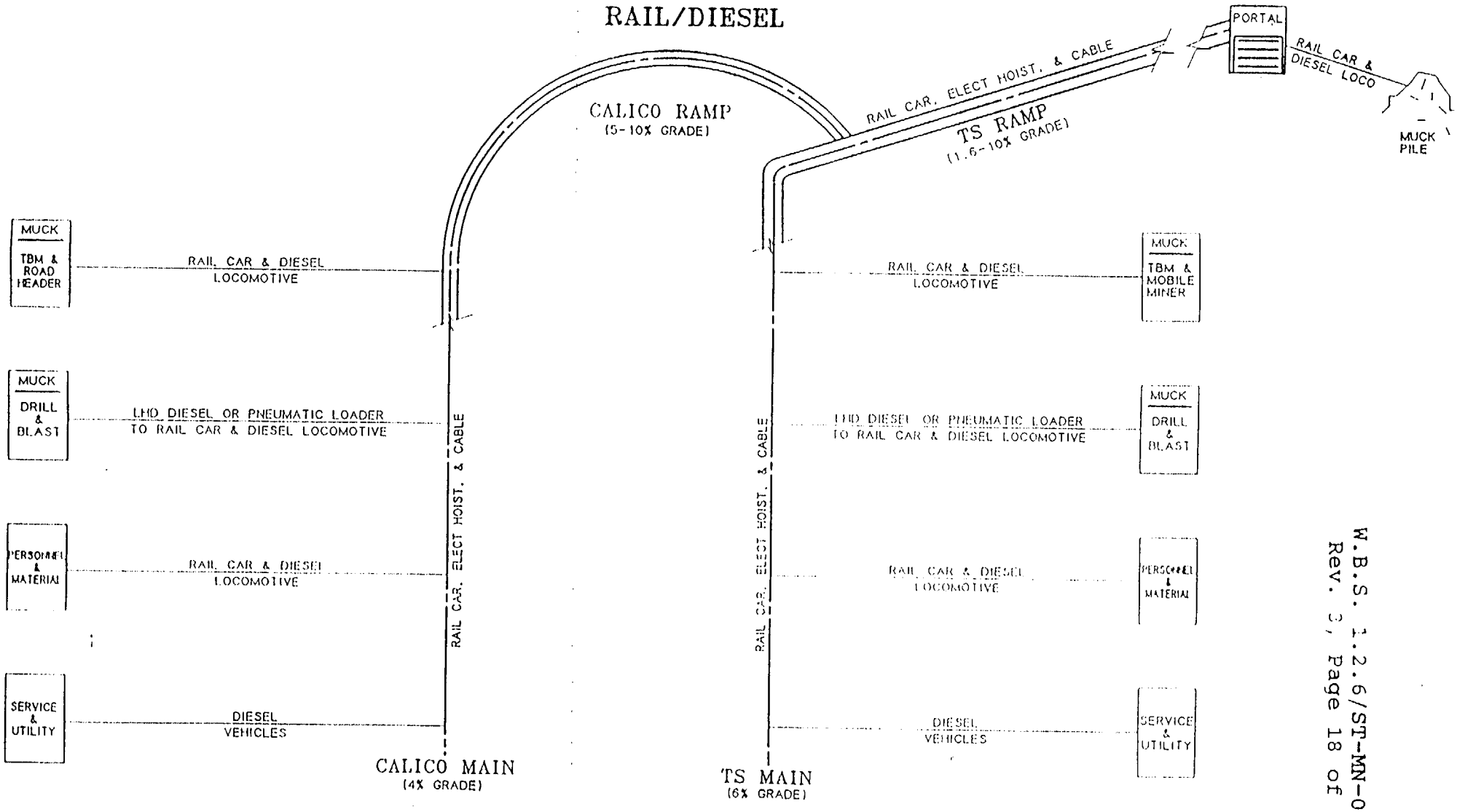
4.4. APPLICATION OF HAULAGE OPTION TO UNIQUE ESF DESIGN FEATURE

Each haulage option is briefly reviewed to evaluate technical feasibility. Comments on the merit of each option is included to base recommendations upon.

4.4.1. Option 1. Rail Haulage and Diesel Locomotives (Figure 4.3.1)

This option has the rock materials loaded on mine cars and pulled/pushed by diesel locomotives travelling along railways. Mining industry

FIGURE 4.3.1 UNDERGROUND TRANSPORTATION STUDY
OPTION 1
RAIL/DIESEL



experience[9] shows that a rail system works best for long distance when haulage grade is less than 4%.

A rail haulage system is not recommended for grades of over 6%. Sizing of locomotives to suit the requirement of the train is dependent upon the load, haulage grade, and coefficient of adhesion between the locomotive driving wheels and rails for effective braking and pulling. Factors such as dry or moist or greasy railways affect the operation of the haulage system.

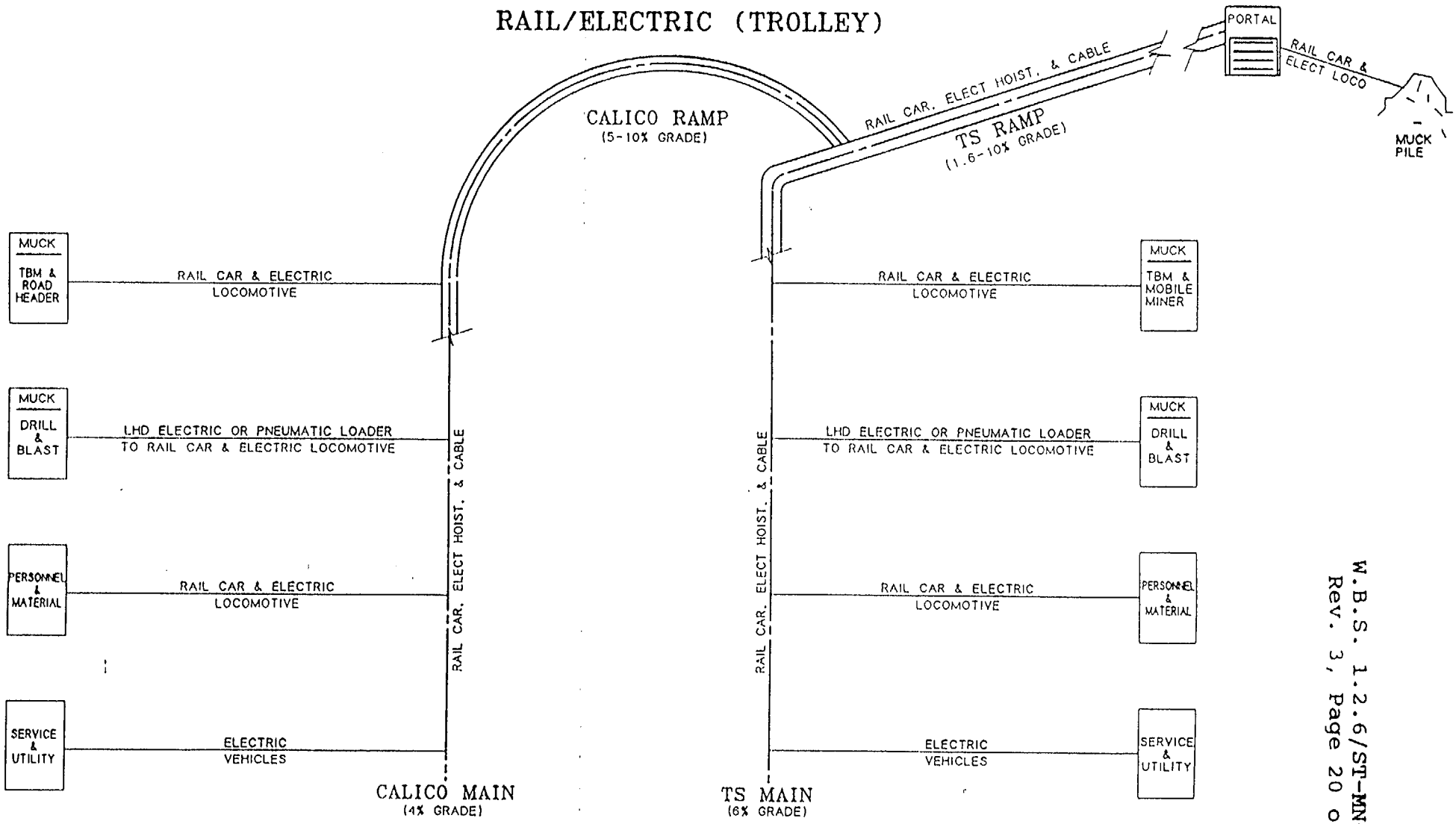
Rail haulage is not feasible for ESF application because of haulage curves and grades ranging from 1.6 to 10%[2,5]. It may be feasible only if special cable hoist and lifting stations are installed to help the train climb up the steep grades, a stage that will complicate the haulage system.

Rail haulage and diesel locomotive option is definitely not applicable.

4.4.2. Option 2. Rail Haulage and Electric (Trolley) Locomotives (Figure 4.3.2).

This option uses railways similar to Option 1, except that instead of using diesel locomotives, electric locomotives on trolley wires are used. In addition to the disadvantage mentioned in Option 1,

FIGURE 4.3.2 UNDERGROUND TRANSPORTATION STUDY
OPTION 2
RAIL/ELECTRIC (TROLLEY)



there is the hazard of trolley wires along the roof of the haulage ways.

Rail haulage and electric locomotive option is definitely not applicable.

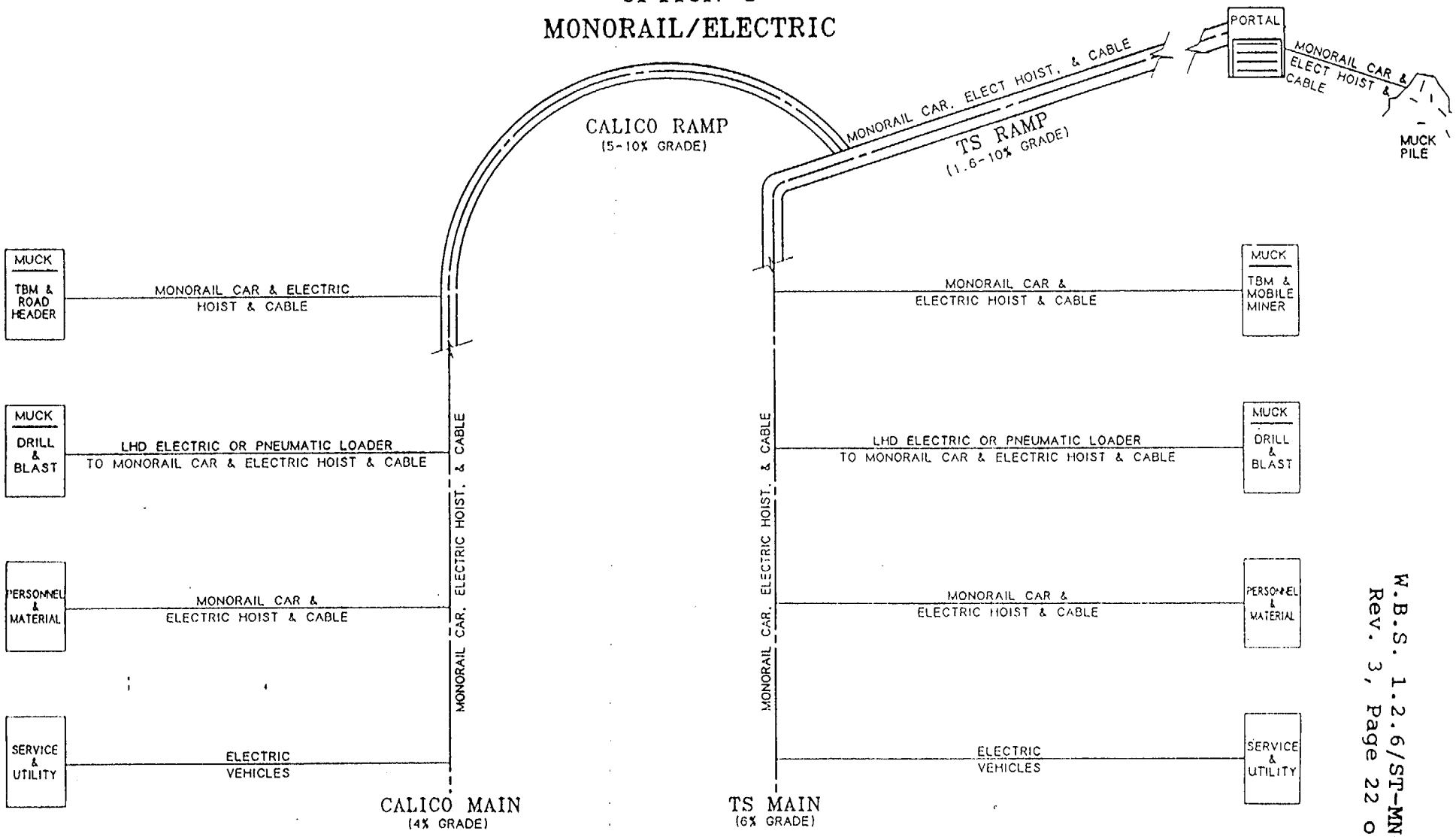
4.4.3. Option 3. Monorail Haulage and Electric Cable Hoist (Figure 4.3.3).

This option has mine development cars travelling on a monorail attached to the floor or roof of the ramps. The movement of the mine cars is powered by electric hoist and cable.

The action of gravity lowers the mine cars while an electric hoist through cables attached to the mine car pulls it up. From this setup, mine car arrangement at the face will have difficulty coping with high instantaneous muck rate of mechanical miners. Another disadvantage is the guiding and maintenance of hoisting cable wires going through curves. The change of haulage grades from negative to positive just after the bottom of the north ramps will require installation of electric hoist in several places where needed.

The option is not viable for ESF application.

FIGURE 4.3.3 UNDERGROUND TRANSPORTATION STUDY
OPTION 3
MONORAIL/ELECTRIC



4.4.4. Option 4. Rubber-Tired (Trackless) Haulage and Diesel Vehicles (Figure 4.3.4).

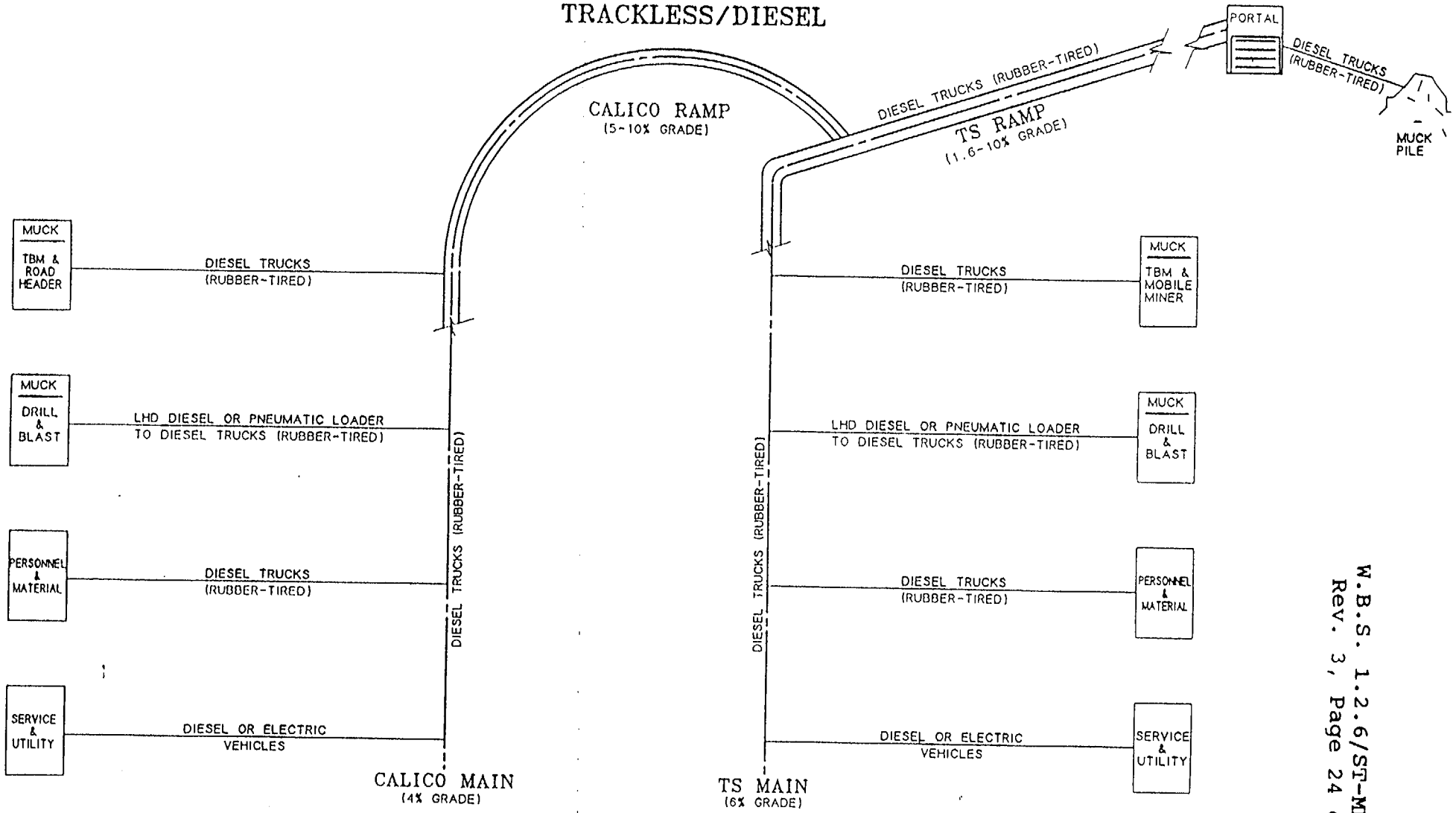
This option has mining products loaded by either the mechanized loading system of the mechanical miner or the mucking machines into rubber-tired dump trucks or rubber-tired shuttle cars hauling muck to the surface.

The description of mechanical mining in the construction of the ESF will have a peak muck products projected at 771 tph on each of the north and south ramps.

Figure 4.1 shows the flow distribution of the muck. The 471 tph muck rate will come from the MTL's TS North TBM, mobile miner and drill and blast products. The other 300 tph will come from the CH North TBM, roadheader, and drill and blast products. The same scenario applies to the South Ramp system.

It will take about 51 trips per hour of shuttle cars or dump trucks with individual capacity of 15 tons per heap load to dispose the muck from the mining face to the surface. This is almost every minute per hour of diesel equipment running possibly up to two miles one way through underground ramps[5] at grades 1.6% to 10%. Rubber-tired diesel equipment are usable in the ESF as they can handle

FIGURE 4.3.4 UNDERGROUND TRANSPORTATION STUDY
OPTION 4
TRACKLESS/DIESEL



haulage grades of 0 to 15%. However, for total haulage application, the ESF would have to have enormous numbers of diesel vehicles requiring unfeasible ventilation airflows. A tentative total estimate of 7,000 BHP of diesel equipment requiring about 450,000 cfm of ventilation would be needed to cope with the ESF instantaneous muck rate.

This system is further complicated by difficulty of traffic control, wider openings for passing and turning, and special roadway construction for dust control.

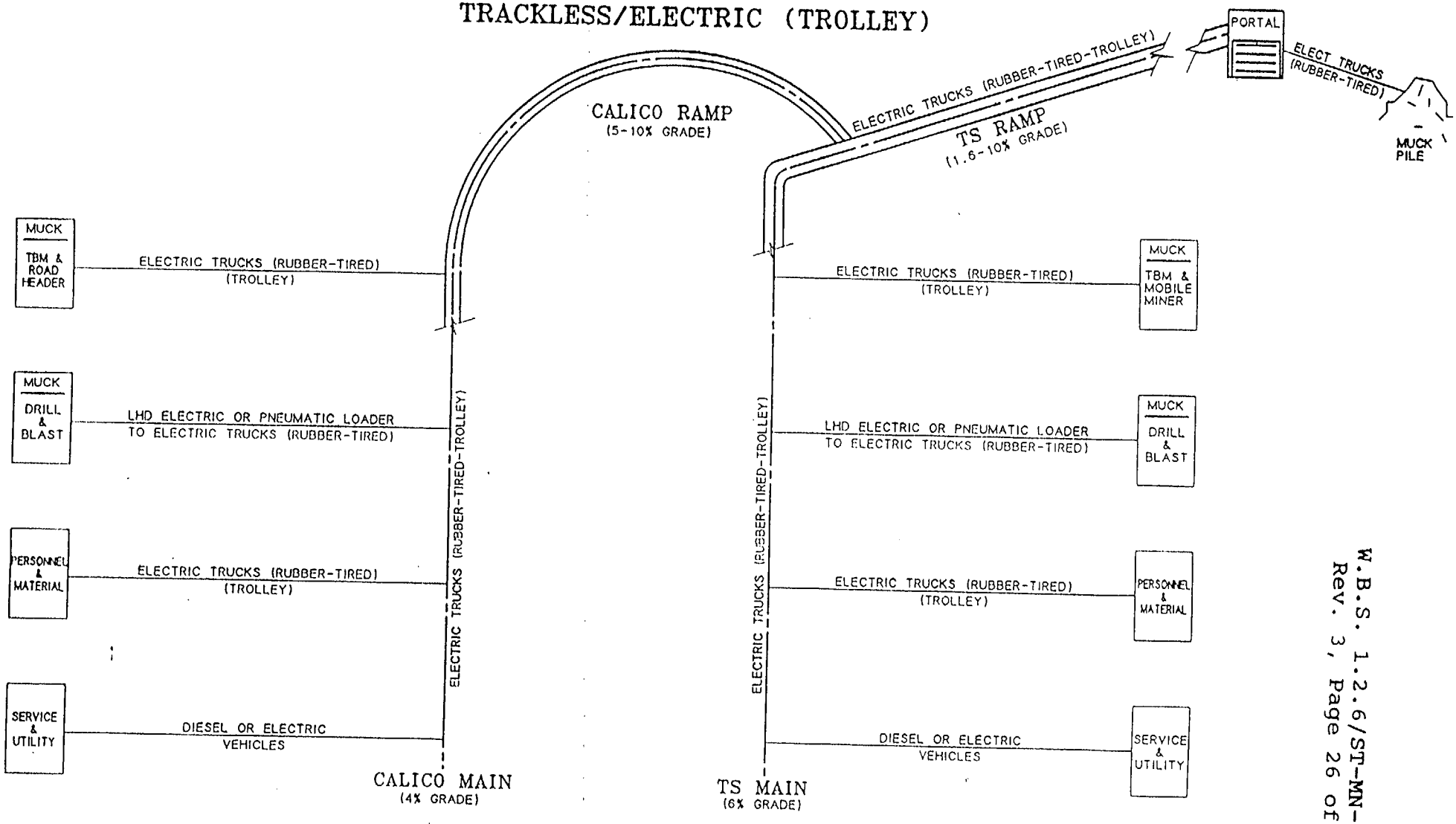
A rubber-tired (trackless diesel) haulage is feasible but not the best for ESF application.

4.4.5. Option 5. Rubber-Tired (Trackless) Haulage and Electric (Trolley) Vehicles (Figure 4.3.5).

This option is similar to Option 4, except that electric vehicles on trolley wires are used instead of diesel equipment. This has the disadvantages mentioned in Option 4 except ventilation requirement for diesel equipment are not applicable for electric vehicles.

The complication of a trolley wire network and the presence of additional hazards of trolley wires

FIGURE 4.3.5 UNDERGROUND TRANSPORTATION STUDY
OPTION 5
TRACKLESS/ELECTRIC (TROLLEY)



in the ramps and drifts make this option less viable.

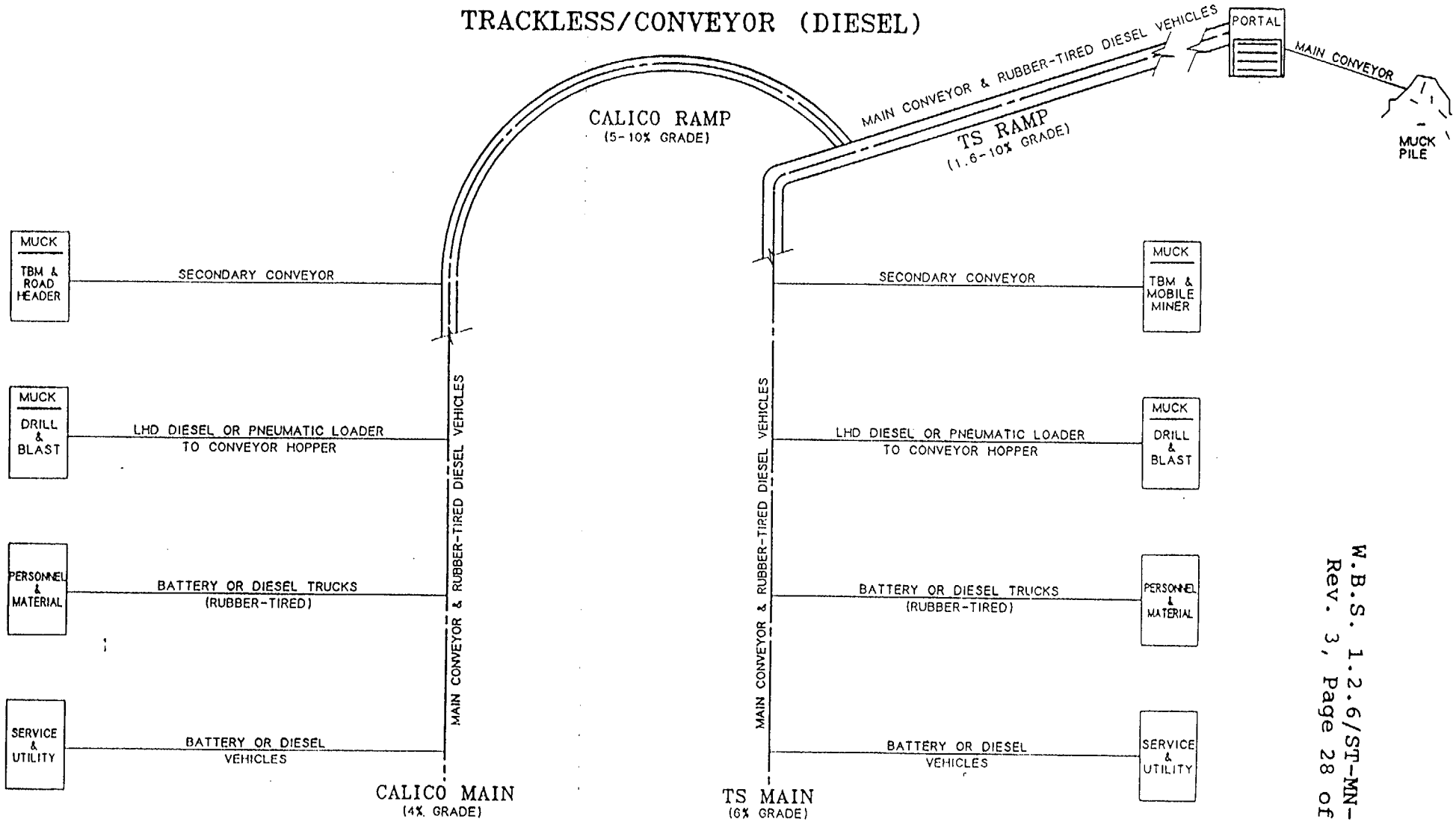
4.4.6. Option 6. Conveyor Haulage and Rubber-Tired (Trackless) Diesel or Battery Vehicles (Figure 4.3.6).

This option of conveyor haulage allows fast movement of muck from the underground to the surface during peak mining construction and operation. By industry experience, an instantaneous muck rate of 771 tph (Figure 4.1) can be easily handled by a 36-inch width troughed conveyor at 300 fpm belt speed (Table 5.1).

More details of conveyor suitability are discussed in Section 5.0. If the conveyor belt is hung in the roof of the ramp or drift, the space below can be fully used as a roadway for rubber-tired diesel or battery vehicles to be used for personnel carrier and logistics.

So far, this is the best feasible option for the ESF needs.

FIGURE 4.3.6 UNDERGROUND TRANSPORTATION STUDY
OPTION 6
TRACKLESS/CONVEYOR (DIESEL)



4.4.7. Option 7 Conveyor Haulage and Rubber-Tired Electric (Trolley) Vehicles (Figure 4.3.7).

The conveyor haulage features are similar to Option 6, except that instead of using rubber-tired diesel or battery vehicles for service and logistics, electric vehicles on trolley wires are used. The complication of a trolley wire network and the hazards of trolley wires in the roof of the haulage way in a testing facility make Option 7 less desirable than Option 6.

4.5. HAULAGE SYSTEM RECOMMENDATION

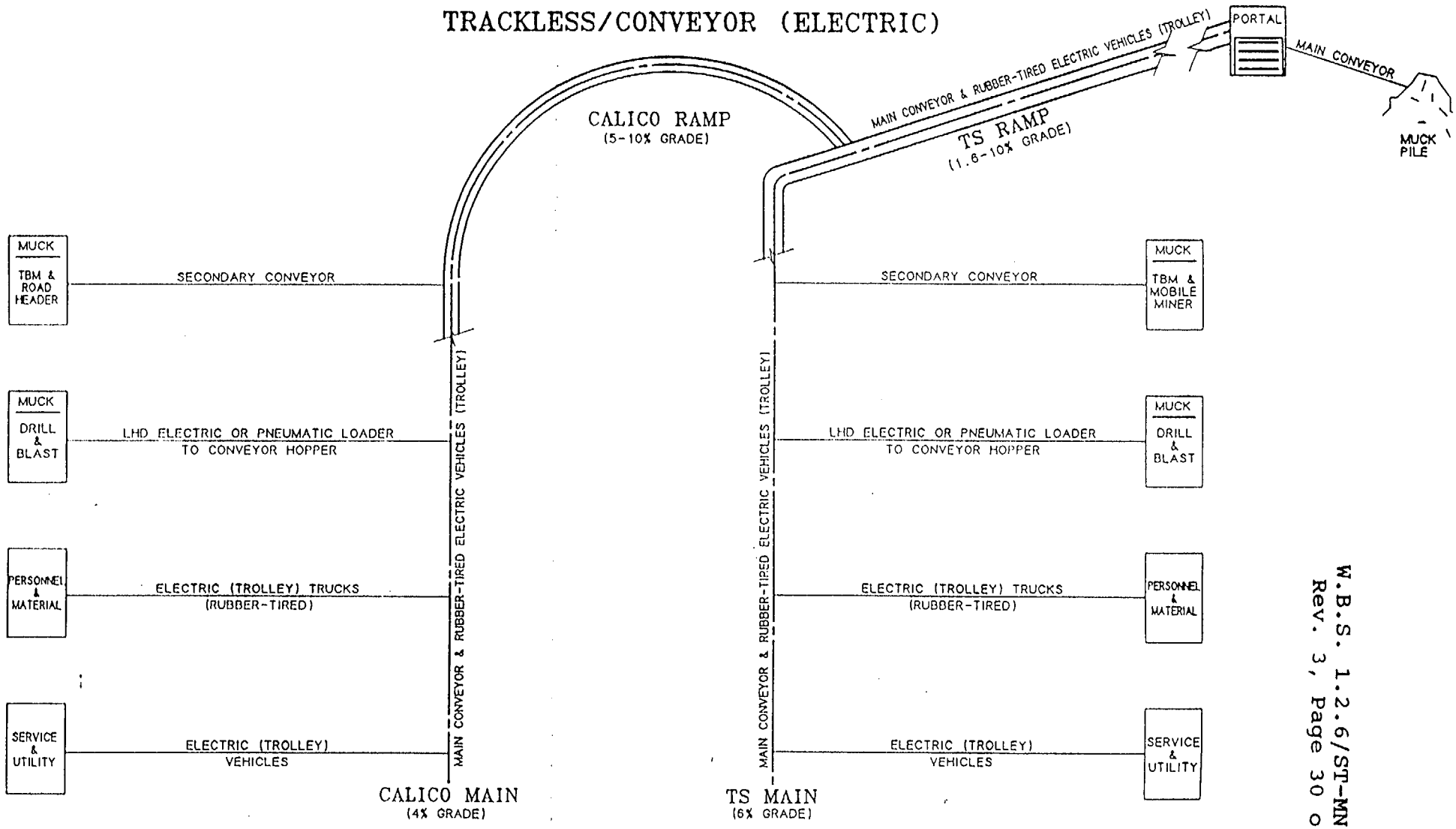
Option 6 is recommended. This is the combination of belt conveyors for haulage and diesel or battery vehicles for personnel carriers and supplies. The conveyor haulage is the best feasible option applicable to the unique features of ESF.

5.0. CONVEYOR HAULAGE AS APPLIED TO ESF

A belt conveyor system is chosen for muck haulage in combination with rubber-tired vehicles for personnel and supply.

The mining industry has a proven track record of successful belt conveyor usage for the last 40 years[9]. Belt conveyors offer the widest range of capacities. The amount of material transported depends only on belt width, belt speed and weight of material.

FIGURE 4.3.7 UNDERGROUND TRANSPORTATION STUDY
OPTION 7
TRACKLESS/CONVEYOR (ELECTRIC)



They can be applied almost universally. They possess the ability to follow level or pitching terrain on the surface or underground, providing fast, constant flow of material as quickly as it is mined.

Table 5.1 shows capacity of troughed conveyors at various width and speed and Table 5.2 shows the maximum belt speeds recommended for general use.

The distance belt conveyors can haul material, for all practical purposes, is enormous, reflecting the development of high-tension conveyor belting. Single conveyors over one mile long are common, and even greater distances are being spanned by using conveyors in series. Belt lines over 10 miles long have been used in several dam construction and tunnel projects.

5.1. CONVEYOR OPTIONS

For ESF application, the high capacity and mobility of conveyors are the principal reason for its recommendation. Three types of conveyor options are available in the market.

5.1.1. WIRE ROPE SIDE-FRAME BELT CONVEYORS MOBILITY, INSTALLATION, AND OPERATIONAL FEATURE

This conveyor can be extended, retracted, dismantled, moved, and reassembled easily, even in relatively confined underground spaces. The intermediate structure consist of rope support

Table 5.1 Capacity of Troughed Conveyors[8], Short Tons per Hour at Various Widths and Speeds (Crushed Stone or Material weighing approximately 100 pounds per cubic feet).

	Belt Speed, S, Fpm												Maximum Size of Lumps, In., for Various Widths	
Width W, In.	100	150	200	250	300	350	400	450	500	550	600	650	If Uniform in Size	If Mixed with Fines
14	30	45	60	75	90	105							2	4
16	42	63	84	105	126	147							3	5
18	56	84	112	139	167	195	223						4	6
20	72	107	143	179	215	251	287						4	6
24	109	164	218	273	327	382	437	491	546				5	8
26	131	196	262	327	392	458	523	588	654				6	9
30	180	270	359	449	539	629	719	809	899	988	1078		6	10
36	267	401	535	668	802	936	1070	1203	1337	1471	1604		7	12
42	372	558	744	930	1116	1302	1488	1674	1860	2046	2232		8	14
48	493	740	987	1234	1480	1727	1974	2221	2467	2714	2961	3208	10	16
54	632	947	1263	1579	1895	2211	2527	2842	3158	3474	3790	4106	11	20
60	786	1180	1573	1966	2359	2752	3146	3539	3932	4325	4719	5112	12	24
66	958	1437	1916	2395	2874	3352	3831	4310	4789	5268			12	24
72	1146	1719	2291	2864	3437	4010	4583	5156	5729	6301			12	24

Table 5.2 Maximum Belt Speed[8] Recommendation for General Use (Feet per minute)

Belt Width, In.	Grain or Other Free-Flowing Material	Run-of-Mine Coal and Earth	Hard Ores and Stone, Primary Crushed
14	400	300	300
16	500	300	300
18	500	400	350
20	600	400	350
24	600	500	450
26	600	500	450
30	700	600	550
36	800	600	550
42	800	650	550
48	800	650	600
54	...	650	600
60	...	650	600
66	...	650	500
72	...	650	500

stands, wire-rope side frames, wire rope tie-off stands, and the necessary carrying idlers and return idlers.

An important feature is the ability to suspend the intermediate sections from the roof in the underground mining to improve housekeeping and to permit free passage of cars, service vehicles and other mining equipment.

The open construction permits quick visual checks of conveyor components for malfunctioning equipment or conveyor-belt misalignment. Other advantages leading to utilization of such permanent and semi-permanent installations include: (1) low maintenance costs, (2) easy alignment or training of belt, (3) minimum cleanup resulting from reduced spillage, (4) low installation cost, (5) ability to conform to uneven terrain or mine bottom (less blocking) and (6) ability to span any obstacle without heavy structural support.

Operational flows begin with material received directly from the working face (mechanical miner) into a locally designed conveyor that dumps the muck into either the secondary or main-line conveyor system. Details of the conveyor articulation such as piggybacking and bridging will be designed later. In the case of drill and blast products, local loading stations at strategic locations along the conveyor system will be designed to accommodate the

muck coming from LHDs or dump trucks.

Material lump size should be less than 12 inches for efficient operation including fines and products from drill and blast. Feeder-breakers may be necessary to control material size (Table 5.1).

Slope angle of inclination[13] can be effective up to a maximum 27% (15°) grade which suits the feature of the ESF. Conveyors will have to follow close to the advancing TBM. Conveyors will have to be designed to follow the advancing TBM in order to maintain the capability of muck disposal by the main haulage system. Special conveyors are available in the market which can be designed to follow horizontal curves. The type of conveyor to be used will be selected later, and some of them are discussed in Sections 5.1.2. and 5.1.3.. Conveyor catalogs from various manufacturers, designers, and construction companies are compiled in Vendors Information File No. RSN-VI-001, Transportation Equipment and Accessories[13]. Preliminary contact with these people reveals that the ESF underground conveyor plan to handle the haulage capacity shown in Figure 4.1 is feasible, constructible, and will be operationally sound using current available technology.

5.1.2. PIPE CONVEYOR[13]

The pipe conveyor is a modern transport system which minimizes the problems of training, spillage or scattering and dust. The main features are (1) Forming the conveyor belt into a tubular section, (2) Arrangement of conveyor idlers to maintain a tubular cross-section, and (3) Maintaining stability of the tubular section during travel.

With all materials completely enclosed within the belt pipe, spillage or scattering is eliminated and pollution is effectively controlled. With the pipe conveyor, horizontal as well as vertical curves may be accomplished. This is quite impossible with conventional troughed belt conveyors. Catalogs and pictures of the pipe conveyor are found in RSN-VI-001.

A pipe conveyor technical representative was invited to lecture about the merit of pipe conveyors and its potential application to the ESF. This was held on April 30, 1991 and was attended by some of the RSN design engineering staff. The presentation together with video tapes shown, was successful and left the impression that the current pipe conveyor technology is indeed a viable option applicable to the ESF. A pipe conveyor handling 1,200 tph of muck will occupy a total drift cross-section of 27 inches by 55 inches.

5.1.3. STRETCH-A-TROUGH (SAT) BELT CONVEYOR[13]

The SAT belt conveyor is better described in the catalog and pictures found in RSN-VI-001. It is modern with a proven belt transport system to negotiate horizontal curves. The catalog mentioned that horizontal radius of curvature ranging from 150 to 350 feet can be followed by SAT conveyor installation. This would be ideal for the ESF haulage system.

5.2. TS NORTH RAMP CROSS-SECTION AND THE PREFERRED CONVEYOR LOCATION

The 25 ft diameter TS north ramp cross-section is shown in Figure 5.2. The preliminary maximum vertical clearance of 14 ft on a roadway of 16 ft wide is recommended to maximize the space available for frequent moving vehicles along the roadway with ample space for walkways. The space is conceptually sufficient for anticipated large TBM components which will be transported for the CH ramp construction. The size of mobile miner (with minimum disassembly), moving along the TS ramp for the development of laterals, test alcoves and special drifts is also considered.

The preferred location of the conveyor has not been established. It may be near the roof, suspended away from the personnel and vehicular path for maximum safety. If belts are located near the roadway, haulage grades between 0 to 10% will give potential runaway or uncontrolled vehicles the chance to damage the belts causing total shutdown of the haulage system.

TS NORTH RAMP ACCESS
GENERAL ARRANGEMENT 25' DIAMETER

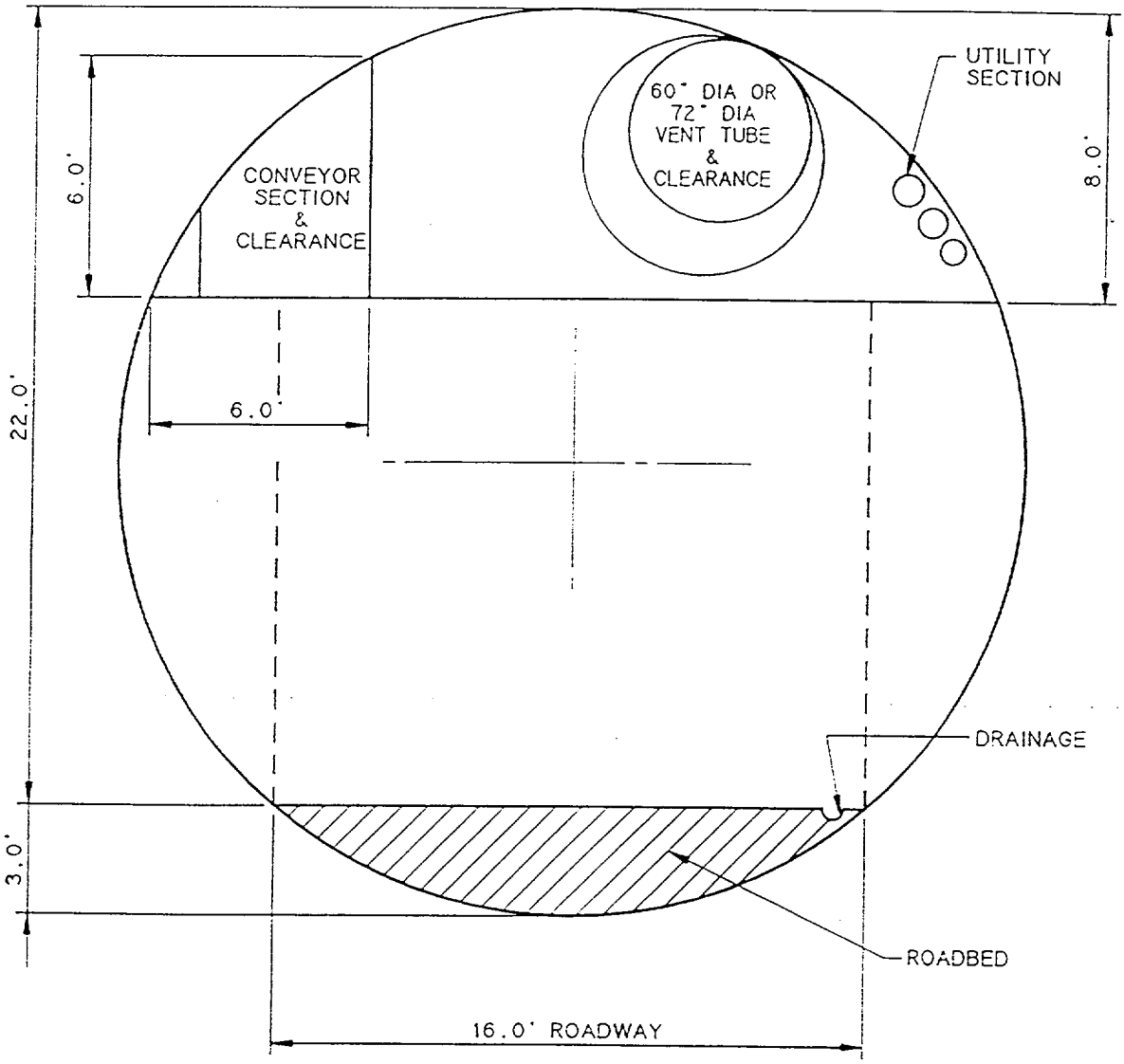


FIGURE 5.2 TYPICAL 25' DIA RAMP/DRIFT WITH 16'x14' HIGH CLEARANCE FOR TRANSPORTION

NOTE:

LATERAL DRIFTS, PASSING CUTOUTS, EMERGENCY REFUGE, ECT. REQUIRES THAT THE 25' DIA RAMP/DRIFT HAS ITS SIDES CLEAR OF UTILITIES.

Another criterion applied is the side clearance of the ramp, free from utilities, allows the flexibility to construct cutouts and turns as needed without much interference with the haulage system.

The final location of conveyor belt in a particular part of the ramp or drift will be determined in Title II. The determination will consider impacts to testing, safety, maintenance and operation.

5.3. CH NORTH RAMP CROSS-SECTION AND THE PREFERRED CONVEYOR LOCATION

The size of the CH north ramp may be finalized later as 18-ft in diameter. Other cross-sectional options are analyzed as shown in Figures 5.3.1, 5.3.2, and 5.3.3 which are 15-ft, 16-ft and 17-ft respectively in diameter. The 15-ft diameter CH ramp will allow a vertical clearance of 6.8 ft (Figure 5.3.1) which is short for the needs of the ESF. Transportation facilities for personnel, supply, material, service and utility (Refer Appendix 5.3 for a list of vehicle sizes that may be used in the ESF) need a minimum height clearance of 8 ft and a roadway width clearance of 10.5 ft including dedicated space for walkways.

With the conveyor belt installed near the roof, it is apparent that a minimum 16-ft diameter CH ramp (Figure 5.3.2) is needed to support sufficient space for ESF activities. A 17-ft diameter CH ramp (Figure 5.3.3) option is shown to compare the next larger size ramp. If later studies will justify the installation of conveyor belt along the side of the roadway, an 18-ft diameter CH ramp will be preferable.

CALICO HILLS RAMP SIZE
OPTION 1

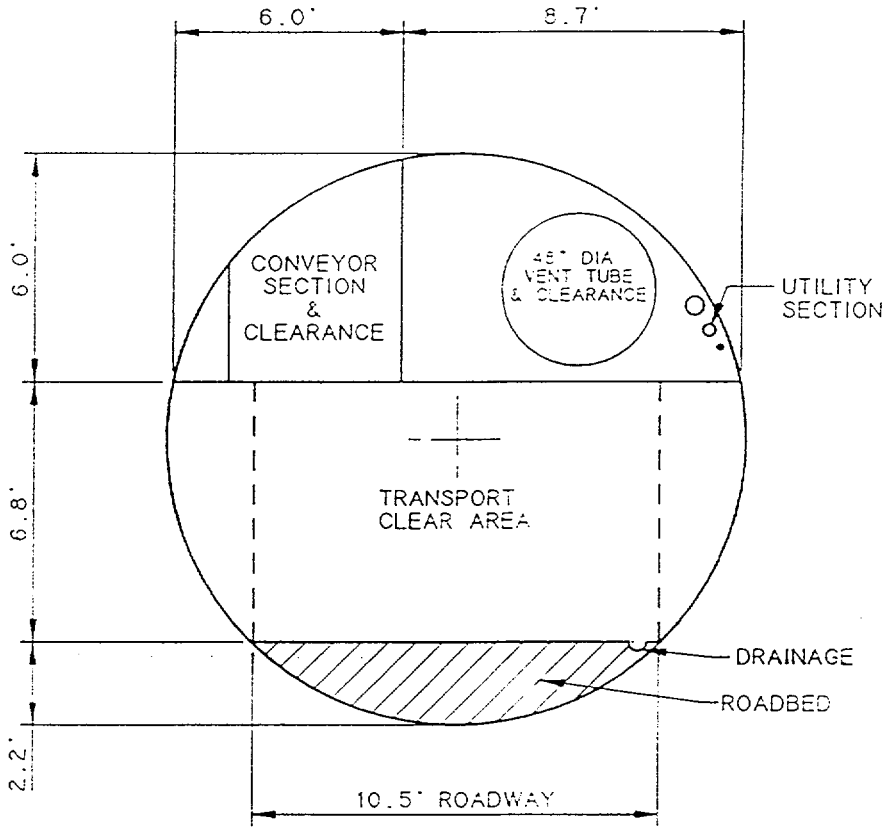


FIGURE 5.3.1 TYPICAL 15' DIA RAMP/DRIFT WITH 10.5'x6.8' HIGH CLEARANCE FOR TRANSPORTATION

NOTE:
WILL NOT HAVE ENOUGH VERTICAL HEIGHT
TO ALLOW A 1.5' CLEARANCE FOR THE 6.3'x6.3' UTILITY VEHICLE AND
ROADHEADER PASSING THROUGH.

CALICO HILLS RAMP SIZE
OPTION 2

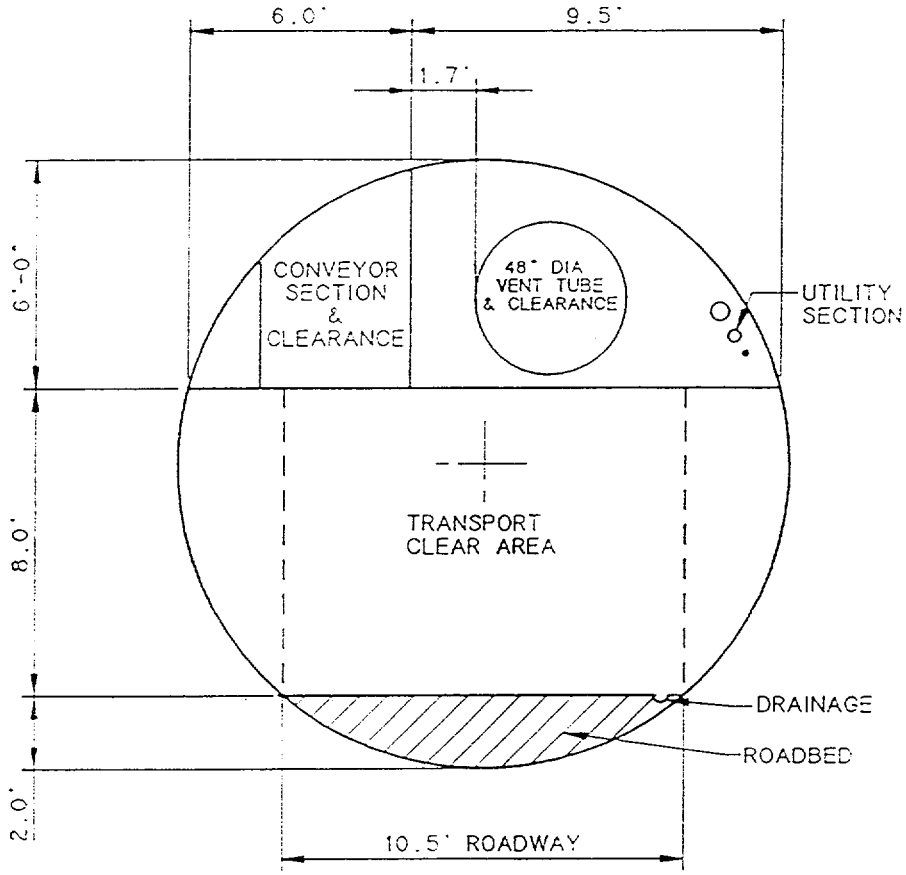


FIGURE 5.3.2 TYPICAL 16' DIA RAMP/DRIFT WITH 10.5'x8.0' HIGH CLEARANCE FOR TRANSPORTATION

NOTE:

THE MAIN RAMP/DRIFT HAS SIDES CLEAR OF UTILITY LINES FOR FLEXIBILITY TO CONSTRUCT LATERAL DRIFTS, PASSING CUTOUTS, EMERGENCY REFUGE, ETC.

CALICO HILLS RAMP SIZE
OPTION 3

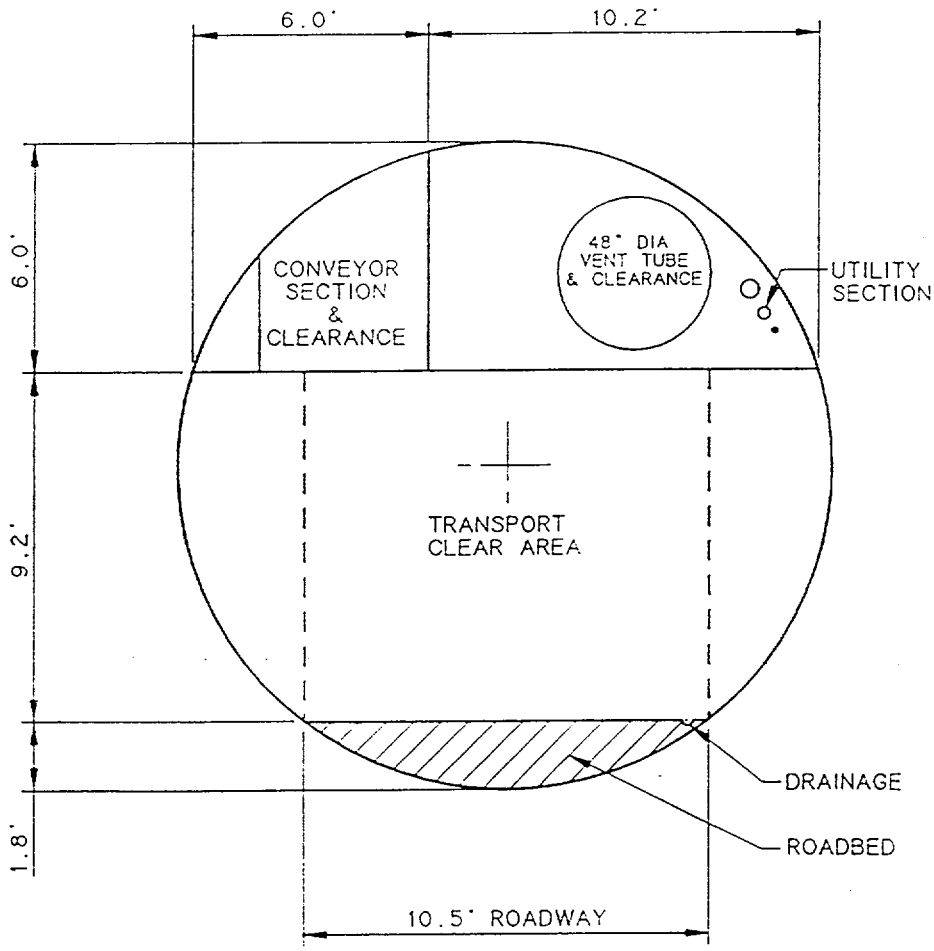


FIGURE 5.3.3 TYPICAL 17' DIA RAMP/DRIFT WITH 10.5'x9.2' HIGH CLEARANCE FOR TRANSPORTATION

There are safety and maintenance trade-offs of locating the conveyor belt near the roof or along the side of the roadway. If suspended near the roof, it has a safety advantage, being away from personnel and vehicular path. It also has safety disadvantage of overhead spillage. Belts located near the roadway are easily accessible for maintenance, but with haulage grades up to 10%, potential runaway or uncontrolled vehicles may damage the belt, causing a shutdown of the haulage system. Belt along the side of roadways requires a wider diameter ramp or drift to accommodate both the space for the belt and the roadway. A conveyor belt near the roof will have side clearance free from utilities, allowing the flexibility to construct cutouts and turns as needed without much interference with the haulage system.

The final location of conveyor belt in a particular part of the ramp or drift will be determined in Title II. The determination will consider impacts to testing, safety, maintenance and operation.

5.4. MTL LATERAL DRIFTS AND SECONDARY HAULAGE

The size of MTL lateral drifts and test alcoves has not been finalized as of this writing. Previous record of sizes (ESFDR 1.2.6.6.PC.1c.ix) shows that some of these drifts may have to be driven initially as 14 ft by 14 ft and later slashed or enlarged to 25 ft by 19 ft. Some cross-sectional options are shown in Figures 5.4.1. and 5.4.2.. Excavation of these drifts from a few feet to a few thousand feet in length may be by mobile miner or by controlled drill and blast. If mobile miner is used, temporary secondary belt conveyors (Figure 5.4.2) will be used as haulage to cope with the instantaneous muck rate of the miner. Shuttle cars

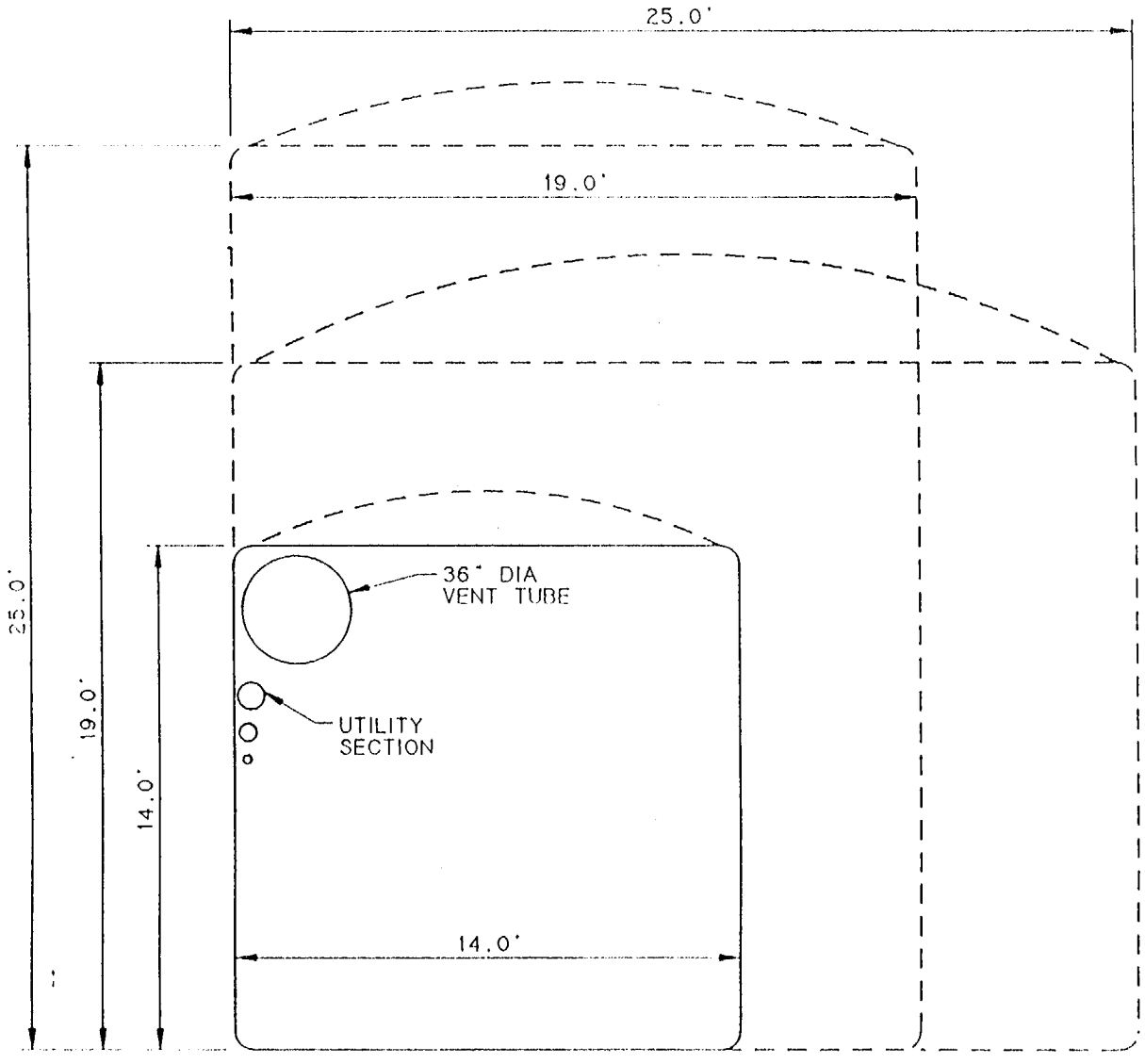


FIGURE 5.4.1 MTL TYPICAL 14'x14' DRILL & BLAST FACE EXPANDED TO 25'x19' MUCK TRANSPORT BY LHD

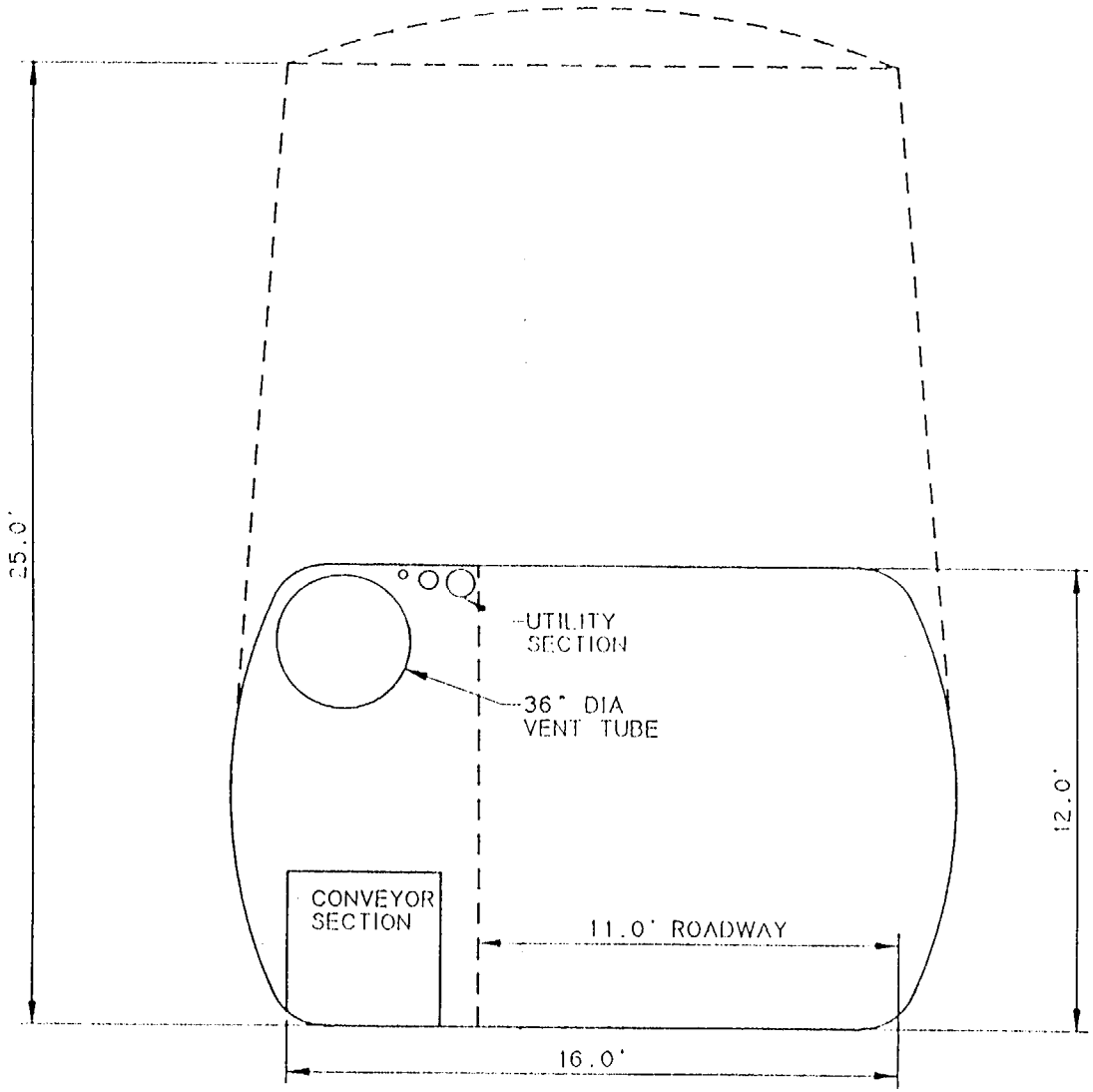


FIGURE 5.4.2 MTL TYPICAL 16'x12' MOBILE MINER (FIRST CUT) FACE

MAY BE EXPANDED TO 16'x25' OR OTHER SIZE EMPLACEMENT TEST DRIFT BY CUTTING THE BOTTOM OR TOP OR SIDE.

may also be used in the MTL lateral drifts in conjunction with the mobile miner. Shuttle cars can operate at the TS level but not in the CH level drifts which are not wide enough.

For drill and blast mining, LHDs or LHDs and dump trucks will be used to muck materials from the face to the local conveyor loading station. This conventional mining face is shown in Figure 5.4.1. More discussion about LHDs are in Section 7.1.

Transportation facilities for personnel, supply, material, service and utility (Refer Appendix 5.3 for a list of vehicle sizes that may be used in the ESF) need a minimum height clearance of 8 ft and a roadway width clearance of 10.5 ft including dedicated space for walkways. The size of MTL lateral drifts will have to accommodate a secondary haulage by either conveyor or rubber-tired units.

5.5. CH LATERAL DRIFTS AND SECONDARY HAULAGE

The size of CH lateral drifts and test alcoves has not been finalized as of this writing. These drifts may have to be driven as small as feasible. Four options are considered and their cross-sections are shown in Figures 5.5.1, 5.5.2, 5.5.3, and 5.5.4. Arching the back of the drift to have a better ground stability will be addressed by another report.

Excavation of these drifts from a few feet to a few thousand feet in length may be by a roadheader or by drill and blast methods. If a roadheader is used, temporary secondary belt conveyors will be used as haulage to cope with the instantaneous muck rate of the roadheader. Shuttle cars may not be a viable

CALICO HILLS LEVEL
LATERAL DRIFT SIZE
OPTION 1

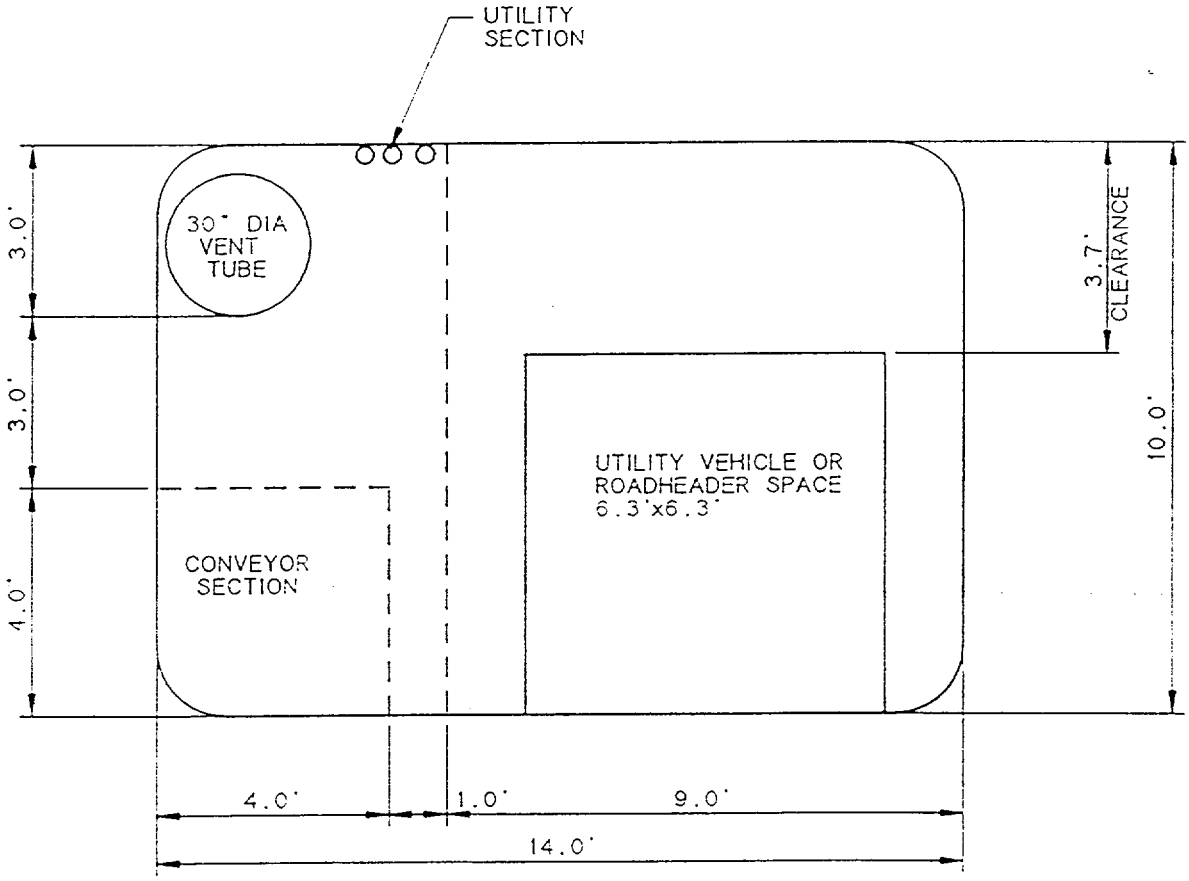


FIGURE 5.5.1
TYPICAL 14'x10' LATERAL DRIFT

NOTE:

1. TEST ALCOVES IF NEEDED, WILL HAVE TO BE IN ONE SIDE ONLY, OTHERWISE CHANGE OF LAYOUT WILL BE NECESSARY.
2. NO DESIGNATED SPACE FOR WALKWAYS.

CALICO HILLS LEVEL
LATERAL DRIFT SIZE
OPTION 2

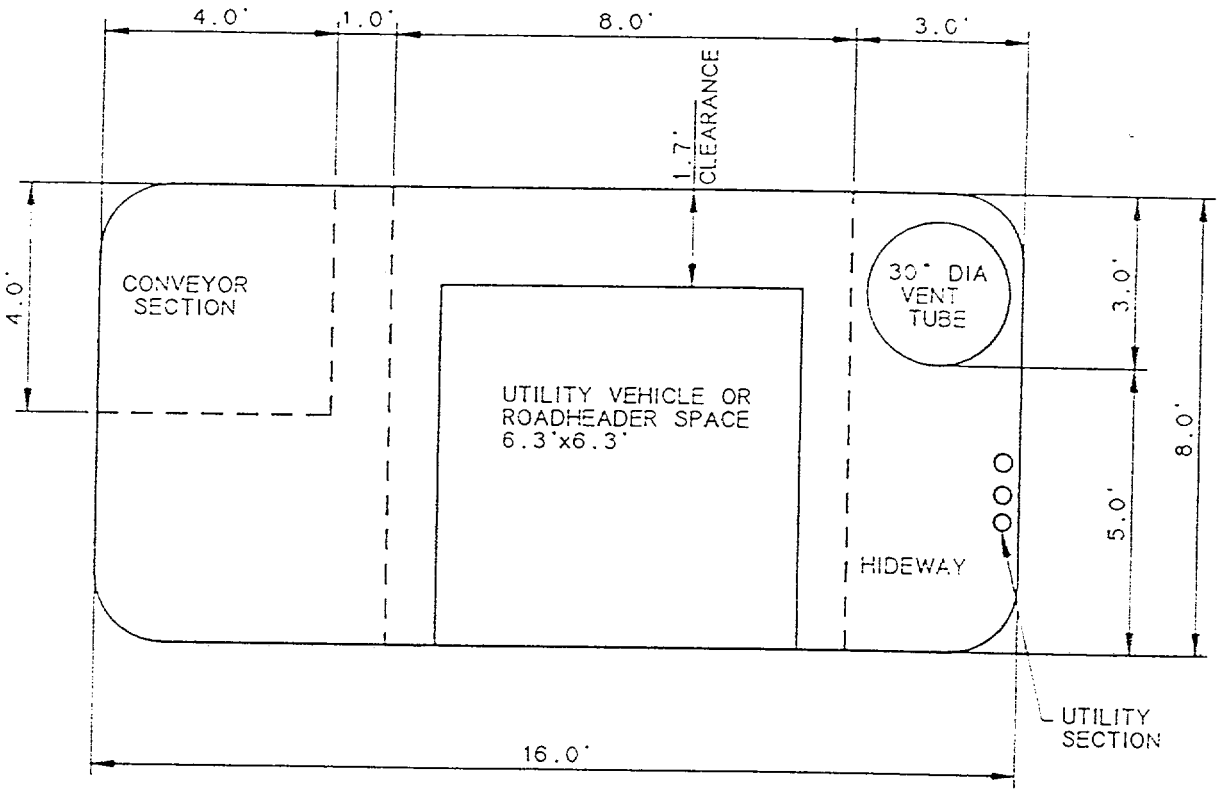


FIGURE 5.5.2
TYPICAL 16'x8' LATERAL DRIFT

NOTE:

1. SIDE UTILITIES MAYBE OBSTRUCTING ACCESS TO TEST ALCOVES.
2. VEHICLE SPACE IS USED AS WALKWAY. WITH HIDEWAY BELOW THE VENT TUBE.

CALICO HILLS LEVEL
LATERAL DRIFT SIZE
OPTION 3

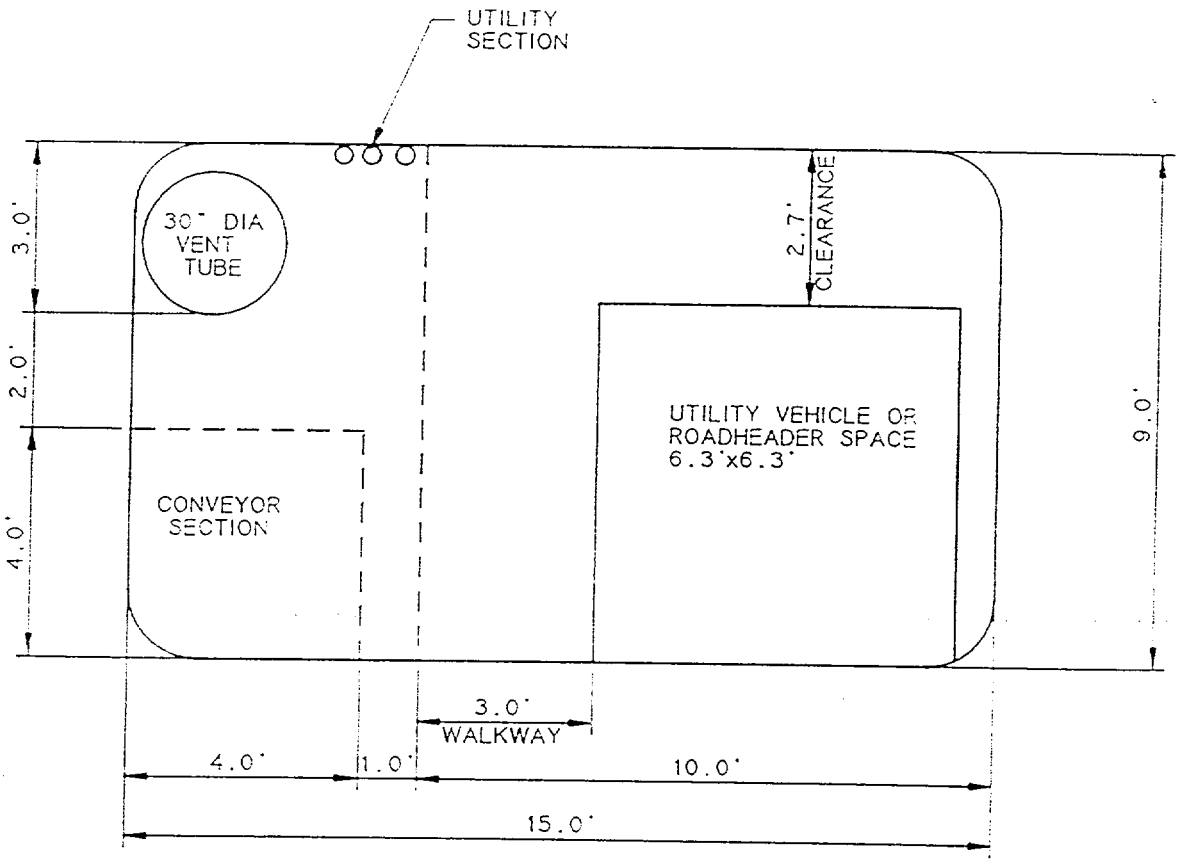


FIGURE 5.5.3
TYPICAL 15'x9' LATERAL DRIFT

NOTE:

1. TEST ALCOVES IF NEEDED. WILL HAVE TO BE IN ONE SIDE ONLY. OTHERWISE CHANGE OF LAYOUT WILL BE NECESSARY.
2. MUCK FEED INTO THE CONVEYOR COMING FROM THE ROADHEADER HAS TO BE DESIGNED TO CLEAR THE VENT TUBE ABOVE THE CONVEYOR SECTION.

CALICO HILLS LEVEL LATERAL DRIFT SIZE OPTION 4

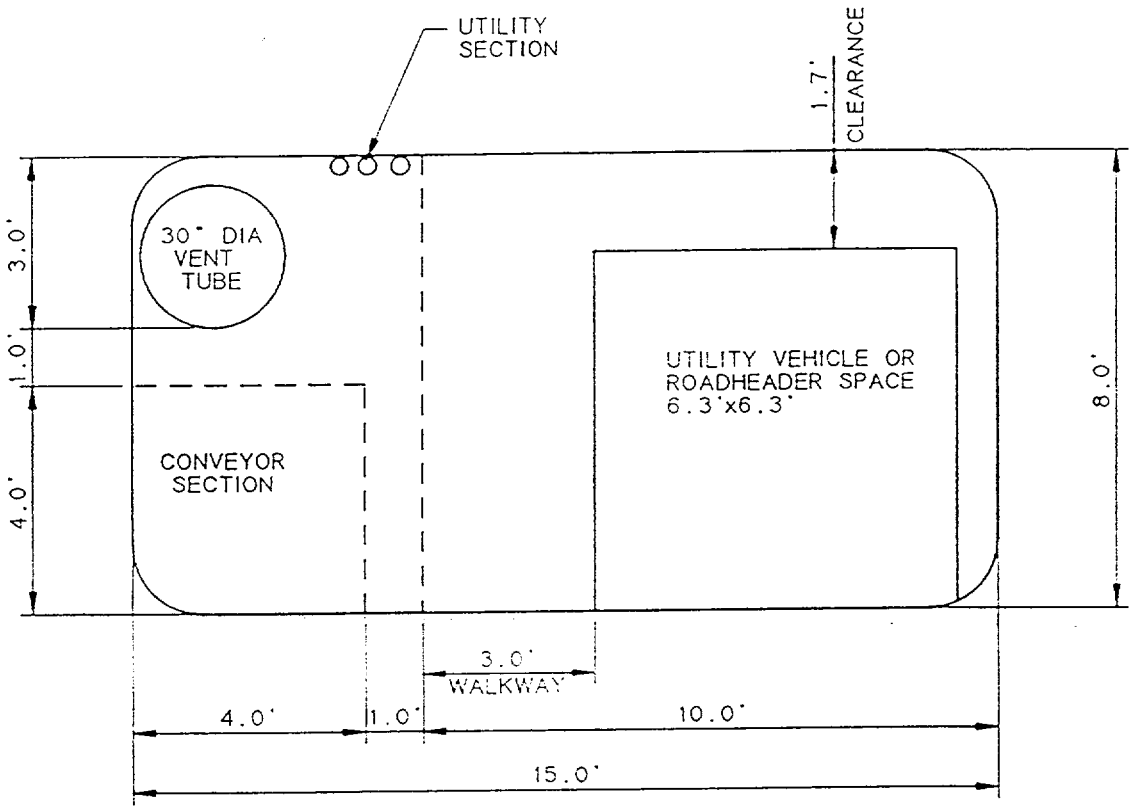


FIGURE 5.5.4 TYPICAL 15'x8' LATERAL DRIFT

NOTE:

1. TEST ALCOVES IF NEEDED. WILL HAVE TO BE IN ONE SIDE ONLY. OTHERWISE CHANGE OF LAYOUT WILL BE NECESSARY.
2. MUCK FEED INTO THE CONVEYOR COMING FROM THE ROADHEADER HAS TO BE DESIGNED TO CLEAR THE VENT TUBE ABOVE THE CONVEYOR SECTION.

option at the CH level development because of the size constraint.

For drill and blast mining, LHDs, or LHDs and dump trucks will be used to muck materials from the face to the local conveyor loading station. More discussion about LHDs is in Section 7.1.

Transportation facilities for personnel, supply, material, service and utility (Refer Appendix 5.3 for a list of vehicle sizes that may be used in the ESF) need a minimum height clearance of 8 ft and a roadway clearance of 10.5 ft including dedicated space for walkways. This can all be accommodated by the space allocated for the CH drifts.

5.6. DRILL AND BLAST FOR ALCOVES AND DRIFTS

It may be common to excavate short alcoves, special cutouts and drifts by drill and blast method. LHDs, or LHDs and dump trucks will be used to muck materials from the face to the local conveyor loading station. More discussion about LHDs and mine trucks are in Sections 7.1 and 7.2. Transportation facilities for personnel, supply, material, service and utility (Refer Appendix 5.3 for a list of vehicle sizes that may be used in the ESF) need a minimum height clearance of 8 ft and a roadway width clearance of 10.5 ft including dedicated space for walkways.

5.7. LOCAL LOADING STATION ALONG RAMPS WITH FEEDER-BREAKERS

A local loading station for muck into the main line conveyor will be designed at a regular interval (To be determined as needed

before Title II design). The loading station accepts muck from both the operational and construction phases, providing muck handling capability at strategic locations of the ESF. Feeder-breakers may be needed to control the lump size feeding the conveyor.

The local loading station of lateral drifts into main line conveyors may be kept in operation, modified to handle muck from LHDs or mine trucks or shuttle cars in subsequent operations.

5.8 BELT CONVEYOR FIRE SAFETY

Mine safety code 30 CFR 57.4263 specifies fire protection shall be provided at the head, tail, drive, and take-up pulleys of underground belt conveyors. Provision shall be made for extinguishing fires along the beltline. Fire protection shall be of a type, size, and quantity that can extinguish fires of any class in their early stages which could occur as a result of fire hazards present.

Mandatory fire protection requires water lines installed all throughout the entire length of the conveyor with fire hose outlets at 300-ft intervals along the conveyor and at the tailpieces, similar to coal mine standards. Another requirement is that 50 ft of water hose be installed at strategic locations along the conveyor. These lines must be capable of delivering 50 gpm at a nozzle pressure of 50 psi. One fire-hose outlet, with hose capable of extending to the drive must be provided within 300 ft of each belt drive.

Two portable fire extinguishers must be provided at each permanent electrical installation. Deluge-type water sprays, foam-generating systems, or dry-powder chemical systems automatically actuated by rise in temperature are required at all main-line and secondary belt drives. The three types must provide fire-suppression protection for the belt drive within 50 ft.

Automatic fire sensors must be installed on each underground conveyor to provide audible and visual signals to facilitate rapid location of a fire. Central monitoring systems can be utilized.

Another provision requires that all underground conveyors be equipped with belt-slippage and sequence-control switches. All conveyors acquired after March 30, 1970 must be flame resistant and approved by MSHA.

6.0. TRANSPORT, MOBILIZATION, AND OPERATION OF TBM

Tunnel Boring Machines of more than 10.0 ft diameter usually are disassembled for shipment to the job site. A typical 16-ft diameter machine may weigh 120 short tons. Because of the weight of the assembled unit, the machine conceptually will be re-assembled on the level where it is to be put into service. Individual components of this size may weigh as much as 35 short tons. Some provision must be made for transporting these large pieces down into the ESF and to the assembly site. The large components may have to be mounted on special dollies and lowered down by a winch or a temporary hoist system. Extra precaution should be exercised in planning the details of the shipment. In

addition, heavy duty rubber-tired muckers and/or low boy trailers may also be used. Once at the site, lifting equipment must be provided for positioning the major pieces for final assembly.

The machine usually is assembled some distance from the face, in a spacious area that provides sufficient room for the assembly work. Usually, the machine is assembled on local rails and moved to the working tunnel face on dollies.

A short starting tunnel (launching chamber) must be prepared, with walls closely approximating the cutting diameter of the machine. The starting tunnel provides the footing for the gripper shoes that react the machine thrust and torque and that allow the machine to propel itself forward. Once in the launching chamber, the dollies are removed, and the machine can begin the typical boring operation.

In typical or historical operations, a TBM's actual utilization will be 40% to 60% of the total time available[9]. The reduction is due to normal delays in tunneling operations; loading and machine conveyor delays, ground support, lunch breaks, machine and backup system maintenance, surveying and laser relocation, mapping, tunnel service installation, cutter changes, shift changes, etc. The utilization of the TBMs for the ESF is likely much lower than the industry factors because the ESF is being constructed to obtain scientific data to characterize Yucca Mountain.

To assure maximum utilization of the tunneling machine, provisions must be made for removing the muck from the heading on a continuous basis. The mechanized muck-removal system must be

capable of disposing of the muck into the ESF's internal muck-handling system without delay. This particular demand can only be satisfied by the use of belt conveyors.

7.0. SECONDARY MUCK TRANSPORT AND SUPPORT VEHICLE

7.1. LOAD-HAUL-DUMP (LHD) MOBILE EQUIPMENT FLEXIBILITY, MOBILITY AND VERSATILITY

An LHD is a common underground mining component regardless of mining method and haulage system used. The ESF will use these units for hauling muck, supplies and materials, and for clearing or cleaning roadways, ditches, etc. The flexibility, mobility, and versatility are important design features inherent in LHD units, expanding the scope of their usefulness in the overall mining method and plan. LHD machines do not perform well when mucking uphill on slopes of greater than 12 to 15% or downhill on slopes of greater than 17%.

Economic haulage distance depends upon the size of the payload, the speed at which the vehicle can operate, the grade of the haulageway, and other factors. LHDs of 1-cu-yd capacity are most efficient at under 300 ft one-way, while the 2-cu-yd machine is most efficient at under 500 ft one way. Travel speed of load-haul-dumps is on the increase. Speeds of up to 15 mph are becoming more common, although the average travel speed is currently 6 to 8 mph. Speed primarily depends upon condition and grade of the roadbed, but operators usually reduce speed in confined haulageways.

In most cases where LHDs are used as a service vehicle, their presence in the underground are rather justified not on hauling economics but on versatility and flexibility to move or service the construction and operation of ESF.

Appendix 5.3 is a list of vehicles that may be used in the ESF, including the size of LHD models that will fit the ESF roadways. In the mining design of drift intersections, appropriate turning radius shall be included for the proper maneuverability of LHDs.

7.2. MINE TRUCKS

Three different types of mine trucks are available for use in the ESF; namely the tip dumpers, telescoping dumpers, and the push-plate dumpers. RSN-VI-001 has pictures and explanation of how each truck works.

A limited number of trucks may be useful in the ESF to move muck from a distance to the main line conveyor. For the application where haulage grade is 0 to 10%, a four-wheel drive truck is recommended.

7.3. SHUTTLE CARS

As the name implies, a shuttle car shuttles back and forth between working face and the unloading point and is not required to turn around. Shuttle cars have served as primary haulage in the

USA since 1940 and still perform this function in some coal mines today. RSN-VI-001 has pictures of shuttle cars. For ESF application, a shuttle car may be a rubber-tired diesel or electric unit use to haul muck from a mobile miner into a local loading station of the main conveyor haulage. A list of shuttle cars available in the market is shown in RSN-VI-001. A 15-ton shuttle car is usually about 10 ft wide by 5.5 ft high and requires a wide drift size to maneuver. Shuttle cars are not quite flexible enough to haul muck in other than large drift excavations of roadways 14 ft width or wider.

8.0 PERSONNEL CARRIER & AMBULANCE

The basic design of personnel carrier vehicles will be governed largely by the physical characteristics of the ESF. Widths and heights will depend on the dimensions of the entries to be travelled and curves to be negotiated. Speed will be governed by condition of the roadbed or roadways and grades encountered. Capacities will depend on size of crews to be transported to a given location. Braking capacity must be ample to provide a safe stop on the steepest grades expected, and towed vehicles should be provided with a safety device to prevent uncoupling.

Provision must be made for three basic types of personnel carriers: transportation of crew between portal and working face at the beginning and end of the shift; transportation of supervisors, inspectors, maintenance personnel, scientists and testers during shift, and visitors; and evacuation of persons or

crew whenever required.

Safety must be recognized as a primary consideration in any form of personnel transport. In transportation of crew, the second consideration is speed. A minimum travel time produces maximum utilization of expensive production equipment and minimum out-of-pocket expense for non-productive labor. Supervisors, inspectors and mechanics need reasonably quick transportation, but travel during the shift must be accomplished without interference with the flow of product or supplies. When transporting injured persons, the emphasis is directed toward keeping them as comfortable as possible and moving them in a way that will not aggravate injuries.

All personnel conveyances should be designed to accommodate first aid supplies including a stretcher. Likewise, roadways must accommodate a space for easy passage of injured to the nearest first aid station or to the surface for medical attention. A list of personnel transport vehicles for ESF use are found in RSN-VI-001.

8.1. PERSONNEL POPULATION NEAR TBM FACE

It is anticipated that the possible maximum personnel group in one area will be at or near the TBM face. The group may have 26 people consisting of the following:

<u>Construction Personnel</u> = 11

one front line supervisor, one TBM operator, two labor/utility persons, two miners/bolters, two electricians, one conveyor person, one hydraulic

mechanic and one service vehicle driver;

Testers, Technical Support,
Management, and Visitors = 15

five geologists/scientists/testers, two survey personnel, two engineers/inspectors, one management person, and five visitors.

8.2 PERSONNEL CARRIER AND EMERGENCY VEHICLE

The size of the group at or near the TBM may require at least two personnel carriers of 12 to 24 capacity each, one permanently assigned to the construction crew and another general service for the rest. The TBM face has a limited ventilation capability and diesel equipment should be used only when allowable.

An emergency ambulance and evacuation vehicle is the same vehicle stationed near the face to service the crew. It is prudent to keep one vehicle ready for emergency at all times.

9.0. MATERIALS AND SUPPLIES

The transportation requirement for materials and supplies needed to support the ESF is predictable and anticipated by mining construction and site characterization activities.

A list of activities and/or related supplies is provided with the following key words:

Ventilation (with vent pipes 12 to 72 inches in diameter by 20 ft or 10 ft long); axial fans (24 inches to 60 inches in diameter); fan silencers;

Compressed air and water pipes; drill rods and pipes; drill casing (up to 12 inches in diameter); drill rigs; jacklegs;

Electric cable in reels; electric conduits; transformers; medium voltage switch gears up to 15 KV;

Mobilization and equipment parts for TBMs, mobile miner, roadheader, trucks, shuttle cars, and LHDs; conveyor belts in reels: conveyor parts; feeder-breakers; precast concrete inverts; ballast;

Oil and diesel fuel drums; lubrication equipment;

Concrete mixers; shotcrete; grout; bolting mats; rock bolts; wire mesh; steel beams; steel plates; timber; lumber; plywood boards; fiberglass boards;

Explosives; ambulance;

Scissor lifts; testers instruments, testers and mappers platforms; survey; geology;

Water tank; dust control applicator; mobile dust collector; stationary dust collector; and firefighting.

10.0. SERVICE/UTILITY

Utility vehicles are adaptable to numerous duties. The most common ones are probably the ordinary haulers with flat bed or low-sided box. They are used for hauling supplies and equipment from one point to another. Some are used occasionally for towing and may pull one or more trailers. Another type of utility vehicle for special application is explosive haulers or loaders, mechanic trucks, lubrication trucks and special carriers.

Utility haulers are essential in the ESF operation to take supplies to advancing headings. Some utility haulers may be dedicated to transporting steel sets, rock bolts and mesh, and may be equipped with boom lifts to unload heavy supports or even place them, as required. A rockbolt hauler may have a boom-mounted operator's basket which can be used for bolt installation and inspection. Various mechanic trucks and pipe trucks service the heading to keep power, air, water, and ventilation at the face and to keep equipment at maximum utilization.

Modified utility vehicles are available from a number of mining equipment companies (RSN-VI-001). These vehicles are provided with diesel engines requiring a specific air quantity for ventilation. Some units are battery powered.

A utility vehicle may be modified with platforms for testers, mappers, surveyors, ventilation and pipe crew, electricians, and conveyor mechanics.

11.0 CONCLUSION AND RECOMMENDATION

Main Haulage

The conveyor haulage system is recommended on the basis of two major criteria: (1) Instantaneous muck rate of 771 tons per hour coming from two TBMs, one mobile miner, one roadheader and other mining products from each of the north and south ramps; and (2) haulage grade along ramps ranging from 0 to 10%.

Conveyor haulage, in combination with rubber-tired vehicle for transportation of personnel, material and supplies, is most appropriate for the ESF. Special conveyor type has to be used to follow the Tunnel Boring Machine operation. Local loading stations for transferring muck into the main conveyor must be provided at regular intervals, as needed.

Main line conveyor installation must consider safety aspects of the ESF activities. Hanging of main line conveyors in the roof of the ramp, away from the travelling path of personnel and vehicles is preferred. The final location of conveyor belt in the ramp or drift will be decided after the impact to safety, maintenance, and operation has been studied. For secondary haulage in the development of lateral drifts by mobile miner or roadheader, conveyors may be installed near the floor with safety barriers.

Conveyor Fire Safety

Conveyor belt fire safety must be observed. This will involve installing water lines, automatic fire suppressors, and automatic fire sensors to provide audible and visual signals for the rapid location of a fire.

Secondary Haulage

Secondary haulage may also be accomplished by rubber-tired shuttle cars or mine trucks in conjunction with the mobile miner or roadheader. Shuttle cars may be used at the TS level where larger drifts are constructed. The smaller drifts at CH level may not accommodate operation of shuttle cars.

LHD

The use of LHD units is also recommended. With articulation, LHDs are very mobile and versatile to haul muck, supplies and materials, and for cleaning or clearing roadways and ditches.

Personnel Carriers

Rubber-tired, personnel transport vehicles, with 12 to 24 capacity, shall be used for both regular and emergency services. The vehicle will transport personnel between the portal and the working face. The same vehicles will be used to evacuate personnel whenever required. All personnel conveyances should be designed

to accommodate first aid supplies including a stretcher.

Utility/Service

Rubber-tired utility vehicles shall be used to adapt to numerous duties. Ordinary haulers with flat bed or low-sided box haul supplies and equipment from one point to another. Explosive hauler or loader, mechanic truck, and lubrication truck are needed. Various mechanic trucks and pipe trucks service the heading to keep up power, air, water, and ventilation. A rockbolt hauler may have a boom-mounted operator's basket which can be used for bolt installation and inspection. The same principle can be applied to modify trucks and scissor lifts with platforms to service geologists, surveyors, testers, electricians, and conveyor mechanics.

12.0. REFERENCES

1. RSN Report, ST-MN-001, Rev. 2 - TS North Portal Siting Analysis.
2. RSN Report, ST-MN-004, Rev. 2 - Preliminary Siting Analysis.
3. RSN Report, ST-MN-006, Rev. 2 - Preliminary Sizing of Optional Shaft.
4. RSN Report, ST-MN-007, Rev. 3 - Preliminary TS North Access Ramp Cross Section Size Analysis
5. RSN Report, ST-MN-020, Rev. 3 - ESF Preliminary Excavation Plan.
6. RSN Report, ST-MN-008, Rev. 2 - Calico Hills North Ramp Sizing Study.
7. FSN Report, FSN-AS-430, Rev. 2 (Alternative Study Option # 30).
8. SME Mining Engineering Handbook, Volume 1, 1973 Edition by Cummins and Given.
9. Underground Mining Methods Handbook, SME 1982 Edition, W. A. Hustrulid, Editor.
10. Mine Ventilation and Air Conditioning, Second Edition, 1982 Release, by Hartman, Mutmanski, and Wang.
11. Excavator Performance Predictions Using Existing Databases (SLTR 90-7003) by Levent Ozdemir, Leslie E. Gertsch, James E. Friant, David M. Neil.

12. Diesel Equipment Listing for Diesel-Powered Equipment Approved Under Part 32, 30 CFR Program Circular PC 4800-0, 1987.

13. RSN Vendors Information File # RSN-VI-001, Transportation Equipment and Accessories.

14. RSN Report, ST-MN-030, Rev. 0 - Preliminary Ventilation Analysis, ESF Construction Phase.

APPENDIX 4.1

HAULAGE CAPACITY CALCULATION

I. D. # "TRANSMUC" File

DETERMINING MUCK RATE FOR ESF HAULAGE SYSTEM
(INSTANTANEOUS MUCK RATE)

ASSUMPTION

A) Worst case when four headings are developed simultaneously with one TBM and one Mobile Miner at the Topopah Spring Level, and one TBM and one Road Header on the way to Calico Hills Level.

B) Density of rock in place = 2.3* or Specific Weight = 140 lbs per ft^3
(* Refer RIB Ver. 4, Rev. 4, issued 4/8/91)

C) Haulage system uncertainty allowance, 25% over design capacity.

	CROSS AREA ft^2	VOLUME Ft^3/Hr	MUCK Tons/Hr	Muck System Total Tons/hour	Total Including 25% Uncertainty Muck Allowance Tons/hour
TOPOPAH SPRING (TS) LEVEL HAULAGE SYSTEM DESIGN CAPACITY					
One TBM 25 feet diameter advancing at 8.8 feet per hour (TS Ramp or TS Main Drift)	491	4320	302		
One Mobile Miner 14x22 feet tunnel advancing at 3.5 feet per hour (TS Core Drifts)	308	1078	75		
		TS Level Haulage System Design Capacity =		377	471
18 FT DIA CALICO LEVEL (CH) HAULAGE SYSTEM DESIGN CAPACITY					
One TBM 18 feet diameter advancing at 9.5 feet an hour or 17' dia at 10.63'/hr. (CH Ramp or CH Main Drift)	254	2417	169		
One Roadheader 14x16 feet tunnel advancing at 4.5 feet per hour (CH Drift)	224	1008	71		
		CH Level Haulage System Design Capacity =		240	300
TS + CH Total Haulage System Muck Design Capacity at Ramp (from Y-Intersection to Portal)				617	771

APPENDIX 5.3

MINING EQUIPMENT DIMENSION

AND VENTILATION REQUIREMENT

I.D. # "Tran-EQT" File

List of Mining Equipment, Dimension, and Ventilation Requirement
(Source: RSN-VI-001, Transportation Equipment and Accessories)

Compiled: R.S. Jurani 4/22/91
Save (Metric Conversion Factor)= 304.8

	HEIGHT (Feet)	WIDTH (Feet)	LENGTH (Feet)	TURNING RADIUS Outer (Feet)	TURNING RADIUS Inner (Feet)	ENGINE TYPE	HORSEPOWER (HP)	VENTILATION (CFM)
SERVICE/UTILITY (Per TUS NT 60, EJC, & Wagner Trackless Utility System)								
High Lift Truck	6.5	5.9	27.6	19.7	11.4	F6L 912W	87	7,500
High Lift Truck	6.6	5.9	25.9	18.9	11.4	F6L 912W	87	7,500
EJC 975A /Scissor Lift	6.2	6.4	20.4	18.1	10.8	F6L 912W	77	7,500
Jut-41SL Scissor Lift	7.5	8.0	20.8	19.5	12.0	F6L 912W	77	7,500
Low Lift Truck	7.5	5.9	22.0	18.2	11.4	F6L 912W	87	7,500
EJC 975A /Boom Truck	5.8	6.7	23.3	19.5	11.8	F6L 912W	77	7,500
Charging Truck	6.9	4.6	23.6	19.5	12.0	F6L 912W	87	7,500
Emulsion Charging Truck	7.1	7.2	23.5	19.4	10.7	F6L 912W	87	7,500
Material Transport Truck	6.5	5.9	21.0	18.0	11.4	F6L 912W	87	7,500
Shotcreting Truck	6.5	5.9	30.8	19.4	11.4	F6L 912W	87	7,500
Wet Concrete Transmixer	7.9	5.9	21.7	18.0	11.4	F6L 912W	87	7,500
Dry Concrete Transport	7.5	5.9	22.6	18.0	11.4	F6L 912W	87	7,500
Maintenance Truck	7.2	5.9	21.3	18.0	11.4	F6L 912W	87	7,500
Riding Workshop Truck	7.2	5.9	22.0	18.0	11.4	F6L 912W	87	7,500
EJC 975A Flatbed	5.8	6.7	21.3	18.1	10.7	F6L 912W	77	7,500
EJC 975A Lube Truck	5.8	6.7	23.3	19.6	11.8	F6L 912W	77	7,500
PERSONNEL CARRIER								
Personnel (22 Pass)/Material Transporter	6.6	5.9	23.0	18.5	11.4	F6L 912W	87	7,500
EJC 955 Minetender/9 Passenger truck	5.8	5.2	15.3	12.8	7.3	F3L 912W	40	4,500
EJC 975A /13 Passenger Carrier	5.8	6.8		18.1	10.7	F6L 912W	77	7,500
LOAD-HAUL-DUMP (LHD'S)								
EJC 60 LHD / 6000 lb/1.5 yd^3 Heaped	6.3	4.7	19.3	13.2	6.9	F5L 912FW	68	6,500
EJC 80 LHD / 8000 lb/2.25 yd^3 Heaped	6.7	5.3	22.0	15.2	9.3	F6L 912FW	82	7,500
EJC 80 LHD / 8000 lb/2.25 yd^3 Heaped	6.7	5.3	22.0	15.2	9.3	Electric	86	TBD
EJC 100 LHD / 10000 lb/2.8 yd^3 Heaped	7.3	5.6	24.1	17.0	10.3	Cat 3304	100	10,700
EJC 100 LHD / 10000 lb/2.8 yd^3 Heaped	7.3	5.6	24.1	17.0	10.3	F5L 413FRW	116	10,000
EJC 100 LHD / 10000 lb/2.8 yd^3 Heaped	7.3	5.6	24.6	17.0	10.3	Electric	100	TBD
EJC 120 LHD / 12000 lb/3.0 yd^3 Heaped	6.7	6.6	24.0	18.0	10.3	Cat 3304	100	10,700
EJC 120 LHD / 12000 lb/3.0 yd^3 Heaped	6.7	6.6	24.0	18.0	10.3	F6L 413FW	139	12,000
EJC 130 LHD / 13000 lb/3.5 yd^3 Heaped	7.4	7.0	27.8	18.8	10.5	F6L 413FW	139	12,000
EJC 130 LHD / 13000 lb/3.5 yd^3 Heaped	7.4	7.0	27.8	18.8	10.5	Cat 3304	165	33,000
EJC 130 LHD / 13000 lb/3.5 yd^3 Heaped	7.4	7.0	28.3	18.8	10.5	Electric	125	TBD

	HEIGHT (Feet)	WIDTH (Feet)	LENGTH (Feet)	TURNING RADIUS Outer (Feet)	TURNING RADIUS Inner (Feet)	ENGINE TYPE	HORSEPOWER (HP)	VENTILAT (CFM)
EJC 180 LHD / 18000 lb/5.0 yd^3 Heaped	7.8	7.8	29.3	21.4	11.9	F8L 413FW	185	16,00
EJC 180 LHD / 18000 lb/5.0 yd^3 Heaped	7.3	7.8	29.3	21.4	11.9	Electric	150	TE
EJC 210 LHD / 21000 lb/6.0 yd^3 Heaped	7.6	8.9	30.4	23.2	11.5	F10L 413F	231	20,00
EJC 240 LHD / 24000 lb/7.0 yd^3 Heaped	7.6	9.7	31.5	23.5	13.7	F12L 413F	277	24,00
EJC 300 LHD / 30000 lb/8.0 yd^3 Heaped	8.2	8.9	34.1	23.0	11.8	F12L 413F	277	24,00
EIMCO 913 LHD / 3 yd^3 Heaped	7.0	6.0	24.1	16.2	8.5	FL6413FW	100	12,00
EIMCO 913C LHD / 4.5 yd^3 Heaped	5.8	6.0	24.7	16.9	8.5	Cat	100	13,90
EIMCO 925 LHD / 5 yd^3 Heaped	7.8	7.5	28.4	20.3	10.8	F8L 413W	185	16,00
EIMCO 925 LHD / 5 yd^3 Heaped	7.8	7.5	28.4	20.3	10.8	ELEC-AC TEFC	150	TE
EIMCO 928 LHD / 8 yd^3 Heaped	8.3	8.5	33.1	21.8	10.8	F12L413W	275	24,00
Wag. LHD HST-1A 1 yd^3 Heaped	6.1	4.0	17.3	11.5	5.8	F4L 912W	55	5,00
Wag. LHD ST-2D 2.5 yd^3 Heaped	6.5	5.4	22.9	15.4	8.8	F6L 912W	82	7,50
Wag. LHD ST-3.5 3.5 yd^3 Heaped	5.7	6.3	27.8	17.8	9.0	F8L 413FW	185	16,00
Wag. LHD ST-6C 5 yd^3 Heaped	7.0	8.0	30.2	20.5	10.0	F10L 413F	231	20,00
Wag. LHD ST-8A 8 yd^3 Heaped	7.3	8.2	33.8	21.8	10.7	F12L 413F	277	24,00
JS-350 LHD / 3.5 yd^3 Heaped	7.6	6.3	27.6	17.8	9.6	F6L 413FW	139	12,00
DUMP TRUCKS								
Wag. MT 406/6.5 Ton Rear Dump Truck	6.2	5.4	16.7	13.3	6.8	F6L 912W	82	7,50
Wag. MT 413/13 Ton Rear Dump Truck	6.8	6.3	22.8	17.7	10.4	F6L 413FW	139	12,00
Wag. MT 416/16 Ton Rear Dump Truck	6.8	7.0	28.4	24.5	15.0	F8L 413FW	185	16,00
JDT-410/10 Ton End Dump Truck	6.8	7.0	22.7	18.7	10.2	F6L 714	135	12,00
JDT-413/13 Ton End Dump Truck	7.5	7.0	30.3	18.7	10.2	F6L 413FW	139	12,00
JDT-415/15 Ton End Dump Truck	7.5	8.3	22.8	18.7	9.5	F8L 413FW	185	16,00
EJC 975 (TS) End Dump Truck	7.0	6.4	17.4	20.0	12.8	F6L 912W	77	9,00
EJC 960 Truck/10000 lb/2.6 yd^3 Heaped	6.4	6.2		15.0	7.0			
Joy Shuttle Cars, 15 ton cap, Vol. Reg/with 9" Side Board.								
Joy 10SC32-40A-3, 127/197 ft^3	5.6	9.2	28.5	21.5	7.5	Electric		
Joy 10SC32-48A-3, 151/234 ft^3	5.6	9.9	28.5	22.0	7.5	Electric		
Joy 10SC32-56A-3, 175/271 ft^3	5.6	10.5	28.5	22.5	7.5	Electric		
Joy 10SC32-59A-3, 184/286 ft^3	5.6	10.8	28.5	22.8	7.5	Electric		
Joy 10SC32-64A-3, 199/307 ft^3	5.6	11.2	28.5	23.0	7.5	Electric		
Joy 10SC22-B, 230 ft^3	6.0	8.0	27.5	21.3	8.1	Electric		
Joy 10SC22-C, 230 ft^3	6.0	8.0	27.5					
With Reg/6" Side Board								
Eimco 48C-61-36, 193/265 ft^3	4.3	10.6	27.5					
Eimco 48C-55-36, 175/241 ft^3	4.3	10.1	27.5					
Eimco 48C-49-36, 156/217 ft^3	4.3	9.6	27.5					
Eimco 48C-43-36, 139/246 Ft^3	4.3	9.1	27.5					
Joy 3FCT Flexible Conveyor Train (10-12 tpm, 90° turns, 4.4'x3.1'H & Inby 8'x3.1'hopper/receiver)	3.1	4.5 Tail 8'	500 ft Section	90° turns				Convey

PRELIMINARY ESF FUNCTIONAL REQUIREMENTS

DESIGN ANALYSIS No. ST-MN-015

REV. 2

WBS No. 1.2.6

AUGUST 20, 1991

RAYTHEON SERVICES NEVADA

Raytheon Services Nevada	DESIGN ANALYSIS Number: ST-MN-015 Rev: 2 Page 1 of 29

WBS No. 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	W. R. Kennedy	W R Kennedy	Sr. Mining Engr.	8/20/9
CHECKER:	R. L. COPPAGE	R. Coppage	SR. MINING ENGR.	8/20/9
APPROVAL - LDE:	Bruce T. Stanley	Bruce T. Stanley	Lead Mining Eng.	8-21-9
APPROVAL - SCDM:	B.R. CHYTROWSKI	B.R. Chytrowski	SCDM	8-22-9
QA CONCURRENCE:	PAUL B. HALE	Paul B Hale	Sr QA Specialist	8-21-9

SUBJECT: PRELIMINARY ASSIGNMENT OF FUNCTIONAL REQUIREMENTS FOR UNDERGROUND ESF AREAS

TITLE: PRELIMINARY ESF FUNCTIONAL REQUIREMENTS

QAG Reference: RSN-GR-013, REV. 0

1.0 PURPOSE

The purpose of this analysis is to preliminarily identify the basic functions which are to be accommodated by the underground excavations included in the Exploration Studies Facility (ESF). The analysis will focus on functional requirements related to site characterization, but future requirements related to repository operations will be briefly discussed, if they are known. The analysis will cover underground accesses, the Topopah Spring (TS) Level Main Test Area, and exploratory drifts on the TS and Calico Hills (CH) levels. Functional requirement assignments determined by this analysis will provide a basis for developing reference designs for the various underground excavations.

Revision 1 incorporates the Management Review comments.
Revision 2 incorporates the Technical Review comments.

2.0 METHOD

The input documents will be reviewed to identify the functions which must be accommodated by each of the underground excavation areas being considered. Information from the input documents, along with engineering judgement, will be used to assign specific functional requirements to each of the excavation areas.

A brief description of the specific functions to be accommodated by each of the underground excavation areas will be prepared.

3.0 ANALYSIS INPUTS

YMP/CC-0013 (ESFDR), Revision dated May 31, 1991:

Section 1.2.6.4 Shaft Access: FR-1; FR-2

Section 1.2.6.5 Ramp Access: FR-1; FR-2

Section 1.2.6.6 Underground Excavations: FR-1; FR-2

Section 1.2.6.7 Underground Support Systems: FR-1; FR-2; FR-3

Section 1.2.6.8 Underground Test Support: FR-1

4.0 CODES AND STANDARDS

30 CFR 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, Revised as of July 1, 1988

10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories, Revised as of January 1, 1988

5.0 ASSUMPTIONS

5.1 It is assumed that the north and south CH ramps will be constructed from the TS ramp intersection down to the CH level using two 16 Ft diameter TBM's. It is further assumed that these machines will be assembled underground. (Assumption used in Sections 9.1 and 9.2)

5.2 It is assumed that all analysis inputs cited in Section 3, will be included in the Basis for Design (BFD).

6.0 REFERENCE MATERIAL

6.1 FSN-AS-430, Rev-2 ESF Alternative Study Data(Option#30)

6.2 ESF TEST PLANNING PACKAGE 91-5 - PRELIMINARY ESF TEST PLANNING PACKAGE FOR SUPPORT OF PRE-TITLE II DESIGN STUDIES, Los Alamos National Laboratory, 5/07/91

6.3 Authorization for Conducting a Design Study to Develop a Reference ESF Design to be Used as Input to Title I Design Summary Report - Letter from Gertz to Bullock (EDD:EHP-2080), dated February 22, 1991

7.0 COMPUTER PROGRAMS

Not Applicable

8.0 UNITS

English Units are used.

9.0 ANALYSIS

9.1 TS NORTH RAMP

The TS North Ramp will be one of two accesses between the surface and underground ESF areas and will also have utility in the potential repository. During repository operations, the ramp would be used as an emplacement ventilation intake and as the main route for transportation of waste for underground emplacement.

Functions to be accommodated by the TS North Ramp during site characterization include:

Transportation of Personnel - The TS North Ramp will provide the primary means of access for personnel between the surface and the TS horizon. Personnel associated with on-going construction and operations activities, as well as those involved with testing/test support activities, will access underground facilities through the north ramp. In addition, visitors must be accommodated. The probable means of transporting personnel along the ramp will be via rubber-tired, diesel powered vehicles. Design considerations with respect to personnel access include:

- Ramp gradient must be suitable for safe vehicular travel
- Roadway width must be adequate to safely accommodate personnel transporters and must provide sufficient clearance to permit vehicles to safely pass people walking in the ramp
- Provision must be made in the ramp for vehicular turn-around
- Air in the ramp should be of suitable quality and temperature to provide a safe and healthy environment for personnel traveling through or working in the area

Emergency Egress - In the event of an emergency, the north ramp will provide a potential means of emergency egress from the underground facilities. During an emergency, travel up the ramp could be either on foot or via rubber-tired vehicles. The ramp shall have the capability to support the evacuation of all underground personnel to safety within one hour.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the north ramp during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or alternately, it could be excavated into the side of the ramp.

Transport of Materials - Maintenance and operating supplies must be transported down the ramp to support construction, operations, testing and test support activities. Some examples of these items are spare

equipment parts, ventilation tubing, ground support materials, blasting supplies, fuel, hydraulic oil, pipe, electrical cable, bits and cutters, and test supplies. Also, materials such as trash and unusable parts will need to be transported from underground to the surface.

Transport of Equipment - Mining/mining support and test/test support equipment will be taken underground via the north ramp. Some of the mining equipment will travel under its own power while other equipment will be transported as components and assembled underground. The largest piece of equipment to be accommodated in the TS North Ramp is likely to be the tractor/trailer unit transporting the 16 Ft diameter TBM components down to the underground erection chamber located just off the ramp.

Ventilation - During construction of the north ramp, ventilation tubing will be installed to exhaust air from the face area back out to the surface. After the main north-south drifts hole through on both the TS and CH levels, the tubing in the ramp will be removed and flow-through ventilation established. Since the north ramp will be used to transport personnel, and will be the primary testing access, it will serve as the ventilation intake opening.

Muck Haulage - A conveyor will be installed behind the TBM to transport mined rock to the surface during ramp construction. After the main

north-south drifts hole through on both TS and CH levels, the conveyor will be removed from the TS North Ramp and all excavated rock will be transported to the surface via the TS South Ramp. This change can be accomplished concurrent with the changeover to flow-through ventilation.

Accommodation of Support Systems - The TS North Ramp will provide a corridor for components of several underground construction and operations support systems. These items may include power distribution cables, lighting system components, water distribution pipes, water collection pipes, compressed air pipes, and monitoring/warning and communications systems components.

Testing/Test Support Activities - Primary among the functions to be accommodated by the TS North Ramp are the testing and test support activities planned for this access. Additionally, the equipment necessary to carry out the testing activities must be accommodated. Reference 6.2 provides the most definitive information currently available regarding the planned test activities.

9.2 TS SOUTH RAMP

The TS South Ramp will provide a second access between the surface and underground ESF areas, and will also have utility in the potential repository. During repository operations, the ramp would serve as the

main route for muck haulage from the repository development areas to the surface muck disposal area. Exhaust air from the development areas would be routed to the surface via the south ramp.

Functions to be accommodated by the TS South Ramp during site characterization include:

Transportation of Personnel - During construction, the TS South Ramp will provide access for personnel associated with mining and the limited testing activities being performed. Following construction, once the ventilation and muck haulage changeovers are completed, only those personnel involved in inspection/maintenance of south ramp facilities will normally be traveling in that ramp.

Emergency Egress - In the event of an emergency, the south ramp will provide a potential means of emergency egress from the underground facilities. During an emergency, travel up the ramp could be either on foot or via rubber-tired vehicles. The ramp shall have the capability to support the evacuation of all underground personnel to safety within one hour.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the south ramp during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or

alternately, it could be excavated into the side of the ramp.

Transport of Materials - Maintenance and operating supplies must be transported down the ramp to support ramp construction, and testing activities performed during construction. After the completion of ramp construction, only those materials/supplies required for the maintenance of south ramp facilities will normally be transported in that ramp.

Transport of Equipment - Mining and testing equipment used in the south ramp will travel or be transported in that ramp. Some of the mining equipment will travel under its own power while other equipment will be transported as components and assembled underground. The largest piece of equipment to be accommodated in the TS South Ramp is likely to be the tractor/trailer unit transporting the 16 Ft diameter TBM components down to the underground erection chamber located just off the ramp.

Ventilation - During construction of the TS South Ramp, ventilation tubing will be installed to exhaust air from the face area back out to the surface. After the main north-south drifts hole through on both the TS and CH levels, the tubing in the ramp will be removed and flow-through ventilation established. The south ramp will then serve as the ventilation exhaust opening.

Muck Haulage - A conveyor will be installed behind the TBM to transport mined rock to the surface during ramp construction. After the main north-south drifts hole through on both TS and CH levels, the conveyor will be removed from the TS North Ramp and all excavated rock will be transported to the surface via the TS South Ramp. This change can be accomplished concurrent with the changeover to flow-through ventilation.

Accommodation of Support Systems - The TS South Ramp will provide a corridor for components of several underground operations support systems. These items may include power distribution cables, lighting system components, water distribution pipes, water collection pipes, compressed air pipes, and monitoring/warning and communications systems components.

Testing/Test Support Activities - The scope of the testing program in the TS South Ramp is expected to be considerably less than for the north ramp. Definitive information concerning south ramp testing is yet to be developed. Whatever the extent of the test program, the activities and equipment necessary to carry it out must be accommodated.

9.3 CH NORTH RAMP

The CH North Ramp, which starts at an intersection with the TS North Ramp above the TS Level, will be one of two accesses to the CH Level.

The ramp will have no utility with respect to potential repository operations. During the repository operations phase however, the ramp may continue to be used to access test areas on the CH Level.

Functions to be accommodated by the CH North Ramp during site characterization include:

Transportation of Personnel - The CH North Ramp will be the primary access route to the CH horizon. Personnel associated with CH construction and operations activities, or testing/test support activities, will travel in the CH North Ramp. Visitors to the CH Level must also be accommodated. The probable means of transporting personnel along the ramp will be via rubber-tired, diesel powered vehicles. Design considerations with respect to personnel access include:

- Ramp gradient must be suitable for safe vehicular travel
- Roadway width must be adequate to safely accommodate personnel transporters and must provide sufficient clearance to permit vehicles to safely pass people walking in the ramp
- Provision must be made in the ramp for vehicular turn-around
- Air in the ramp should be of suitable quality and temperature to provide a safe and healthy environment for personnel traveling through or working in the area

Emergency Egress - In the event of an-emergency, the CH North Ramp will provide a potential means of emergency egress from the CH Level. During an emergency, travel up the ramp could be either on foot or via rubber-tired vehicles. The ramp shall have the capability to support the evacuation of all personnel on the CH Level to safety within one hour.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the ramp during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or alternately, it could be excavated into the side of the ramp.

Transport of Materials - Maintenance and operating supplies must be transported down the ramp to support construction, operations, testing and test support activities in the ramp or on the CH Level. Some examples of these items are spare equipment parts, ventilation tubing, ground support materials, blasting supplies, fuel, hydraulic oil, pipe,electrical cable, bits and cutters, test supplies, and other items which will be required to construct/operate the CH Level. Also, materials such as trash and unusable parts will need to be transported from the CH Level back up the ramp.

Transport of Equipment - Mining/support and testing/support equipment required on the CH Level will travel via the CH North Ramp. The mining equipment will be assembled on the surface and trammed down the ramp

while other equipment will be transported via rubber-tired vehicles. The largest piece of equipment to be transported in the CH North Ramp is likely to be a roadheader used to mine CH Level exploration drifts.

Underground TBM Assembly and Launching - Preliminary plans are to transport the 16 Ft diameter TBM components down the TS North Ramp to an erection chamber excavated at the upper end of the CH North Ramp. This erection chamber must be sized and equipped to accommodate off-loading and assembly of the TBM components. After being erected, the TBM will be moved into the launch area and begin boring the CH North Ramp.

Ventilation - During construction of the CH North Ramp, ventilation tubing will be installed to exhaust air from the face area back out to the surface. After the main north-south drifts hole through on both the TS and CH levels, the tubing in the ramp will be removed and flow-through ventilation established. Since the north ramp will be used to transport personnel, and will be the primary testing access, it will serve as the ventilation intake opening.

Muck Haulage - A conveyor will be installed behind the TBM to transport mined rock to the surface during ramp construction. After the main north-south drifts hole through on both TS and CH levels, the conveyor will be removed from the CH North Ramp and all excavated rock will be transported to the surface via the CH and TS South Ramps. This change

can be accomplished concurrent with the changeover to flow-through ventilation.

Accommodation of Support Systems - The CH North Ramp will provide a corridor for components of several underground construction and operations support systems. These items may include power distribution cables, lighting system components, water distribution pipes, water collection pipes, compressed air pipes, and monitoring/warning and communications systems components.

Testing/Test Support Activities - Primary among the functions to be accommodated by the CH North Ramp are the testing and test support activities planned for this access. Additionally, the equipment necessary to carry out the testing activities must be accommodated. Reference 6.2 provides the most definitive information currently available regarding the planned test activities.

9.4 CH SOUTH RAMP

The CH South Ramp, which starts at an intersection with the TS South Ramp above the TS Level, will provide a second access to the CH Level. The ramp will have no utility with respect to potential repository operations. During the repository operations phase however, the ramp may continue to be used to support on-going testing activities on the CH

Level.

Functions to be accommodated by the CH South Ramp during site characterization include:

Transportation of Personnel - During CH South Ramp construction, the ramp will provide access to the face for the miners and personnel involved with testing activities being performed in the ramp. Following construction, once the ventilation and muck haulage changeovers are completed, only those personnel involved in the inspection/maintenance of the ramp facilities will normally be traveling in it.

Emergency Egress - In the event of an emergency, the CH South Ramp will provide a potential means of emergency egress from the CH Level. During an emergency, travel up the ramp could be either on foot or via rubber-tired vehicles. The ramp shall have the capability to support the evacuation of all personnel on the CH Level to safety within one hour.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the ramp during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or alternately, it could be excavated into the side of the ramp.

Transport of Materials - Maintenance and operating supplies must be transported down the ramp to support ramp construction and testing activities performed during construction. After the completion of ramp construction, only those materials/supplies required for the maintenance of the CH South Ramp facilities will normally be transported in that ramp.

Transport of Equipment - Only the mining and testing equipment actually used in the CH South Ramp will normally travel or be transported in that ramp. The largest piece of equipment to be transported in the CH South Ramp could be a roadheader used to mine CH Level exploration drifts.

Underground TBM Assembly and Launching - Preliminary plans are to transport the 16 Ft diameter TBM components down the TS South Ramp to an erection chamber excavated at the upper end of the CH South Ramp. This erection chamber must be sized and equipped to accommodate off-loading and assembly of the TBM components. After being erected, the TBM will be moved into the launch area and begin boring the CH South Ramp.

Ventilation - During construction of the CH South Ramp, ventilation tubing will be installed to exhaust air from the face area back out to the surface. After the main north-south drifts hole through on both the TS and CH levels, the tubing in the ramp will be removed and flow-through ventilation established. The CH South Ramp will then serve as

the main ventilation exhaust for the CH Level workings.

Muck Haulage - A conveyor will be installed behind the TBM to transport mined rock to the surface during ramp construction. After the main north-south drifts hole through on both TS and CH levels, the conveyor will be removed from the CH North Ramp and all excavated rock will be transported to the surface via the CH and TS South Ramps. This change can be accomplished concurrent with the changeover to flow-through ventilation.

Accommodation of Support Systems - The CH South Ramp will provide a corridor for components of several underground operations support systems. These items may include power distribution cables, lighting system components, water distribution pipes, water collection pipes, compressed air pipes, and monitoring/warning and communications systems components.

Testing/Test Support Activities - The scope of the testing program in the CH South Ramp is expected to be considerably less than for the north ramp. Definitive information concerning south ramp testing is yet to be developed. Whatever the extent of the test program, the activities and equipment necessary to carry it out must be accommodated.

9.5 OPTIONAL SHAFT

The optional shaft will be constructed during the site characterization phase only if it is required for the acquisition of scientific information about the rock above the Topopah Spring horizon (Reference 6.3). The shaft, if constructed, will also have utility in the potential repository. During repository operations, the shaft would be used for emplacement exhaust ventilation.

Functions to be accommodated by the Optional Shaft during site characterization include:

Transportation of Personnel - During construction, the shaft will provide access for personnel involved with the sinking and testing activities being performed. Following completion of construction, it is expected that the shaft would continue to be used primarily as an access for test personnel working in the shaft.

Transport of Materials - Maintenance and operating supplies must be transported down the shaft to support shaft construction and testing activities performed during construction. After the completion of shaft construction, only those materials/supplies required for shaft maintenance or to support testing activities will be transported in the shaft.

Transport of Equipment - The only equipment likely to be transported in the shaft is that required to support shaft construction and testing activities.

Ventilation - Since the shaft construction method is yet to be determined, the specific means of ventilation is not known. Whatever shaft sinking method is employed, ventilation is a basic function which must be accommodated.

Muck Haulage - The muck haulage function in the shaft will apply only during shaft construction. Muck transport will most likely be accomplished with a muck bucket and hoisting system. However, if the sinking method employs a pilot shaft, then the muck will fall down the hole and be transported from the shaft bottom to the surface via the muck ramp.

Accommodation of Support Systems - Only those systems necessary to support the mining and testing activities in the shaft will be located therein.

Testing/Test Support Activities and Equipment - Definitive information concerning testing in the shaft is yet to be developed. Whatever the extent of the test program, the activities and equipment necessary to

carry it out must be accommodated.

9.6 TS LEVEL MAIN TEST AREA

The TS Level Main Test Area will be located in the northeast corner of the potential repository block. The area will be dedicated to site characterization testing activities but will also have utility in the potential repository. During repository operations, the area would provide space for a training area for waste emplacement activities and for emergency and mine rescue activities.

Functions to be accommodated by the TS Level Main Test Area during site characterization include:

Transportation of Personnel - The Main Test Area must accommodate the transportation of personnel within the area. Personnel associated with mining/support and testing/test support activities will travel in the Main Test Area. In addition, visitors must be accommodated. The probable means of transporting personnel within the area will be via rubber-tired vehicles.

Emergency Refuge - A permanent emergency refuge area will be provided in the TS Main Test Area. The refuge area should accommodate the maximum number of personnel expected to be underground.

Transport of Materials - Maintenance and operating supplies must be transported in the Main Test Area to support construction, operations, testing and test support activities. Some examples of these items are spare equipment parts, ventilation tubing, ground support materials, blasting supplies, fuel, hydraulic oil, pipe, electrical cable, bits and cutters, and test supplies.

Transport of Equipment - Mining/mining support and testing/test support equipment will travel in or be transported through the Main Test Area. Some of the mining equipment will travel under its own power while other equipment will be transported via rubber-tired vehicles. The largest piece of equipment to be accommodated in the Main Test Area is likely to be the mobile miner used for development mining in the area.

Ventilation - Ventilation quantities necessary to support development mining and concurrent testing activities must be provided in the Main Test Area. A definitive ventilation scheme will be prepared based on the Main Test Area layout which is yet to be developed.

Muck Haulage - A muck transport system to support development mining in the Main Test Area must be provided. System design will be based on the Main Test Area layout which is yet to be developed.

Accommodation of Operations Support Areas - The TS Level Main Test Area development must provide space for maintenance shops, offices, parts/supplies storage, and a fueling area.

Accommodation of Support Systems - Several underground construction and operations support systems must be accommodated in the TS Level Main Test Area. Components of the power distribution, lighting, water distribution, water collection, compressed air, monitoring/warning, and communications systems are included in this group.

Testing/Test Support Activities - Primary among the functions to be accommodated in the Main Test Area are the testing and test support activities planned for this area. Additionally, the equipment necessary to carry out the testing activities must be accommodated. The most definitive information currently available regarding the planned test activities is provided in Reference 6.2.

9.7 TS LEVEL EXPLORATORY DRIFTS

The TS Level exploratory drifts, as currently envisioned, will consist of a main north-south trending drift along the long axis of the potential repository block and three east-west trending laterals driven at right angles to the north-south drift. These drifts will be driven to explore the potential emplacement horizon, including characterization

of the Imbricate and Ghost Dance Faults, but will also have utility in the potential repository. During repository operations, the north-south drift would become a repository main entry and the east-west drift would be integrated into the emplacement rooms, but would not be used to store waste.

Functions to be accommodated by the TS Level exploratory drifts during site characterization include:

Transportation of Personnel - The exploratory drifts must accommodate the transportation of personnel. Personnel involved with mining/support and testing/support activities will use the drifts as travelways. In addition, visitors must be accommodated. The probable means of transporting personnel within the area will be via rubber-tired vehicles.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the TS north-south drift during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or alternately, it could be excavated into the side of the drift.

Transport of Materials - Maintenance and operating supplies must be transported in the exploratory drifts to support construction, operations, testing and test support activities. Some examples of these

items are spare equipment parts, ventilation tubing, ground support materials, blasting supplies, fuel, hydraulic oil, pipe, electrical cable, bits and cutters, and test supplies.

Transport of Equipment - Mining/mining support and testing/test support equipment will travel in or be transported through the exploratory drifts. Some of the mining equipment will travel under its own power while other equipment will be transported via rubber-tired vehicles. The largest piece of equipment to be accommodated in the TS Level exploratory drifts is likely to be the mobile miner used for drift development.

Ventilation - Ventilation quantities necessary to support development mining and concurrent testing activities must be provided in the exploratory drifts. Exhaust tubing will be used in the north-south drift until flow-through ventilation can be established. The lateral drifts will be ventilated using tubing and auxiliary fans.

Muck Haulage - A muck transport system to support development mining in the exploratory drifts must be provided. The system could employ conveyors in the north-south drift and longer lateral drifts. Short lateral drifts could use rubber-tired equipment hauling muck to a conveyor loading point.

Accommodation of Support Systems - Several underground construction and operations support systems must be accommodated in the exploratory drifts. Components of the power distribution, lighting, water distribution, water collection, compressed air, monitoring/warning, and communications systems are included in this group.

Testing/Test Support Activities - Primary among the functions to be accommodated in the exploratory drifts are the testing and test support activities planned for this area. Definitive information concerning testing in the exploratory drifts is yet to be developed. Whatever the extent of the test program, the activities and equipment necessary to carry it out must be accommodated.

9.8 CH LEVEL EXPLORATORY DRIFTS

The CH Level exploratory drifts, as currently envisioned, will consist of a main north-south trending drift parallel to the long axis of the potential repository block and four east-west trending laterals driven off the north-south drift. These drifts will be used to explore and characterize the non-welded tuffs which underlay the potential emplacement area. The drifts will have no utility with respect to potential repository operations. During the repository operations phase however, the drifts may continue to be used to support on-going testing activities on the CH Level.

Functions to be accommodated by the CH Level exploratory drifts during site characterization include:

Transportation of Personnel - The exploratory drifts must accommodate the transportation of personnel. Personnel involved with mining/support and testing/support activities will use the drifts as travelways. In addition, visitors must be accommodated. The probable means of transporting personnel within the area will be via rubber-tired vehicles.

Emergency Refuge - It is likely that an emergency refuge area will be provided in the CH north-south drift during construction. This may be a portable refuge chamber pulled along behind the tunnel boring machine (TBM), or alternately, it could be excavated into the side of the drift. A permanent refuge area, capable of accommodating the maximum number of people working on the CH Level, may be provided after development is complete.

Transport of Materials - Maintenance and operating supplies must be transported in the exploratory drifts to support construction, operations, testing and test support activities. Some examples of these items are spare equipment parts, ventilation tubing, ground support materials, blasting supplies, fuel, hydraulic oil, pipe, electrical cable, bits and cutters, and test supplies.

Transport of Equipment - Mining/mining support and testing/test support equipment will travel in or be transported through the exploratory drifts. Some of the mining equipment will travel under its own power while other equipment will be transported via rubber-tired vehicles. The largest piece of equipment to be accommodated in the CH Level exploratory drifts is likely to be the roadheader used for drift development.

Ventilation - Ventilation quantities necessary to support development mining and concurrent testing activities must be provided in the exploratory drifts. Exhaust tubing will be used in the north-south drift until flow-through ventilation can be established. The lateral drifts will be ventilated using tubing and auxiliary fans.

Muck Haulage - A muck transport system to support development mining in the exploratory drifts must be provided. The system could employ conveyors in the north-south drift and longer lateral drifts. Short lateral drifts could use rubber-tired equipment hauling muck to a conveyor loading point.

Accommodation of Support Systems - Several underground construction and operations support systems must be accommodated in the exploratory drifts. Components of the power distribution, lighting, water

distribution, water collection, compressed air, monitoring/warning, and communications systems are included in this group.

Testing/Test Support Activities - Primary among the functions to be accommodated in the exploratory drifts are the testing and test support activities planned for this area. Definitive information concerning testing in the exploratory drifts is yet to be developed. Whatever the extent of the test program, the activities and equipment necessary to carry it out must be accommodated.

10.0 CONCLUSIONS

This preliminary analysis has identified the basic functions to be accommodated by the underground excavations that comprise the ESF. It is apparent that many of the functional requirements are common to several different areas of the ESF. Table 1 summarizes the permanent ESF functions of the eight areas discussed above.

TABLE 1
PERMANENT FUNCTIONS OF ESF AREAS

ESF FUNCTIONS \ ESF AREAS	TS NORTH RAMP	TS SOUTH RAMP	CH NORTH RAMP	CH SOUTH RAMP	OPTIONAL SHAFT	TS MAIN TEST AREA	TS EXPL. DRIFTS	CH EXPL. DRIFTS
PRIMARY ACCESS FOR PERSONNEL	X		X					
EMERGENCY EGRESS TO SURFACE	X	X	X	X				
EMERGENCY REFUGE						X		X
PRIMARY SUPPLY CORRIDOR	X		X				X	X
PRIMARY EQUIPMENT TRANSPORT ROUTE	X		X				X	X
MAIN VENTILATION INTAKE ACCESS	X		X					
MAIN VENTILATION EXHAUST ACCESS		X		X				
MUCK HAULAGE ACCESS		X		X				
UTILITIES CORRIDOR	X	X	X	X		X	X	X
OPERATIONS SUPPORT						X		
PRIMARY TESTING	X		X		X	X	X	X
REDUCED SCOPE TESTING		X		X				

ESF PRELIMINARY EXCAVATION PLAN

ST-MN-020

REVISION 3

AUGUST, 1991

RAYTHEON SERVICES NEVADA

Raytheon Services Nevada	DESIGN ANALYSIS Number: ST-MN-020 Rev: 3 Page 1 of 24

WBS No. 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	M. J. Esp	Mark J. Esp	SR. MINING ENG.	8/19/91
CHECKER:	W. R. Kennedy	W R Kennedy	SR MINING ENGR	8/20/91
APPROVAL - LDE:	B. T. Stanley	Bruce T. Stanley	Lead Mining Eng.	8/20/91
APPROVAL - SCDM:	B. R. Chytrowski	B.R. Chytrowski	SCDM	8/20/91
QA CONCURRENCE:	P. B. Hale	Paul B Hale	Sr QA Specialist	8-20-9

SUBJECT: ESF Accesses

TITLE: ESF Preliminary Excavation Plan

QAG Reference: RSN-GR-013, Rev. 0

ESF PRELIMINARY EXCAVATION PLAN

1.0 PURPOSE

The purpose of this report is to define, communicate and document a generalized scope of work for the underground mining construction and development of the YMP Exploratory Studies Facility (ESF).

The purpose of ST-MN-020, Rev. 1, was to incorporate and satisfy comments generated during the Management Review of June, 1991.

The purpose of ST-MN-020, Rev. 2, was to incorporate and satisfy comments generated during the subsequent Technical Review (also in June, 1991). Nomenclature was also changed for uniformity based on the RSN letter IC-1552, dated 6-10-91, Calovini to YMP personnel. Construction sequence concepts were modified to reflect more current thinking based on the second deliverable package (July 31, 1991) and new vendor information.

The purpose of ST-MN-020, Rev. 3, is to incorporate and satisfy a comment generated during a second Technical Review held on August 12, 1991.

2.0 METHOD

The method used in this report consists of a generalized collection of ideas relating to the following major topics:

A.) Construction and Construction Sequencing

B.) Equipment

C.) Muck Haulage

D.) Ventilation

The ideas presented in this report are conceptual in nature and may be subject to refinement as Title II proceeds.

3.0 DESIGN INPUTS

ESFDR - (YMP/CC-0013, REV. 5-31-91).

1.2.6.5.FR1. (Used throughout the report.)
1.2.6.6.FR1. (Used throughout the report.)
1.2.6.0.PC1h. (Page 8 of 24)
1.2.6.5.PC1a.i. (Pages 6, 14 of 24)
1.2.6.5.PC1c.iii. (Pages 9, 10, 23, 24 of 24)
1.2.6.5.PC1d.viii. (Pages 7, 10, 11, 12, 14, 17 of 24)
1.2.6.5.PC1f.i. (Pages 9, 23 of 24)
1.2.6.5.PC1f.iv. (Pages 7, 12, 14, 15, 16, 19, 20, 21 of 24)
1.2.6.5.PC2a.ii.a. (Page 7 of 24)
1.2.6.5.PC2h. (Page 10 of 24)
1.2.6.5.PC2i.iv. (Used throughout the report.)
1.2.6.6.PC1a.iii. (Used throughout the report.)
1.2.6.6.PC1a.iv. (Used throughout the report.)
1.2.6.6.PC1i.iii. (Pages 8, 9, 15 of 24)
1.2.6.6.PC2j.v. (Used throughout the report.)
APPENDIX A.1.1a. (Pages 6, 14, 17 of 24)
APPENDIX A.1.1b. (Page 24 of 24)
APPENDIX B. (Pages 9, 10, 11, 23 of 24)

4.0 CODES AND STANDARDS

No local codes or standards apply to this conceptual plan and schedule. The actual design, construction, and operation of the ESF will, however, comply with the following federal regulations:

10 CFR 60, "DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES," revised as of January 1, 1988.

10 CFR 960, "GENERAL GUIDELINES FOR THE RECOMMENDATION OF SITES FOR THE NUCLEAR WASTE REPOSITORIES," revised as of January 1, 1988.

30 CFR 57, "SAFETY AND HEALTH STANDARDS - UNDERGROUND METAL AND NONMETAL MINES," revised as of July 1, 1988.

5.0 REFERENCE MATERIAL

A.) ENGINEERING PLAN FOR THE DESIGN STUDY NEEDED FOR THE REVISION OF TITLE I DESIGN STUDY REPORT, Raytheon Services Nevada, Revision 2, May 1991.

B.) ESF ALTERNATIVES STUDY - OPTION 30, (FSN-AS-430, REV. 2, Alternatives Study, Option # B7, Scenario 2.)

C.) RECORD OF VERBAL COMMUNICATION, From Richard L. Coppage, RSN., 4/25/91, Subject: USBR - RSN Meeting Re: Ramp Mapping

D.) RECORD OF VERBAL COMMUNICATION, From Bruce Stanley To Nick Tamondong, 4/9/91, Subject: Layout Of Waste Ramp & Calico Hills Access Ramp.

E.) YUCCA MOUNTAIN PROJECT - REFERENCE REPOSITORY COORDINATES, CLTR88-PB07, Prepared by M. Fowler, Parsons Brinckerhoff Quade & Douglas, Inc., January 1990, Prepared For Sandia National Laboratories.

F.) RECORD OF VERBAL COMMUNICATION, From Mark Esp to Romeo Jurani, RSN, 5/13/91, Subject: Preliminary Transportation and Ventilation Plans for ESF Construction.

G.) FINDINGS OF THE ESF ALTERNATIVE STUDY, SAND90-3232, Prepared by Sandia National Laboratories, Printed March, 1991.

H.) REFERENCE INFORMATION BASE, YMP/CC-0002, Version 4, Revision 4, Chapter 1, Section 2, Item 5, Page 3 of 4, 8/06/90, CR38.

I.) EXCAVATOR PERFORMANCE PREDICTIONS USING EXISTING DATABASES, SAND-SLTR90-7003, Earth Mechanics Institute - Colorado School Of Mines, 1/31/91.

J.) ESF TEST PLANNING PACKAGE 91-5 PRELIMINARY ESF TEST PLANNING PACKAGE FOR SUPPORT OF PRE-TITLE II DESIGN STUDIES, Los Alamos National Laboratory, 5/07/91.

K.) Authorization for Conducting A Design Study to Develop a Reference Exploratory Shaft Facility (ESF) Design To Be Used As Input To Title I Design Summary Report (WBS 1.2.6), Gertz (YMPO) to Bullock (RSN), stamped 2/22/91, EDD:EHP-2080.

L.) ESF GENERAL ARRANGEMENT, Subsurface Access General Arrangement - Plan, Drawing #YMP-Q25-1-MING-MI01, Rev. C.

M.) ESF NOMENCLATURE UNIFORMITY, Calovini (RSN) to YMP personnel, 6/10/91, IC-1552.

N.) Letter from Nick Tamondong (RSN) to Jim Grenia (PBQD), 7/23/91, IC-1625, Subject: Size of CH North/South Ramp and Main Drift.

O.) LONG AIRDOX CONTINUOUS TUNNELING CONVEYOR SYSTEM, General Vendor Information Brochures and System Description, Supplied by Steve Brown, (Long Airdox Co.) to Dick Coppage (RSN), 4/8/91.

6.0 ASSUMPTIONS

A.) Two 25′ diameter Tunnel Boring Machines (TBM's) will be used to drive the north/south drift on the Topopah Spring (TS) Level and two 18′ diameter TBM's will be used to drive the north/south drift on the Calico Hills (CH) Level. This assumption is based on the ESF Alternative Study - Option 30 (enhanced), which specifies the concept of drifting with TBM's towards the center of the repository block until a connection is made. (Used throughout the report.) This assumption will have to be verified as the design proceeds.

B.) TBM will be moved to the initial cutting face via rail dollies. (p. 7 of 24) This transport concept will be detailed as the design matures.

C.) Ground Control will be manageable through fault zones provided proper ground control techniques are practiced. These techniques are conceptual at this time and will be verified as the design proceeds. (pp. 13, 15, 18 of 24)

D.) It is assumed that all inputs will be included in the completed Basis for Design (BFD).

7.0 COMPUTER PROGRAMS USED

Not Applicable.

8.0 UNITS

English Standard Units.

9.0 ANALYSIS INTRODUCTION

As per the introduction of the ESFDR, the primary direction for the Yucca Mountain Exploratory Studies Facility is as follows:

A.) "All ESF workings will be restricted to the unsaturated zone. The candidate host rock will be a section of the welded interior of the Topopah Spring Member of the Paintbrush Tuff. The design of the ESF will consider the need to obtain significant and unique information about site properties during underground ramp construction."

B.) "The ESF will be constructed with the necessary and adequate facilities and so that the ESF testing will focus on the information necessary to support the site characterization program and license application."

C.) "Construction of the ESF will provide access for detailed studies of the potential host rock as well as the overlying and underlying geologic strata."

The Nuclear Regulatory Commission has also expressed three major concerns regarding the acceptability of the potential Exploratory Studies Facility. These concerns are also listed in the ESFDR Introduction and state:

A.) "The ESF design, construction, and operations should not compromise the ability of the site to isolate waste."

B.) "The ESF design, construction, and operations should not compromise the ability to characterize the site."

C.) "The ESF design, construction, and operations should provide representative data."

Given these parameters, Raytheon Services Nevada has developed the following ESF preliminary excavation plan:

9.1 SITE PREPARATION

9.1.1 Surface Facilities

The sequence of construction for the Exploratory Studies Facility (ESF) will conceptually start with the construction of roads to two different portal sites - the TS North Portal site and the TS South Portal site. Needed utility lines such as power and water will be routed from existing locations to both portal sites concurrent with road construction. After access to both portal sites has been achieved, site preparation activities will commence. These activities will include pad construction, site leveling, grading, drainage, and surfacing to facilitate the actual portal construction. Support buildings such as office space, equipment shops, storage space, primer/powder magazines, compressor facilities, electrical substations, etc. will have to be constructed after initial site preparation. Additionally, access roads and site preparation for the ESF muck disposal site will need to be developed at this time. Construction of the overland conveyor can proceed after route access has been gained. After pad construction has been completed, and concurrent to the construction of support facilities, portal highwall excavation and ground support activities will commence.

9.1.2 Portal Construction

It should be noted at this point that the initial emphasis on construction shall be put on the TS north portal site. As per the ESFDR, Appendix A.1, the test area on the Main Test Level (TS Main Drift) is to be located in the northeastern part of the proposed repository block. Emphasizing north portal site construction will allow quicker access to this test area. Construction of the south portal site will follow as soon as practical to allow both the TS north and south ramps to progress toward a common meeting point on the Topopah Spring (TS) horizon. (Refer to Fig. 3, pg. 50, - RSN Engineering Design Schedule, RSN - Engineering Plan, May 1991).

Actual portal construction at both sites will commence after a stable portal highwall has been provided. Controlled drill and blast methods in conjunction with necessary ground support will be used to initially gain access to the underground environment. The dimension of the portal should allow for the later transport of a fully assembled 25 ft. diameter Tunnel Boring Machine (TBM) through it. The preliminary concept for portal ground support includes rectangular steel sets and lagging. As stable ground conditions are encountered, the use of steel sets and lagging will not be necessary and will be replaced with more conventionally supported techniques. This development will continue until the tunnel is of adequate length to launch the TBM. The TBM launching facility will consist of a chamber with concrete walls to provide a smooth initial surface for the TBM to grip against.

Preliminary plans call for the two 25′ diameter Tunnel Boring Machines being used on the TS north and south ramps to be delivered and erected on the portal pads concurrent to portal construction. This approach will avoid unnecessary delays between the time of portal completion and the TBM's start-up.

A concrete floor with embedded rail from the portal pad to the launching chamber is planned at this time. This type of floor facilitates the transportation of each TBM to its respective launching chamber after erection. As the design matures and better data becomes available, a detailed design will be developed.

It is assumed that the TBM's will be transported to their respective launch chambers via rail transport dollies as soon as construction work on the portal has been completed. After the TBM is at the face, the necessary utility installation will be completed between the portal pad and the TBM. Pre-TBM start-up activities include; compressed air and water line installation, power cable and switchgear installation, conveyor installation from the TBM discharge to the overland conveyor, communications, installation of ventilation fans and

duct, etc. At this time, the transport dollies will be removed and the TBM readied for use.

9.2 ACCESS RAMP EXCAVATION

9.2.1 Ventilation System & Constraints

The general concept developed in Option 30 (enhanced) of the ESF Alternative Study provides a basis for the assumption that two 25′ diameter TBM's will be used to excavate separate declined ramps down to the Topopah Spring horizon. These TBM's will then drift from the bottom of both ramps towards the center of the proposed repository block on the TS Main Drift until a connection or breakthrough is achieved. This breakthrough is a major construction milestone as flow-through ventilation and a secondary means of emergency egress will then be possible. Flow-through ventilation will be supplied by large exhaust fans and an air-lock structure located near the TS South Portal. After flow-through ventilation is established, sufficient ventilation for several active headings will be available. Prior to the north/south ESF connection, ventilation will be provided by means of a ventilation duct and booster fan network exhausting air from each active workface to the surface. In this scenario, only enough ventilation will be available for each TBM drive and one other active heading per TBM drive. (Ref. #5.0.F.).

9.2.2 Refuge Chambers

As per 30 CFR 57.11050, refuge shall be provided for every employee who cannot reach the surface from his workplace through at least two separate escapeways within a time limit of one hour. This constraint will apply until a breakthrough is achieved to provide a secondary means of emergency egress. A portable refuge chamber pulled along with each TBM will satisfy this requirement. This chamber could be part of the permanent trailing deck of the TBM. This chamber would be stocked with emergency tools, first aid equipment, water/food, self-contained breathing apparatus′, and emergency oxygen supplies. If this system is not sufficient, excavated refuge chambers will be provided.

In this case, delays to TBM operations will result while a refuge is constructed. The design of these chambers will be developed later in the design (Title II).

9.2.3 Grade & Curve Constraints - TS Ramps

The TBM's will begin boring the ramps with the TS north ramp preliminarily expected to start prior to the TS south ramp by a short period. For the purpose of conceptual design, the maximum allowable grades for straight sections of the ramps will be 10%. The maximum allowable grade for curved sections of the ramp will be 6%. Horizontal curves in the TS ramps will be limited to a minimum radius of 600 feet. (See Ref. #5.0.C.).

9.2.4 TBM Muck Haulage

Both ramps will tentatively employ conveyor muck haulage methods following behind the TBM's. At this time, it is envisioned that a short transfer conveyor will feed an advancing permanent conveyor system at the same rate the TBM advances. (See Ref. #5.0.0.). When the advancing conveyor reaches its limit (i.e., runs out of belt storage), tunneling activities will be temporarily suspended while new belt is added to the system. Ideally, this activity would be accomplished during a maintenance or other non-cutting shift on a scheduled basis to match the advance rates of the TBM.

9.2.5 Geologic Mapping

A clear area or "window" between the trailing gear of the TBM and the permanent ventilation duct, utilities, and roadbed will be provided to facilitate mapping. This "window" will contain the conveyor system and necessary utility lines arranged to maximize the tunnel periphery surface available for detailed mapping. A portable mapping platform will be provided in this area to allow mapping personnel access to the tunnel walls. (See Ref. #5.0.C.). Permanent utility and hardware installations such as vent duct, additional piping and power cables, IDS instrumentation, etc., will follow along behind this "window" as the TBM advances. One advantage this "window" provides is the early identification of alcove locations that will be used for testing purposes.

9.2.6 Ground Support

Initial ground support, such as rockbolting will be started immediately, (as required), after the ground is exposed behind the cutterhead shield. An area between the TBM and the trailing decks will also be used as an additional rockbolting area. Every attempt will be made to delay further ground support that may obstruct mapping functions (such as wire mesh, shotcrete, mats, or steel sets and lagging) until mapping is finished. However, proper ground support will be installed prior to mapping if a serious safety hazard exists (i.e., to prevent the potential for deleterious rock movement). (See Ref. #5.0.C.).

9.2.7 Alcove Construction

The preliminary information received from Los Alamos National Laboratory indicates that the majority of alcove construction and testing in the ramps is to be conducted on a non-interference basis with respect to TBM operations. (See Ref. #5.0.J.). Ventilation constraints and forward exploratory drifting considerations will dictate that flow-through ventilation be established before many of the test alcoves can be excavated. However, if tests considered necessary for site characterization are on the critical path to license application, these high priority alcoves will be excavated prior to the establishment of flow-through ventilation.

Delays to TBM operations can be minimized by alcove construction in the relatively clear area or "window" between the TBM and the permanent utilities. Once one of these alcove locations has been established through geologic mapping, the TBM will be shut down and controlled drilling and blasting or other appropriate excavation means will begin in this area after it is cleared of all utilities. Blasting mats and/or other procedures will be used to protect the TBM, the temporary facilities, and the permanent installations from damage. Load-Haul-Dumps (LHD's) will be used for mucking operations to load either trucks or a conveyor loading facility. (Please note that mechanical excavation means will be used where feasible and practical; excavation methods for each individual alcove will ~~be~~ determined in Title II.) After the alcoves are finished, or at

least advanced in a reasonable distance, the TBM can proceed and utility installation can resume past the alcove. The advantage of locating the alcove construction in the mapping "window" is that some of the permanent arrangements will not have to be dismantled to facilitate drilling and blasting (or other excavation means) because permanent utilities will be lagging some distance behind this work.

At this point in time, it appears that two of the testing activities which specifically require alcove construction may delay TBM operations for alcove construction. These two tests are: (1) the Excavation Effects Test, and (2) the Hydrologic Properties of Major Faults test. Two other tests that might potentially impact TBM operations but do not require specific alcoves are: (1) the Seismic Topography/Vertical Seismic Profiling test, and (2) the Perched Water test. (See Ref. #5.0.J.).

9.2.8 TS/CH Intersection Excavations

Section 6.6.PCla.iv. of the ESFDR along with the ESF Alternatives Study, FSN-AS-430, Rev. 2, Option #B7, Scenario 2, call for internal ramp access to the Calico Hills level for further ESF testing purposes. These accesses are to be given high priority because they are on the critical path to early exploration of the expected fault crossings in the Calico Hills horizon. (See Ref. #5.0.G.) The preliminary plan calls for two 18′ diameter tunnel-bored accesses to the Calico Hills level, one will be launched from the Topopah Spring north ramp and the other from the Topopah Spring south ramp. Excavation of these intersections will be completed prior to establishing flow-through ventilation because of the high priority given to the exploration of the planned fault crossings in the Calico Hills horizon. (See Ref. #5.0.G.).

The 25′ diameter Topopah Spring TBM's will stop after they have passed by the planned locations for the TS/CH intersections. Any utilities or hardware that interferes with the excavation of these intersections will be temporarily relocated to accommodate the excavation process. It is planned to excavate these

intersections using controlled drill and blast techniques due to the ease of mobilization, and the flexibility of a conventional system. Adjacent to each intersection will be an erection area for the assembly of the 18′ diameter Calico Hills TBM's as well as a launching facility for the mobilization of the Calico Hills TBM's. As the excavation proceeds in the erection chamber, and enough clearance is gained between the active face and the Topopah Spring ramp, the utilities and hardware can be re-installed along the Topopah Spring ramps so that the 25′ diameter TBM drives can continue.

Upon completion of the excavation and construction of the launching facilities, the 25′ diameter Topopah Spring TBM's may have to be temporarily stopped again to allow for the transport of the 18′ diameter Calico Hills TBM's to their respective erection chambers. These 18′ diameter TBM's will be taken down the 25′ diameter north and south access ramps in pieces and then assembled in the chamber provided. After transport and during assembly of the 18′ diameter TBM's, the 25′ diameter Topopah Spring TBM's can resume development on the Topopah Spring level. New utility tie-ins required for the Calico Hills TBM drives such as air, water, power, ventilation, and conveyors will be installed in the intersection behind the 18′ diameter TBM's, as required, on scheduled non-cutting shifts to avoid delaying the Topopah Spring TBM drives. The 18′ diameter Calico Hills TBM's will then be launched from a chamber adjacent to the TS/CH intersection on both the north and the south ramps.

9.2.9 Excavation Parameter Summary for Four TBM's

It is assumed at this point that four separate TBM's will be operating at the same time. Two 25′ diameter TBM's will be heading for a common intersection point on the Topopah Spring Level, and two 18′ diameter TBM's will be heading for a common intersection point on the Calico Hills Level. (See Ref. #5.0.B.).

As the 25′ diameter machines near the Topopah Spring test horizon, the two TBM's will be turned to drive the Topopah Spring north/south drift (TS Main Drift) from opposite directions. As previously stated, the grade through these

curves will be reduced to a maximum of 6% to enhance access safety. The minimum horizontal curve radius planned for the Topopah Spring Level TBM drives will be 600 feet. The point at which the north/south drift alignment becomes common to both machines is the point at which the ramps enter the proposed repository block. (See Ref. #5.0.D.) The Topopah Spring North Ramp is planned to enter the proposed repository block at an invert elevation of 3100.0 ft. above sea level. The expected coordinates of the entry point are N767,500.0, E564,053.0. (See Ref. #5.0.E., page 3-5). The coordinates and elevation of the southern end of the TS Main Drift are currently unknown but will be determined in an ongoing calculation. It is expected that the TS North Ramp TBM will breach the Drill Hole Wash Fault in the area that the TS North Ramp curves horizontally prior to entering the proposed repository block on the north end. (See Ref. #5.0.B.). Ground conditions through this fault are assumed to be manageable with proper ground control techniques.

The preliminary plan for the two 18′ diameter Calico Hills TBM's is for each machine to enter a decline after they are launched from the TS north and south ramps respectively. These declines will progress downward and curve around to a common north/south drift alignment on the CH Level, just as the Topopah Spring TBM's have done. The Calico Hills declines will also have a maximum straight ramp grade of 10% and a maximum curved ramp grade of 6% to enhance access safety. The minimum radius for horizontal curves on these ramps has been planned at 300 feet. The Calico Hills North Access entry point will conceptually enter the proposed repository block outline directly under the Topopah Spring level entry point at an invert elevation of 2702.0 ft. above sea level. (See Ref. #5.0.D. & #5.0.B.). The coordinates and elevation of the Calico Hills South Access entry point are currently unknown but will be determined in an ongoing calculation.

9.3 TOPOPAH SPRING LEVEL

9.3.1 TS Main Drift Construction Activities

The general concept on both the Topopah Spring level and the Calico Hills level is to drift from the bottom of both ramps towards the center of the proposed repository block with TBM's until a connection is made. (See Ref. #5.0.B.). As the 25' diameter TBM's begin their final drive toward each other on the Topopah Spring level, preliminary plans include access to a Main Test Area in the northeastern part of the repository block. (Appendix A.1, ESFDR, Rev. 5/31/91). The primary lateral access to the Main Test Area also serves as an access to intercept and explore the expected Imbricate Fault Zone on the Topopah Spring level. East and west exploratory laterals are also planned near the center of the repository block on the Topopah Spring level. The eastern exploratory lateral is to intercept the Ghost Dance Fault and eastern repository boundary. The western lateral will explore that side of the proposed repository block, including any north/south trending structures which may be present in that area. (See Ref. #5.0.B.).

9.3.2 TS Imbricate Drift/Main Test Area

The current concept for the initial excavation of the TS Imbricate Drift is to stop the TS North Ramp TBM after it passes the Main Test Area intersection location and start the drive. The intersection will be located inside the "window" provided for the mappers. Utilities and other hardware that interferes with intersection construction will be temporarily relocated. The current excavation plan is to use controlled drill and blast procedures for the initial TS Imbricate drift excavation. As sufficient clearance is gained, TS Main Drift utilities will be reinstalled to allow the TS North Ramp TBM to resume boring towards a breakthrough with the TS South Ramp TBM. Upon completion of controlled drill and blast activities, a Mobile Miner with disc cutters will be transported from the surface to the intersection location and will begin development for the sequential drift mining and heated rooms test. (Current thinking suggests that this development will be done prior to developing the TS Imbricate Drift with

an 18′ diameter TBM. The development strategy in the Main Test Area is preliminary and ongoing, and will be detailed in full in Title II.) A transfer conveyor system or possibly LHD transport to a transfer conveyor will be used for muck haulage in the Main Test Area. (See Ref. #5.0.F.).

It should be noted again that prior to north/south ESF connection, only enough ventilation will be provided for each TBM drive and one other small heading per TBM drive. (Ref. #5.0.F.). It is consistent with the preliminary ventilation plan for one excavator to be working in the Main Test Area/Imbricate Drift heading while the North Ramp TBM is still operating. If other excavations are needed concurrent to TBM operations, such as a refuge chamber, adequate ventilation will only be supplied for the TBM and that one priority heading.

At this point in the development, five headings will be active; the TS North Ramp TBM heading for an intersection with the TS South Ramp TBM, the CH North Ramp TBM heading for an intersection with the CH South Ramp TBM, and a Mobile Miner in the Main Test Area/Imbricate Drift. Both 25′ diameter Topopah Spring TBM's should be beginning their final drive toward an intersection. It is perceived that the 18′ diameter Calico Hills TBM's will still be excavating their respective declines down to the Calico Hills horizon.

9.3.3 TS Main Drift Breakthrough

The TS North Ramp TBM should breach the Ghost Dance fault prior to intersecting the TS South Ramp TBM. It is assumed that ground control will be manageable through this fault zone provided proper ground support techniques are followed. As the breakthrough point between the TS North Ramp TBM and the TS South Ramp TBM is neared, both of the machines will stop in preparation for the final breakthrough.

Only one machine will actually excavate the breakthrough. The inactive machine will be dismantled into smaller pieces for transport to the surface or storage underground. Drilling a small diameter hole between the two tunnels will

provide final survey alignment information to allow the best possible alignment at the breakthrough point. After all alignment considerations are taken into account, the remaining machine will start advancing again until a breakthrough is achieved.

After breakthrough, the remaining machine will be demobilized. Care will be taken in the design of these machines to provide for dismantling them into components that can be readily removed through the existing tunnel profile. The components of the 25′ diameter TBM′s will then be transported to the surface via LHD′s, trucks, or specially designed carriers. (Alternately, one or both of the machines could be stored underground).

9.3.4 TS Main Drift Flow-Through Ventilation

Prior to the breakthrough, the primary exhaust fans and an airlock structure will be installed at the South Portal site. After both TBM′s have been dismantled enough to allow adequate ventilation flow-through, these primary exhaust fans will replace the temporary ventilation system of fan duct and multiple booster fans. The air will then flow on a negative pressure system through the Topopah Spring level from the north portal to the south portal. (Ref. #5.0.F.). The vent duct and fans will be left in place for the forced ventilation of ongoing development. (Ref. #5.0.F.). Ventilation tubing in the TS Main Drift may be permanently needed to exhaust air from the Main Test Area to the TS South Ramp.

At this point in the development, it is perceived that the two Calico Hills TBM′s will be nearing the Calico Hills test horizon or possibly already in the Calico Hills test horizon, heading for a common intersection point. (It should be emphasized here that the exploration of the planned fault crossings in the Calico Hills horizon is still top priority, but the CH TBM′s will not have advanced far enough to provide access to these locations yet). A Mobile Miner will still be advancing in the Main Test Area.

9.3.5 TS East and TS West Drift Excavation

After the 25′ diameter TBM's have been removed, and the flow-through ventilation system is in place on the Topopah Spring level, a second Mobile Miner will be transported to the location of the east and west exploratory laterals near the center of the TS Main Drift. Utilities that interfere with the excavation of the exploratory lateral development will be temporarily relocated. Since these exploratory laterals are in close proximity to one another, both intersections will be excavated with the Mobile Miner before re-installing the TS Main Drift utilities and utility transfer points into both development areas. (If it is impossible to maneuver the Mobile Miner into position to excavate the intersection mechanically, controlled drill and blast methods will be used for this initial excavation).

After the necessary utilities and hardware are re-installed, the second Mobile Miner will begin excavating the eastern exploratory lateral, (TS East Drift), prior to the western one, (TS West Drift), so that access can be gained to the expected crossing of the Ghost Dance fault and eastern repository boundary first. A separate transfer conveyor or possibly LHD transport to a conveyor loading facility is planned for muck removal. (See Ref. #5.0.F.).

Upon completion of the Main Test Area's access drifts for the sequential mining test, that Mobile Miner can be transported to the TS West Drift near the center of the proposed repository block to excavate to the western repository boundary. Again, a separate conveyor or LHD transport to a conveyor loading facility is planned for muck removal.

When the TS East and the TS West Drifts are completed, both Mobile Miners will be transported to the Main Test Area in the northeastern corner of the repository block. They will be used to excavate the test core areas and maintenance shop areas located in the Main Test Area. These excavations were left until last due to the higher priority given to the exploratory drifting on the Topopah Spring level to help define the faults. (See Ref. #5.0.G.).

9.4 CALICO HILLS LEVEL

9.4.1 CH Main Drift Construction Activities

As previously stated, the general concept of TBM excavation on the Calico Hills level is to drift from the bottom of both ramps toward the center of the proposed repository block until a connection or breakthrough is made. (See Ref. #5.0.B.).

In addition to the tunnel-bored north/south drift (CH Main Drift) between the CH North Ramp and the CH South Ramp, there will also be several exploratory laterals located on the Calico Hills level to define and study expected faults. Preliminary plans call for the use of roadheaders for the excavation of these exploratory laterals. (See Ref. #5.0.B.). The roadheader concept was selected in part due to the performance criteria stated in the ESFDR, Rev. 5/31/91, which states that mechanical excavation techniques should be used when feasible and practical. (ESFDR, 1.2.6.6.PC2j.v.). Also, the "softer", more easily cuttable non-welded tuff in the Calico Hills horizon lends itself to roadheader excavation. (See Ref. #5.0.B., #5.0.H., #5.0.I.).

The priority on the Calico Hills level is to do the exploratory drifting necessary to gain access to the expected fault zones in order to characterize them. (See Ref. #5.0.G.). The CH North Ramp TBM should cross the Drill Hole Wash Structure prior to entering the repository boundary. Ground control through this structure is assumed to be manageable with proper ground support. Four separate east/west exploratory laterals are planned along the CH Main Drift. These laterals will be driven from the north/south trending CH Main Drift to intersect and help characterize expected faults on the Calico Hills horizon. These faults include the Imbricate Fault Zone, the Ghost Dance Fault, and the Solitario Canyon Fault. (See Ref. #5.0.B.). High priority has been given to the access laterals for these fault zones. Other exploratory drifting, including exploratory laterals on the TS Level, are to be driven on a non-interference basis with this drifting. (See Ref. #5.0.G.).

9.4.2 CH West Ghost Dance Drift & CH Imbricate Drift

After the CH North Ramp TBM reaches the Calico Hills horizon and enters the proposed repository block outline, it will begin driving a north/south trending drift, (CH Main Drift), towards an intersection point with the CH South Ramp TBM. Near the northern part of the proposed repository outline, two exploratory laterals are planned at the Calico Hills level. (See Ref. #5.0.B.). The first lateral, (CH West Ghost Dance Drift), turns to the west off of the CH Main Drift to intercept the Ghost Dance Fault. The second lateral, (CH Imbricate Drift), turns to the east off of the CH Main Drift to intercept the Imbricate Fault Zone. The West Ghost Dance Drift is approximately 1/3 the length of the Imbricate Drift. Both intersections are conceptually planned to be in close proximity to each other along the CH Main Drift. (See Ref. #5.0.B.). The general concept for the construction of these laterals requires stopping the CH North Ramp TBM after it passes both planned intersection locations.

Utility work that interferes with the intersection excavation will be temporarily relocated. A roadheader will then be transported from the surface to the intersection locations on the Calico Hills level. Both the east and the west intersections will be excavated prior to installing new access lateral utilities and re-installing the CH Main Drift utilities. This will avoid having to remove the utilities a second time. After both intersections are completed, the roadheader will begin excavating the CH West Ghost Dance Drift. The CH North Ramp TBM can then resume boring activities towards a breakthrough with the CH South Ramp TBM. Muck produced by the roadheader will be handled by a transfer conveyor loading the main conveyor or by LHD's hauling to a main conveyor loading point. (See Ref. #5.0.F.). The CH West Ghost Dance Drift will be driven first because it is the shorter of the two drives, (this allows quick access for site characterization).

After the roadheader finishes the West Ghost Dance drive, it will excavate the CH Imbricate Drift. The muck haulage for the Imbricate Drift will be the same as was used for the West Ghost Dance drive.

In this scenario, the Calico Hills excavation plan is consistent with the preliminary ventilation plan. (i.e., Adequate ventilation for both a TBM drive and one other heading at a time). (Ref. #5.0.F.).

9.4.3 CH Solitario Drift

Concurrent to the roadheader operations in the northern part of the CH Main Drift, the CH South Ramp TBM will be progressing toward an intersection with the CH North Ramp TBM. A third exploratory access lateral is planned near the bottom of the Calico Hills South Ramp. This exploratory lateral turns off the CH Main Drift towards the west. The purpose of this lateral is to explore the Solitario Canyon Fault for site characterization purposes.

Plans include using a second roadheader to drive this access lateral because the first roadheader will still be driving exploratory laterals in the northern part of the proposed repository block. A second roadheader will allow mechanical excavation of this lateral and quick access for exploration activities.

The preliminary construction sequence would be to temporarily stop the CH South Ramp TBM after it passes the intersection location. Utilities would be temporarily relocated to avoid interference with the intersection excavation. The second roadheader would then be transported to the intersection and the excavation process would proceed. As soon as the intersection is advanced a suitable distance off of the CH Main Drift, excavation activities would temporarily stop while utilities are re-installed and additional utilities are installed to support the Solitario Drift drive. At this point, both the TBM drive and the CH Solitario Drift drive could resume operations.

This scenario would be consistent with the ESF ventilation system capacity. (Ref. #5.0.F.). Roadheader muck could again be handled by transfer conveyor transport to the CH Main Drift conveyor or by LHD's transporting muck to a conveyor loading point in the CH Main Drift. (Ref. #5.0.F.).

At this point in time, the two 18′ diameter TBM's will be heading for an intersection point on the Calico Hills Main Drift. One roadheader will be excavating an exploratory lateral in the northern sector of the Calico Hills Main Drift and another roadheader will be excavating another exploratory lateral in the southern sector of the Calico Hills Main Drift. The 25′ diameter TBM's on the Topopah Spring level will have already made their breakthrough. These two TBM's will have been dismantled and transported to the surface or possibly stored underground. The two Mobile Miners are planned to continue excavating exploratory access laterals on the Topopah Spring level.

9.4.4 CH Main Drift Breakthrough

As the 18′ diameter Calico Hills TBM's near the center of the proposed repository block, a breakthrough point will be determined. The two TBM's will be stopped when they reach a specified (T.B.D.) distance from each other. One of the machines will then be retreated a short distance from the face and will be demobilized. Drilling a small diameter diamond drill hole between the two tunnels will be used to provide final survey alignment information to allow small course adjustments for the final breakthrough. After all alignment considerations are taken into account, the remaining TBM will resume operations until a breakthrough is achieved.

After breakthrough, the remaining TBM will be dismantled. Care should be taken in the design of these TBM's to provide a way to dismantle them into smaller components that can be readily removed through the existing tunnel profile. As the TBM demobilization process proceeds, one TBM will be transported to the surface or possibly stored underground for future use. The exact mode of transporting the components has not yet been determined. The remaining 18 ft. diameter TBM will be transported to the Main Test Area for use on the TS Imbricate Drift drive and Sequential Drift Mining test.

9.4.5 CH Main Drift Flow-Through Ventilation

After breakthrough, and after the TBM's have been sufficiently demobilized to allow for ventilation flow-through, the ventilation duct and booster fan network can be turned off and the primary surface fan arrangement will allow proper ventilation. These fans conceptually will create a negative pressure system whereby air will be "sucked" through the ESF from the north portal site to the south portal site. At the Topopah Spring/Calico Hills north intersection, the air will be split with adequate ventilation planned for both the Topopah Spring and the Calico Hills level. After traversing the two north/south drifts, the air will merge together again at the Topopah Spring/Calico Hills south intersection and be discharged at the south portal site. The ventilation duct and fan network will be left in place to provide auxiliary ventilation for site characterization exploratory drifting. (Ref. 5.0.F.).

9.4.6 CH East Ghost Dance Drift

As soon as a roadheader becomes available, the fourth planned exploratory lateral, (CH East Ghost Dance Drift), can be driven. This lateral is located on the Calico Hills level near the southcentral part of the proposed repository block outline. This lateral is to be driven to the east in order to intersect the Ghost Dance Fault for further site characterization purposes. Utilities that interfere with the excavation process will be temporarily relocated in the CH Main Drift. The second roadheader will be used to excavate this lateral after it is finished driving the CH Solitario Drift because it is expected that the first roadheader will still be driving towards the CH Imbricate Drift in the northern sector of the Calico Hills test horizon. After the roadheader excavates the intersection, utilities will have to be re-installed before resuming roadheader operations. Roadheader muck will again be handled by transfer conveyor transport to the CH Main Drift conveyor or by LHD transport to a conveyor loading facility. (Ref. #5.0.F.).

9.5 DEFERRED TEST ALCOVE CONSTRUCTION

Upon the establishment of flow-through ventilation, the remaining exploratory drifting to fault zones will be given immediate priority particularly on the Calico Hills level. (See Ref. #5.0.G.). The establishment of flow-through ventilation will allow several headings to progress at one time. Therefore, this is the appropriate time to excavate the remaining test alcoves that were deferred during TBM excavation. (See Ref. #5.0.F.).

The conveyor belt arrangement is the same as when the TBM drives were in progress. (i.e., The belts on the Topopah Spring level are running from the center of TS Main Drift to their respective portal sites; the belts on the Calico Hills level are running from the center of the CH Main Drift to their respective TS/CH intersections.) Before starting the test alcove excavation, the preliminary plan is to temporarily suspend all excavation activities while the conveyor belts originating at the South Portal site are extended from both central breakthrough points to the bottom of the TS North and the CH North ramps. The conveyor belts originating at the North Portal site would then only be used for transporting muck generated from excavation activities along the TS North and CH North ramps. All other muck generated during site characterization activities would be transported, (in conjunction with the exhaust air), to the South Portal site. (Ref. 5.0.F.). After the belts are arranged in this manner, excavation activities would resume on the Topopah Spring and Calico Hills test levels. The muck generated during alcove construction along the North Ramps would be independent of the remainder of the muck generated.

Upon establishment of the muck haul system, alcove construction is perceived to proceed on a priority basis to be established by the testing group. At this point the alcove construction is planned to be a combination of mechanical and conventional excavation methods.

9.6 OPTIONAL ESF SHAFT

Currently, the possibility exists of providing a vertical shaft for the acquisition of scientific information about the rock above the Topopah Spring unit and to facilitate underground operations. Little else is known about this Optional Shaft at this time. It is perceived that the construction of this shaft will be deferred until it is required and will not interfere with the construction of the ESF ramp and exploratory lateral system. (Ref. #5.0.K.)

10.0 CONCLUSIONS

The conclusion of this report is that the mining construction and development plan presented is feasible from a logistical standpoint and offers rapid ESF development for testing purposes. It is recommended that the concepts presented in this report be studied from a scheduling and critical path point of view.

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WBS No. 1.2.6.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	DANIEL A. VERONICA	Daniel A. Veronica	SR. MECH. ENGR.	8/22/9
CHECKER:	BERT H. ANZAI	Bert H. Anzai	SR. ENGINEER II	8/22/9
APPROVAL - LDE:	N/A	NA	NA	NA
APPROVAL - SCDM:	JAMES D. GRENIO	J. D. Grenio	DESC	8/22/9
QA CONCURRENCE:	PAUL B. HALE	Paul B. Hale	SR. QA Specialist	8-22-9

SUBJECT: UNDERGROUND SUPPORT SYSTEMS

TITLE: UNDERGROUND WATER DISTRIBUTION SYSTEM

QAG Reference: RSN-GR-013, REV. 0

1.0 PURPOSE:

This analysis identifies and evaluates the underground water distribution system demand requirements, and develops the piping system and components that distribute water within the Exploratory Studies Facility (ESF).

Revision 1 incorporates the comments received from the Management Review and Technical Review during August 1991.

2.0 METHOD:

This calculation will be performed by analyzing the construction schedule, the available equipment options and will be extended to form an estimate of water consumption rate at various stages of the ESF construction and operation.

3.0 DESIGN INPUTS:

3.1 The underground portion of the ESF shall incorporate a fire protection system to control and limit the impact of credible fires in the ESF. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.8 PC1a)

3.2 The fire suppression system shall be capable of operating automatically and/or manually. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.8 PC1b)

3.3 The underground water distribution system shall be adequately sized, with sufficient capacity for fire protection and for process water throughout the ESF in accordance with all anticipated needs and services for construction, testing, and operation of the ESF. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.5 PC1)

3.4 All water used during operation and construction of the ESF shall be provided with chemical tracers as required by testing. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.5 CA)

3.5 The water distribution system will not be suitable for drinking purposes (i.e., water will be nonpotable). Bottled water will be provided underground for drinking purposes. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.5 A1)

4.0 CODES AND STANDARDS:

4.1 National Fire Protection Association (NFPA)

a. NFPA 13 Installation of Sprinkler Systems; 1989 Edition
b. NFPA 123 Underground Bituminous Coal Mines; 1990 Edition

5.0 REFERENCE MATERIAL:

5.1 Vendor Data Sheets: Atlas Copco H235 Jumbo with COP 1238 Drill; Longyear - 38 diamond core drill; Tarve and Watson HDC-750-BB-360 Pump

5.2 SME Mining Engineering Handbook - Volume 1; 1st Edition (American Institute of Mining, Metallurgical and Petroleum Engineers, 1973)

5.3 Mining Engineering Handbook; 3rd Edition (Wiley, 1945)

5.4 Crane Technical Paper No. 410, "Flow of Fluids" (Crane Co., 1988)

5.5 Practical Plumbing Engineering; C. M. Harris; 1st Edition (McGraw-Hill 1991)

5.6 Automatic Sprinkler Systems Handbook; R. Solomon, 4th Edition (NFPA 1989)

6.0 ASSUMPTIONS:

6.1 (YMP-025-2-MECH-PI01) A single piping system shall provide both mining supply water and fire protection water. (No Verification Required)

6.2 (YMP-025-2-MECH-PI01) To provide reliable water supply distribution and system redundancy, water supply piping from both ramps shall be utilized at the Topopah Spring level and Calico Hills level. (No Verification Required)

6.3 (Section 9.5) Underground water supply pressure will normally be regulated to 80 psi. Supply pressure available at each ramp portal will be at least 80 psig. (Verification required in Title II Design)

6.4 (Section 9.5.5) Reasonable maximum design velocity from the mine supply water piping shall be from 4 fps to 10 fps based on accepted practice in references 5.5 and 5.6. (No Verification Required)

6.5 (Section 9.3) A load factor of 1.0 will be used for the mine supply water demand analysis. (No Verification Required)

6.6 (YMP-025-2-MECH-PI01) Metering and monitoring systems for the water distribution piping will be provided. (No Verification Required)

6.7 (Section 9.4) In the event of fire, mining water demand will cease, and fire protection water will be used. The underground water distribution system piping size determination will be made using the higher demand, fire protection water or mining water. (No Verification Required)

6.8 (Section 9.1; 9.5) The maximum fire protection requirement of the underground water distribution system shall be based on a 3,000 square foot hydraulic design area with an Ordinary Hazard Group 2 rating (Ref. NFPA 13). To have redundant sources of water for fire protection in this area, it must be located within the northernmost half of either the TS or CH main drifts. Water supplied from the north portal facilities will have marginal static pressure in the south halves of the two main drifts. (Verification requirement during Title II Design)

6.9 (Section 9.6) The minimum pipe size for underground water distribution shall be 2 inches. This is recommended for structural stability and visibility in the underground environment. (No Verification Required)

6.10 (Tables 3; 4) Ramp distances and grades as shown in Figure 1.1, General Mechanical Mining Plans of RSN Design Analysis ST-MN-010. (Verification Required in Title II Design)

6.11 (YMP-25-2-MECH-PI01) Elevations of key points and intersections as shown on RSN drawings YMP-025-1-MING-MI01 and YMP-025-1-MING-MI13. (Verification Required in Title II Design)

7.0 COMPUTER PROGRAM:

None

8.0 UNITS:

English Engineering System

9.0 CALCULATIONS/ANALYSIS:

This analysis will derive a total underground water system demand value based on the highest of either the fire protection flowrate or the equipment spread flowrate requirements. The water demand for fire protection and equipment spread varies depending on the phase of construction, testing or operation in effect.

9.1 The design maximum fire protection flowrate is based on guidance from DOE 6430.1A that requires a 3000 square foot hydraulic design area at an ordinary hazard group rating. Selecting the more conservative ordinary hazard rating (Group 2), NFPA 13 indicates a corresponding density of .165 gpm/s.f., which leads to a design flowrate as follows:

3,000 s.f. x .165 gpm/s.f. = 495 gpm

495 gpm x 1.10 (overage factor) = 545 gpm

Applying the hose stream requirements from NFPA 123 (mines) in lieu of those for buildings:

545 gpm + 150 gpm (hose stream) = 695 gpm 700 gpm
(NFPA 123)

The fire protection flowrate requirement applies to each of two mains, one in each ramp. This assumption provides redundancy in the fire protection water flow path. (NFPA 123)

9.2 The maximum flowrate required to supply the equipment spread occurs during the construction phase when two tunnel boring machines (TBMs) are driving the Topopah Spring and Calico Hills accesses simultaneously from each ramp. Concurrent with TBM operation, the use of a 2-drill jumbo/rock bolter may be required in each excavation to stabilize rock structure. The resulting water demand is shown in Table 1.

TABLE 1

Tunneling Equipment Water Usage (Per Ramp)

Item	Quantity	Unit Flow (GPM)	Total Flow (GPM)
Rock Bolter/Jumbo (2 drills/each)	4 drills	18*	72
TBM 25 ft. dia.	1	140**	140
TBM 18 ft. dia.	1	76**	76
			288 gpm

Notes:

* Typical for COP 1238
** Conservative value based on commercial experience with no water conservation

9.3 The water demand for peripheral excavation activity (alcoves, test drifts, intersections) and for core drilling is shown on Table 2.

TABLE 2

Other Equipment Water Usage (Per Operation)

Operation/Equipment	Quantity	Unit Flow (GPM)	Total Demand (GPM)
Drill and Blast (Alcove/ Intersection)			
Rock Drill/Jumbo (3 Drill Jumbo)	3	18	54
Blast Face Spray	1	3	3
Blow Pipe	1	N/A	N/A
Diaphragm Pump	1	N/A	N/A
			57 gpm
Drift Excavation			
Mobile (Continuous) Miner or Roadheader	1	35	35
			35 gpm
Testing			
Core Drill (Large)	1	35*	35
Core Drill (Small)	1	7**	7
			42 gpm

Notes:

* Typical for Longyear 38 ESH
** Typical for Longyear 65

According to ST-MN-020 "Preliminary Excavation Plan" the anticipated condition for maximum equipment water demand occurs when each ramp must supply tunneling operations (per Table 1) plus one drift excavation on each ESF level:

Maximum Equipment Water Demand = 288 + 2(35) = 358 gpm

9.4 Since the equipment water demand is lower than the design fire protection water flowrate (358 vs. 700 gpm), the fire protection flowrate will determine the minimum pipe size used in the underground ESF. The underground fire protection system water supply is redundant, in that, the system can function fully with water supplied from either portal facility alone.

9.5 The optimal pipe size for the water distribution mains is the smallest size which will carry the design flow rate (700 gpm) without unacceptable pressure loss due to flow friction. For the ESF, an unacceptable pressure loss due to flow friction would be a value that is significantly less than the available static pressure. Since the surface facilities supply water is an assumed minimum 80 psig (Section 6.3), the pressure loss due to flow friction can not exceed the static pressure gained from elevation head.

9.5.1 For the Topopah Spring (TS) main drift, based on the assumptions of Section 6.8, the most remote point applicable is the middle of the drift when measured from the north portal facilities or the north end of the drift when measured from the south portal facilities. Table 3 shows the resulting pressure loss for various pipe sizes.

9.5.2 For the Calico Hills (CH) main drift, based on the assumptions of Section 6.8, the most remote point applicable is the middle of the drift when measured from the north portal facilities or the north end of the drift when measured from the south portal facilities. Table 4 shows the resulting pressure loss for various pipe sizes.

9.5.3 From the data Table 3, it is evident that a 6" diameter pipe is too small for the delivery of 700 gpm from the North Portal facilities to the middle of TS main drift, because the flow friction value exceeds the static pressure gained from elevation head (-194.0 psi vs. +118.1 psi). A similar situation exists for the pipe run from the south portal facilities to the sound end of TS main drift. As a result, the next larger size (8") pipe is required for piping in the TS ramps and TS Main Drift.

9.5.4 Considering the Calico Hills data in Table 4, there is no situation where the flow friction value exceeds the static pressure gained. Thus, 6" piping is satisfactory for piping in the CH ramps and CH Main Drift.

9.5.5 Referring to Appendix A-4, the velocity of a 700 gpm flow in the 8" piping (4.5 fps) and the 6" piping (7.8 fps) are within the limits of Section 6.4.

TABLE 3

PIPING PRESSURE LOSSES TO TS MAIN DRIFT

Location	Piping Run	Static Gain (psi)	Friction Loss (psi) 10"	8"	6"
TS North Portal to TS Lowest Point	6,652 ft	+254.8	-7.5	-22.8	-89.8
TS Lowest Pt to TS Main Drift Midpoint	5,323 ft	-136.7	-6.0	-18.3	-71.9
Friction Loss Subtotal			-13.5	-41.1	-161.7
Fitting Allowance (20%)			- 2.7	- 8.2	- 32.3
Total Pressure Loss/Gain		+118.1	-16.2	-49.3	-194.0*
TS South Portal to TS Main Drift South End	9,820 ft	+ 87.2	-11.0	-33.7	-132.6*
TS Main Drift South End to TS Main Drift North End	10,645 ft	+273.4	-11.9	-36.5	-143.7
Friction Loss Subtotal			-22.9	-70.2	-276.3
Fitting Allowance (20%)			- 4.6	-14.0	- 55.3
Total Pressure Loss/Gain		+360.6	-27.5	-84.2	-331.6

*Frictional loss exceeds static pressure gain (Section 9.5.3)

TABLE 4

PIPING PRESSURE LOSSES TO CH MAIN DRIFT

Location	Piping Run	Static Gain (psi)	Friction Loss (psi) 10"	8"	6"
TS North Portal to CH Low Point	10,967 ft	+427.5	-12.3	- 37.6	-148.1
CH Low Point to CH Main Drift Midpoint	5,318 ft	- 93.7	- 6.0	- 18.2	- 71.8
Friction Loss Subtotal			-18.3	- 55.8	-219.9
Fitting Allowance (20%)			- 3.7	- 11.2	- 44.0
Total Pressure Loss/Gain		+333.8	-22.0	- 67.0	-263.9
TS South Portal to CH Main Drift South End	15,908 ft	+345.5	-17.8	- 54.6	-214.8
CH Main Drift South End to North End	10,635 ft	+187.5	-11.9	- 36.5	-143.6
Friction Loss Subtotal			-29.7	- 91.1	-358.4
Fitting Allowance (20%)			- 5.9	- 18.2	- 71.7
Total Pressure Loss/Gain		+533.0	-35.6	-109.32	-430.1

9.6 The pipe sizing for side drifts utilizes the flow rates in Table 2, and the velocity limit of 10 fps (Section 6.4). From Appendix A-4 the pipe sizes, velocities and flow rates can be easily compared and determinations made. For a 2-inch Schedule 40 pipe (minimum size for ESF distribution system) at 9.56 fps, the corresponding flow rate is 100 gpm. Then the 2-inch pipe size is sufficient for taps from the 8-inch main with flows of 100 gpm or less. A 4-inch line could be used for flows up to 375 gpm. Using the 8-inch main, 2-inch or 4-inch tap concept, a water supply distribution system can be developed utilizing the construction and testing schedules. The detailed routing and sizing of underground water distribution pipe will be part of Title II design when more information on end user locations, fire protection demands, and construction schedules are available. "Underground Water Distribution System - Schematic Flow Diagram" shows the flow logic and includes the various valves and water control components to facilitate a working water distribution system.

9.7 To establish a reliable, working system, the following features are incorporated into the water distribution system design.

- Line break isolation valves are placed at strategic locations to interrupt water flow in the event of excess flow due to damaged or severed water main piping. These valves can be individually set for required conditions and are used in the ESF to limit the amount of water introduced into the ground structure.

- Pressure reducing valves will be utilized to reduce the high head pressure present in the ramp piping to a level that can be safely used by personnel. These devices will be primarily located near each ramp station where supply water piping branches off to serve a given level. There are valves available which incorporate the pressure reducing feature and the flow control feature in one unit.

- Pressure relief valves will be placed in-line just downstream of pressure regulators for safety to users on the low pressure side. Other pressure relief valve locations may be required as Title II piping layout is developed.

- Manual shutoff valves will be placed as required to provide isolation of piping sections for maintenance or component inspection.

- Water hammer arresters may be used to minimize hydraulic shock caused by sudden reduction of flow in a piping system. Various devices will be located in the piping system to provide maximum protection to components. Detailed analysis of water hammer in the mine water system, and methods to suppress hydraulic shock will be part of the Title II design.

- Pressure indicators or self-sealing taps for insertion of local pressure indicators will be used to verify system safety and performance.

10.0 RECOMMENDATIONS:

Based on the design criteria, assumptions, and maximum demand requirements derived in this analysis, it is recommended that the ESF underground water distribution system be developed as shown on drawing YMP-025-2-MECH-PI01. The water supply piping in either ramp is capable of meeting the design flow demand. Therefore, after completion of main drift construction (i.e., connection of TBMs and thus, north and south ramp water supplies), twice the design flow demand will be available. This arrangement prevents further increases in pipe line size should expected water demand increase.

APPENDIX A

A-1 Vendor Data Sheets

A-2 Air-Water Blast Device

A-3 Test Holes - Water Flushed Coring

A-4 Flow of Water - Crane Table B-14

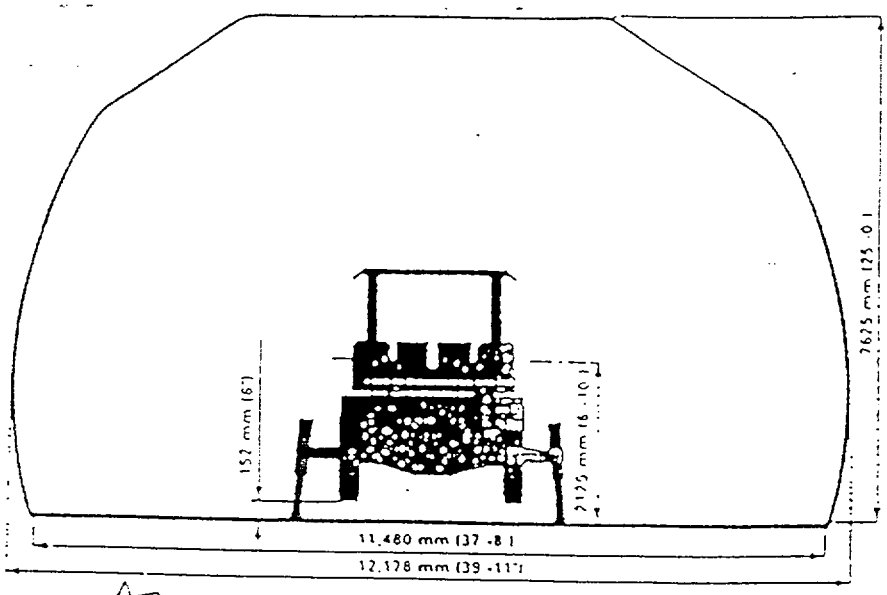
APPENDIX A-1

Atlas COPCO H 235 Jumbo with COP 1238 Rock Drill

Longyear 38 ESH

Boomer H 235

Coverage area



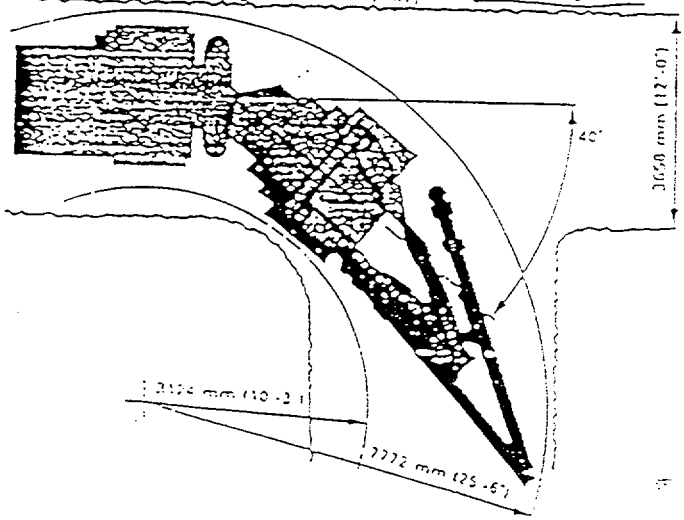
APPENDIX A-1

BEST COPY AVAILABLE LWB 7-22-88

Rock drill COP 1238

Drill steel	R38
Impact power, max.	15 kW (20 hp)
Impact rate	40-60 Hz
Lub. air consump. (at 2 bar)	2.5 l/s (5.3 cfm)
Flushing water consumption (at 12 bar)	1.1 l/s (14.5 gpm imperial)
Rotation system	Separate rotation
Rotation speed	0-300 rpm
Weight	151 kg (332 lbs)
Printed Matter No.	E 11370 A

$\frac{1.1\ l}{sec} \times \frac{0.2642\ gal.}{l} \times \frac{60\ sec.}{min} = 17.44\ gpm \approx 18\ GPM$



Power pack BHU 38 — 2 DCS

Elec. pump motors	2 × 45 kW (60 hp)
Voltage	440-600 V
Frequency	60 Hz
Hydraulic pumps	2 × double radial piston pumps with variable displacement
System pressure, impact mechanism	150-250 bar (2175-3625 psi)
Hyd. oil tank vol.	435 l (95 gal imperial)
Hydraulic oil types	Mineral
Water booster pump	100 l/m (22 gpm imperial)

Electrical system

Total el. power cons.	100 kW (134 hp)
Voltage	440-600 V
Frequency	60 Hz
Cable reel	120 m (395 ft) capacity

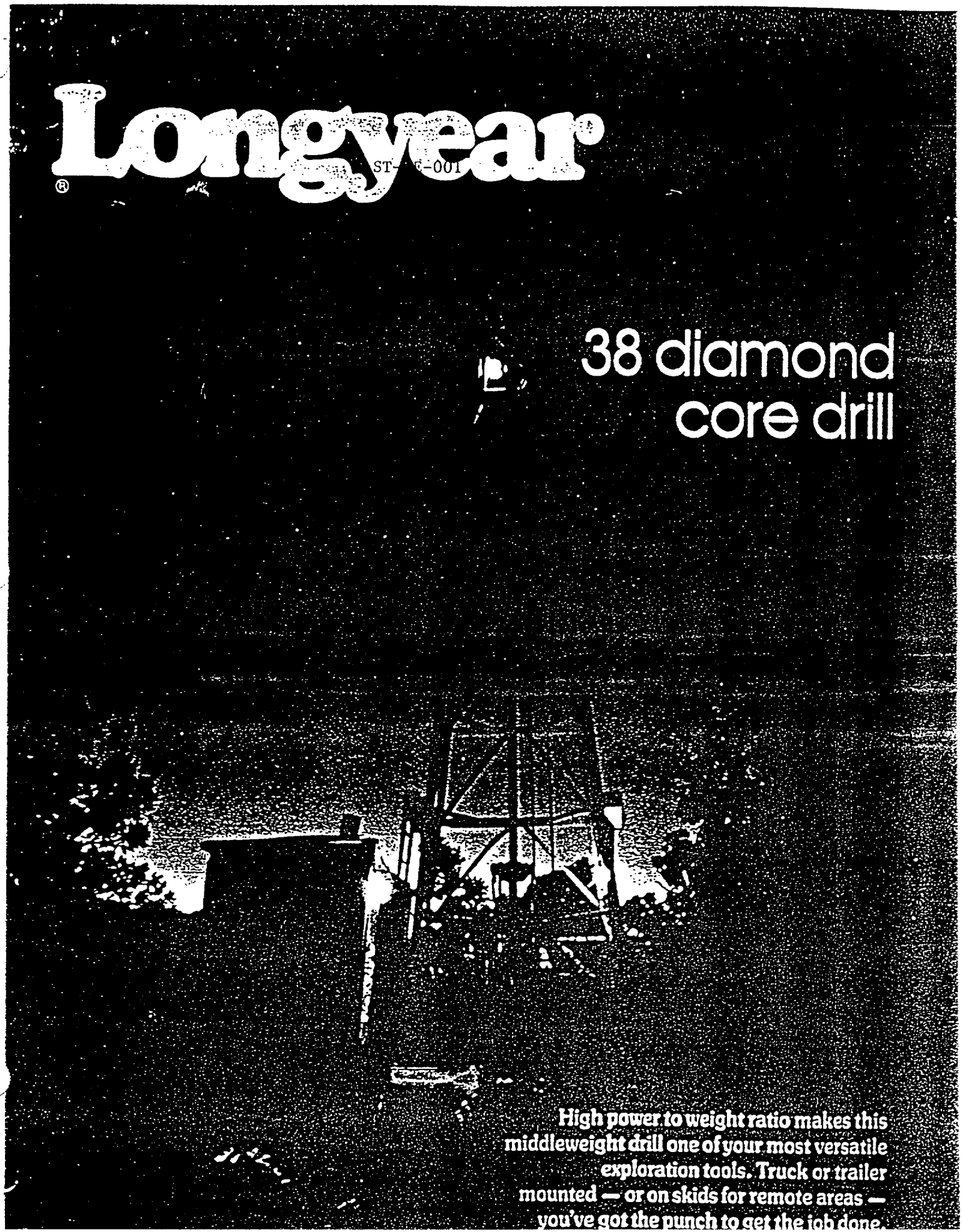
Dimensions and weights

Height	2438 mm (8'0")
Ht. with protective roof, transport	2718 mm (8'11")
Ht. with protective roof, drilling	3353 mm (11'0")
Width	2438 mm (8'0")
Length (with BMH 614)	14,630 mm (48'0")
Turning rad., inner	3124 mm (10'3")
outer	7772 mm (25'6")
Gross weight	30,825 kg (67,820 lbs)

Optional equipment

- Protective roof
- Silenced operators cabin
- Service platform
- Exhaust scrubber
- Exhaust catalyzer
- Caterpillar 3304 PCNA 75 kW (100 hp)

Atlas Copco


Longyear®
ST-ME-001
38 diamond core drill
High power to weight ratio makes this middleweight drill one of your most versatile exploration tools. Truck or trailer mounted — or on skids for remote areas — you've got the punch to get the job done.

PUMPING UNITS

Longyear

CATALOG PARTS LIST
Effective January 1, 1986
Replaces list dated March 1, 1982

PUMP SELECTION TABLE

KEY:
RO = with multi-speed transmission
A = air powered
D = diesel powered
E = electric powered
EHS = electro-hydrostatic
G = gasoline powered
H = hydraulic powered
see page 4 for complete drill make-up code

P/N	MODEL	OUTPUT FLOW gpm	OUTPUT FLOW L/min	OUTPUT PRESSURE psi	OUTPUT PRESSURE Mpa	NET WEIGHT lb	NET WEIGHT kg	EXPORT BOXING cu ft	EXPORT BOXING cu m
44191	870RO	10-70	38-265	800	5.516	830	377	65	1.84
44150	870ROD	10-70	38-265	800	5.516	1370	623	93	2.63
44503	835ROD	10-35	38-132	800	5.516	1390	631	69	1.95
36705	535RO	10-35	38-132	500	3.448	680	308	58	1.64
36706	535ROD	10-35	38-132	500	3.448	1290	585	67	1.90
36707	535ROG	10-35	38-132	500	3.448	1020	463	69	1.95
38689	535A	0-35	0-132	500	3.448	890	405	23	0.65
43350	535H (H44)	2-35	8-132	500	3.448	620	282	23	0.65
36711	535*	35	132	500	3.448	585	265	42	1.19
36712	535D	35	132	500	3.448	1195	542	57	1.61
36713	535G	35	132	500	3.448	925	420	58	1.64
50633	722EHS	2-22	7-80	700	4.823	945	430	40	1.13
36708	520RO	6-20	23-76	500	3.448	496	225	46	1.30
36709	520ROD	6-20	23-76	500	3.448	859	389	53	1.50
36710	520ROG	6-20	23-76	500	3.448	686	311	49	1.39
38688	520A	0-20	0-76	500	3.448	465	210	16	0.45
36714	520*	20	76	500	3.448	410	184	22	0.62
36715	520D	20	76	500	3.448	775	350	33	0.93
36716	520G	20	76	500	3.448	600	270	30	0.85
36984	335ROD	10-35	38-132	300	2.069	1290	585	67	1.90
36982	335ROG	10-35	38-132	300	2.069	1020	463	69	1.95
36980	320ROD	6-20	23-76	300	2.069	859	389	53	1.50
36985	335D	35	132	300	2.069	1195	542	57	1.61
36983	335G	35	132	300	2.069	925	420	58	1.64
36981	320D	20	76	300	2.069	775	350	33	0.93
30459	315G	13	50	300	2.069	175	80	12	0.34
30434	315A	0-13	0-50	300	2.069	172	78	6	0.17
30847	315D	13	50	300	2.069	185	84	12	0.34
36995	310A	0-10	0-38	300	2.069	82	38	2.2	0.06
57743	712H	1-12	4-46	700**	4.826	121	55	2.8	0.08

* P/N 36881, Coupling Group, is required with stub-shaft units

Capacities based on gasoline-powered pumping units with transmission input speeds of 3000 rpm for models 535, and 3100 rpm for model 520. Capacities may vary depending on power unit used

** air motor ratings based on 90 psi (0.62 MPa). Lower pump pressure with lower air press...

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APPENDIX A-2

Air-Water Blast Device
(From Reference 5.2)

unit available from a number of manufacturers. The effectiveness of this device is determined by the fineness of the mist or fog produced, and the "throw" and "spread" of the mixture. An unpublished report, covering tests made on 11 different types, indicated that the water consumption varied from 0.75 to 8.0 gpm; compressed air, 105 to 300 cfm (free air). It is apparent that a particular design should not be adopted as standard for use in all working places in all mines. A working area with little or no ventilation would benefit most from the unit providing the high rate of airflow. On the other hand, it would be poor engineering to waste expensive compressed air in a place well ventilated by conventional means. Similar reasoning may be applied to the utilization of the water delivered, particularly for blasts in drifts and raises vs. the larger ones in stopes involving much greater tonnages of broken material.

An important feature of the air-water nozzle is the manner in which the compressed air and water are blended before dispersal. The design should incorporate means precluding the drainage of water into the compressed-air line, particularly when the pressure of the latter is lower than that in the former. Two suitable types of nozzle are illustrated in the text published by the ILO,[32] and the details of a number of others are available on request from the Mines Accident Prevention Association of Ontario.[46]

The final step in the control of contaminants resulting from blasting is providing means to cleanse pollutants. A unique type of collector used in South Africa consists of a bed of vermiculite, treated with a solution of sodium carbonate and potassium permanganate, which removes the nitrous fumes, and a flannel filter for the collection of dust particles. After treatment, the air is returned to a fresh-air split where the dilution ratio is at least 5 to 1. Plant details are presented by Rabson.[47]

In the absence of a filtering system, blasting dust and fumes should be diluted and exhausted to surface via an untraveled route, preferably an upcast raise designed for that purpose. If this is not feasible, the blasting schedule should be arranged so that the vitiated air will pass through working places when the miners are absent. Failure to do this creates an undesirable health hazard and reduces production efficiency due to miners leaving their working places for the time necessary to clear the dust and fumes.

Mechanical Loading—Utilization of an air-water blast for a suitable period after blasting obviates the need for applying a water spray immediately before commencing the loading operation. On the other hand, if the rock pile has to be wetted by means of a hand-held hose, the quality of the environment will deteriorate considerably because the application of water under these conditions is similar to directing a stream into a barrel of flour.

Investigation of a rock pile after it apparently is soaked with water will reveal that the depth and extent of water penetration are shallow and limited. In other words, it is practically impossible to wet a pile of rock thoroughly by conventional spraying methods. As a result, dry dusty material is exposed continuously as the loading or scraping operation progresses. Under these circumstances, it is necessary to maintain a continuous mist or water spray at the point where new fragmental material is exposed. Use of a hand-held hose is not recommended, because the operator, on exposing new rock during the process of loading an ore carrier, may be tempted to complete the cycle before applying more water. Some success has been achieved by installing a nozzle spray on the front end of compressed-air-operated loading machines. A nozzle which provides a flat diverging stream of mist-size water droplets produces a good wetting action with minimum water consumption.

The scraping of rock in stopes and scram drifts produces large amounts of dust, particularly if the material is dry and the speed of the operation is high. A successful method of controlling this dust is to install a bar-type water spray where the scraper "bites" into the rock pile, with one or more additional nozzle-type sprays at intervals over the path followed by the scraper. A mist type of spray at the ore-pass or loading point will reduce dust dispersal and condition the rock

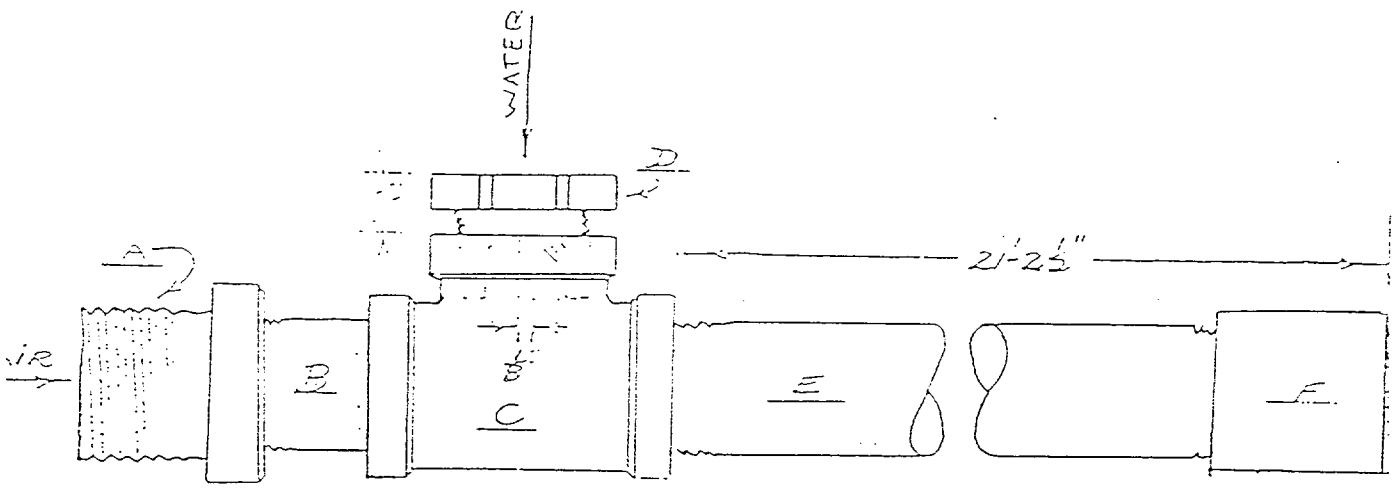
THE ANACONDA COMPANY

ENVIRONMENTAL ENGINEERING DEPARTMENT

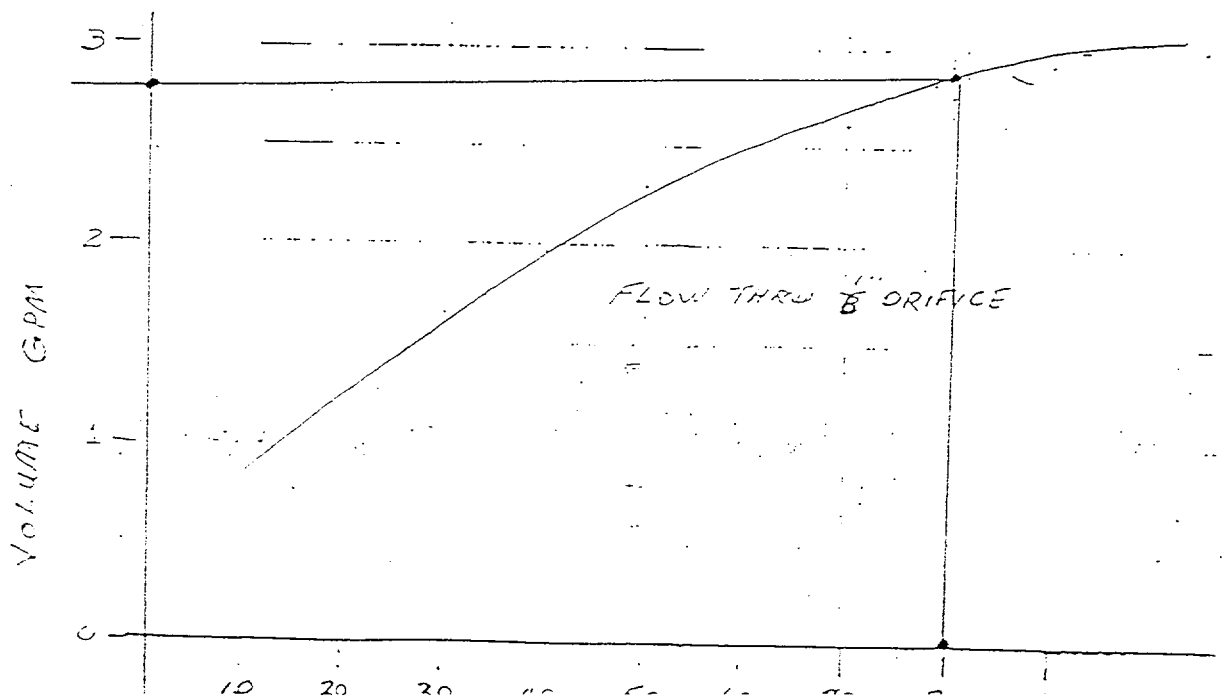
DATE 7/12/67 SUBJECT DUST CONTROL PLANT ALL MINES

REMARKS AIR-WATER BLAST BY RJL FILE

N.B. REDUCER MAY BE USED ON END OF PIPE TO CONFINE & DIRECTIONALIZE SPRAY.



A = STANDARD 1" MALE SPUD, COMPRESSED AIR NOMINAL — 100 psi.
B = STANDARD 1" NIPPLE, BLACK IRON
C = STANDARD 1" TEE, BLACK IRON
D = 1"x3/8" BUSHING, PLUGGED & DRILLED WITH 1/8" ORIFICE.
E = STANDARD 1" MALE, BLACK IRON MAXIMUM LENGTH AS SHOWN
F = STANDARD 1" COUPLING, BLACK IRON.



APPENDIX A-3

Test Holes - Water Flushed Coring
(From Reference 5.3)

galena. Quantity of water to produce desired veloc varies with diam of hole and rods (Table 38). With this rising current, the veloc in the small space around the core is much higher, sometimes causing so great a loss of core in soft rocks that veloc must be reduced. In general, much water means rapid drilling and low core recovery; little water increases core recovery at expense of progress, and too little may result in a burned bit. If the hole is tight and nearly all the water pumped down returns to surface, the overflow from sludge box can be reused; loss of water is then about 25%; reused water must be freed from oil. Measurements at 3 drill holes, where all return water was saved, show that 76–80 gal per hr were used; holes, 1.5 in, cores 7/8 in. Drilling a 3-in hole and recovering 2-in core in broken formation when prospecting for coal, required 305 gal of water per hr; in fairly deep drilling, 105–123 gal per hr may be used.

Table 38. Vol of Water Required to Produce a Veloc of 1.5 ft per sec
(E. J. Longyear Co)

Size rod	Size hole or casing	Gal per hr
E	EX hole	120
E	AX "	390
A	AX "	192
A	BX "	660
A	NX "	1 400
B	BX "	432
B	NX "	1 182
N	NX "	732
E	EX casing	204
A	AX "	300
B	BX "	540
N	NX "	822

19. TIME DISTRIBUTION IN DIAMOND DRILLING

Table 39. Approx Time for Hoisting and Lowering Rods (E. J. Longyear Co.)

Depth of hole, ft	Time for pulling rods, removing core and lowering
500	40 min
1 000	90 "
1 500	2 hr
2 000	2.5 "
2 500	3.25 "
3 000	4 "
4 000	5– 6 "
5 000	6– 7 "
6 000	9–10 "

Time effic, the percentage of total working time spent in actual drilling, rarely exceeds 60%, and depends on depth and character of overburden, time for hoisting and lowering rods, and delays (Table 39). Time for handling rods depends on depth of hole, and length of rod sections between breaks. Number of lifts depends on nature of ground, kind of bit, and kind and length of core barrel. Uniform rock sometimes cores the full length of barrel; in broken ground, cores break up and tend to jam in the barrel or be lost. Double core barrels (Art 17) tend to overcome this difficulty. A solid bit needs to be raised only to change it. Table 40 shows distribution of delays in 1 200 shifts at United Verde mine (50). Due to 8-hr law, 1 hr aver was taken for traveling to working place and return; adding 0.5 hr for lunch left 6.5 hr. Actual drilling time, 68.88% of total time.

Table 40. Delays in Diamond Drilling (50)

Cause of delay	Percent of total working time
Moving	17.02
Cementing	3.55
Reaming	0.56
Casing ground	0.73
Fishing, rods or bits	0.94
Repairs	1.54
Bits	1.25
Air and water	1.73
Supplies	0.89
Surveying holes	0.36
Mine department	1.46
Drill and equipment	1.09
Total	31.12

Table 41. Time Distribution in Diamond Drilling (51)

Operation	Hours	Percent
Churn drilling near surface	110.0	2.5
Drilling, AX casing bits	150.5	3.2
Drilling, EX bits	3 444.7	74.2
Drilling, AX bits	14.0	0.3
Total actual drilling	3 719.2	80.2
Moving and setting up	279.5	6.0
Repairing machinery	114.5	2.4
Delay, lack of water	27.5	0.6
Cementing	225.0	4.8
Inclination tests	137.5	2.9
Fishing for lost bits	9.0	0.2
Reaming undersized hole	9.0	0.2
Changing water pump	12.0	0.3
Fishing for lost core	17.0	0.4
Installed lighting plant	4.0	0.1
Reaming EX casing	67.0	1.4
Threading pipe	4.5	0.1
Laying water line	4.0	0.1
General	14.5	0.3
Total	4 644.2	100.0

In drilling 10 192 ft (17 angle holes) in about 12 months (Lupa gold field), most of the work was in sheared rocks (Table 41). Cores were EX (7/8 in). Time for lowering and raising rods, removing cores and incidental work is included with EX drilling time. Progress was considerably delayed by frequent pulling of the rods, due to core-blocked bits and barrels (51).

APPENDIX A-4

Flow of Water - Crane Table B-14
(From Reference 5.4)

Flow of Water Through Schedule 40 Steel Pipe

Discharge		Pressure Drop per 100 feet and Velocity in Schedule 40 Pipe for Water at 60 F.															
		Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop
Gallons per Minute	Cubic Ft. per Second	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.
		1/8"		1/4"		3/8"		1/2"									
.2	0.000446	1.13	1.86	0.616	0.359												
.3	0.000668	1.69	4.22	0.924	0.903	0.504	0.159	0.317	0.061	3/4"							
.4	0.000891	2.26	6.98	1.23	1.61	0.672	0.345	0.422	0.086								
.5	0.00111	2.82	10.5	1.54	2.39	0.840	0.539	0.528	0.167	0.301	0.033						
.6	0.00134	3.39	14.7	1.85	3.29	1.01	0.751	0.633	0.240	0.361	0.041						
.8	0.00178	4.52	25.0	2.46	5.44	1.34	1.25	0.844	0.408	0.481	0.102	1"		1 1/4"			
1	0.00223	5.65	37.2	3.08	8.28	1.68	1.85	1.06	0.600	0.602	0.155	0.371	0.048			1 1/2"	
2	0.00446	11.29	134.4	6.16	30.1	3.36	6.58	2.11	2.10	1.20	0.526	0.743	0.164	0.429	0.044		
3	0.00668			9.25	64.1	5.04	13.9	3.17	4.33	1.81	1.09	1.114	0.336	0.644	0.090	0.473	0.043
4	0.00891			12.33	111.2	6.72	23.9	4.22	7.42	2.41	1.83	1.49	0.565	0.858	0.150	0.630	0.071
5	0.01114	2"				8.40	36.7	5.28	11.2	3.01	2.75	1.86	0.835	1.073	0.223	0.788	0.104
6	0.01337	0.574	0.044	2 1/2"		10.08	51.9	6.33	15.8	3.61	3.84	2.23	1.17	1.29	0.309	0.946	0.145
8	0.01782	0.765	0.073			13.44	91.1	8.45	27.7	4.81	6.60	2.97	1.99	1.72	0.518	1.26	0.241
10	0.02228	0.956	0.108	0.670	0.046			10.56	42.4	6.02	9.99	3.71	2.99	2.15	0.774	1.58	0.361
15	0.03342	1.43	0.224	1.01	0.094	3"				9.03	21.6	5.57	6.36	3.22	1.63	2.37	0.755
20	0.04456	1.91	0.375	1.34	0.158	0.868	0.056	3 1/2"		12.03	37.8	7.43	10.9	4.29	2.78	3.16	1.28
25	0.05570	2.39	0.561	1.68	0.234	1.09	0.083	0.812	0.041	4"		9.28	16.7	5.37	4.22	3.94	1.93
30	0.06684	2.87	0.786	2.01	0.327	1.30	0.114	0.974	0.056			11.14	23.8	6.44	5.92	4.73	2.72
35	0.07798	3.35	1.05	2.35	0.436	1.52	0.151	1.14	0.071	0.852	0.041	12.99	32.2	7.51	7.90	5.52	3.64
40	0.08912	3.82	1.35	2.68	0.556	1.74	0.192	1.30	0.095	1.01	0.052	14.85	41.5	8.59	10.24	6.30	4.65
45	0.1003	4.30	1.67	3.02	0.668	1.95	0.239	1.46	0.117	1.13	0.064			9.67	12.80	7.09	5.85
50	0.1114	4.78	2.03	3.35	0.839	2.17	0.288	1.62	0.142	1.26	0.076	5"		10.74	15.66	7.88	7.15
60	0.1337	5.74	2.87	4.02	1.18	2.60	0.406	1.95	0.204	1.51	0.107			12.89	22.2	9.47	10.21
70	0.1560	6.70	3.84	4.69	1.59	3.04	0.540	2.27	0.261	1.76	0.143	1.12	0.047			11.05	13.71
80	0.1782	7.65	4.97	5.36	2.03	3.47	0.687	2.60	0.334	2.02	0.180	1.28	0.060			12.62	17.59
90	0.2005	8.60	6.20	6.03	2.53	3.91	0.861	2.92	0.416	2.27	0.224	1.44	0.074	6"		14.20	22.0
100	0.2228	9.56	7.59	6.70	3.09	4.34	1.05	3.25	0.509	2.52	0.272	1.60	0.090	1.11	0.036	15.78	26.9
125	0.2785	11.97	11.76	8.38	4.71	5.43	1.61	4.06	0.769	3.15	0.415	2.01	0.135	1.39	0.055	19.72	41.4
150	0.3342	14.36	16.70	10.05	6.69	6.51	2.24	4.87	1.08	3.78	0.580	2.41	0.190	1.67	0.077		
175	0.3899	16.75	22.3	11.73	8.97	7.60	3.00	5.68	1.44	4.41	0.774	2.81	0.253	1.94	0.102		
200	0.4456	19.14	28.8	13.42	11.68	8.68	3.87	6.49	1.85	5.04	0.985	3.21	0.323	2.22	0.130	8"	
225	0.5013	...	...	15.09	14.63	9.77	4.83	7.30	2.32	5.67	1.23	3.61	0.401	2.50	0.162	1.44	0.043
250	0.557	...	...	...	...	10.85	5.93	8.12	2.84	6.30	1.46	4.01	0.495	2.78	0.195	1.60	0.051
275	0.6127	...	...	...	...	11.94	7.14	8.93	3.40	6.93	1.79	4.41	0.583	3.05	0.234	1.76	0.061
300	0.6684	...	...	...	...	13.00	8.36	9.74	4.02	7.56	2.11	4.81	0.683	3.33	0.275	1.92	0.072
325	0.7241	...	...	...	...	14.12	9.89	10.53	4.09	8.19	2.47	5.21	0.797	3.61	0.320	2.08	0.083
350	0.7798			...	...	...	...	11.36	5.41	8.82	2.84	5.62	0.919	3.89	0.367	2.24	0.095
375	0.8355			...	...	...	...	12.17	6.18	9.45	3.25	6.02	1.05	4.16	0.416	2.40	0.108
400	0.8912			...	...	...	...	12.98	7.03	10.08	3.68	6.42	1.19	4.44	0.471	2.56	0.121
425	0.9469			...	...	...	...	13.80	7.89	10.71	4.12	6.82	1.33	4.72	0.529	2.73	0.136
450	1.003	10"		...	...	...	...	14.61	8.80	11.34	4.60	7.22	1.48	5.00	0.590	2.89	0.151
475	1.059	1.93	0.054			...	...	...	...	11.97	5.12	7.62	1.64	5.27	0.653	3.04	0.166
500	1.114	2.03	0.059			...	...	...	...	12.60	5.65	8.02	1.81	5.55	0.720	3.21	0.182
550	1.225	2.24	0.071			...	...	...	...	13.85	6.79	8.82	2.17	6.11	0.861	3.53	0.219
600	1.337	2.44	0.083			...	...	...	...	15.12	8.04	9.63	2.55	6.66	1.02	3.85	0.258
650	1.448	2.64	0.097	12"		...	...	...	...	...	...	10.43	2.98	7.22	1.18	4.17	0.301
700	1.560	2.85	0.112	2.01	0.047			...	...	...	...	11.23	3.43	7.78	1.35	4.49	0.343
750	1.671	3.05	0.127	2.15	0.054	14"		...	...	...	...	12.03	3.92	8.33	1.55	4.81	0.392
800	1.782	3.25	0.143	2.29	0.061			...	...	...	...	12.83	4.43	8.88	1.75	5.13	0.443
850	1.894	3.46	0.160	2.44	0.068	2.02	0.042	...	...	...	...	13.64	5.00	9.44	1.96	5.45	0.497
900	2.005	3.66	0.179	2.58	0.075	2.13	0.047	...	...	...	...	14.44	5.58	9.99	2.18	5.77	0.554
950	2.117	3.86	0.198	2.72	0.083	2.25	0.052			...	...	15.24	6.21	10.55	2.42	6.09	0.613
1 000	2.228	4.07	0.218	2.87	0.091	2.37	0.057	16"		...	...	16.04	6.84	11.10	2.68	6.41	0.675
1 100	2.451	4.48	0.260	3.15	0.110	2.61	0.068			...	...	17.65	8.23	12.22	3.22	7.05	0.807
1 200	2.674	4.88	0.306	3.44	0.128	2.85	0.080	2.18	0.042	...	...	...	...	13.33	3.81	7.70	0.948
1 300	2.896	5.29	0.355	3.73	0.150	3.08	0.093	2.36	0.048	...	...	...	...	14.43	4.45	8.33	1.11
1 400	3.119	5.70	0.409	4.01	0.171	3.32	0.107	2.54	0.055					15.55	5.13	8.98	1.28
1 500	3.342	6.10	0.466	4.30	0.195	3.56	0.122	2.72	0.063	18"				16.66	5.85	9.62	1.46
1 600	3.565	6.51	0.527	4.59	0.219	3.79	0.138	2.90	0.071					17.77	6.61	10.26	1.65
1 800	4.010	7.32	0.663	5.16	0.276	4.27	0.172	3.27	0.088	2.58	0.050			19.99	8.37	11.54	2.08
2 000	4.456	8.14	0.808	5.73	0.339	4.74	0.209	3.63	0.107	2.87	0.060	20"		22.21	10.3	12.82	2.55
2 500	5.570	10.17	1.24	7.17	0.515	5.93	0.321	4.54	0.163	3.59	0.091					16.03	3.94
3 000	6.684	12.20	1.76	8.60	0.731	7.11	0.451	5.45	0.232	4.30	0.129	3.46	0.075	24"		19.24	5.59
3 500	7.798	14.24	2.38	10.03	0.982	8.30	0.607	6.35	0.312	5.02	0.173	4.04	0.101			22.44	7.56
4 000	8.912	16.27	3.08	11.47	1.27	9.48	0.787	7.26	0.401	5.74	0.222	4.62	0.129	3.19	0.052	25.65	9.80
4 500	10.03	18.31	3.87	12.90	1.60	10.67	0.990	8.17	0.503	6.46	0.280	5.20	0.162	3.59	0.065	28.87	12.2
5 000	11.14	20.35	4.71	14.33	1.95	11.85	1.21	9.08	0.617	7.17	0.340	5.77	0.199	3.99	0.079	...	...
6 000	13.37	24.41	6.74	17.20	2.77	14.23	1.71	10.89	0.877	8.61	0.483	6.93	0.280	4.79	0.111	...	...
7 000	15.60	28.48	9.11	20.07	3.74	16.60	2.31	12.71	1.18	10.04	0.652	8.08	0.376	5.59	0.150	...	...
8 000	17.82	...	...	22.93	4.84	18.96	2.99	14.52	1.51	11.47	0.839	9.23	0.488	6.38	0.192	...	...
9 000	20.05	...	...	25.79	6.09	21.34	3.76	16.34	1.90	12.91	1.05	10.39	0.608	7.18	0.242	...	...
10 000	22.28	...	...	28.66	7.46	23.71	4.61	18.15	2.34	14.34	1.28	11.54	0.739	7.98	0.294	...	...
12 000	26.74	...	...	34.40	10.7	28.45	6.59	21.79	3.33	17.21	1.83	13.85	1.06	9.58	0.416	...	...
14 000	31.19	...	...	...	...	33.19	8.89	25.42	4.49	20.08	2.45	16.16	1.43	11.17	0.562	...	...
16 000	35.65	...	...	...	...	...	...	29.05	5.83	22.95	3.18	18.47	1.85	12.77	0.723	...	...
18 000	40.10	...	...	...	...	...	...	32.68	7.31	25.82	4.03	20.77	2.32	14.36	0.907	...	...
20 000	44.56	...	...	...	...	...	...	36.31	9.03	28.69	4.93	23.08	2.86	15.96	1.12	...	...

For pipe lengths other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table . . . for 300 feet, three times the given value, etc.

Velocity is a function of the cross sectional flow area; thus, it is constant for a given flow rate and is independent of pipe length.

For calculations for pipe other than Schedule 40, see explanation on next page.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-ME-006 Rev: 1

WBS No. 1.2.6.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	Daniel A. Veronica	Daniel A. Veronica	SR. MECH. ENGR.	8/22/91
CHECKER:	BERT H. ANZAI	Bert H. Anzai	SR. ENGINEER II	8/22/91
APPROVAL - LDE:	N/A			
APPROVAL - SCDM:	JAMES D. GRONIA	J. D. Gronia	DESC	8/22/91
QA CONCURRENCE:	PAUL B. HALE	Paul B. Hale	SR. QA Specialist	8-22-91

SUBJECT: UNDERGROUND SUPPORT SYSTEMS

TITLE: UNDERGROUND WASTE WATER COLLECTION SYSTEM

QAG Reference: RSN-GR-013, Rev. 0

1.0 PURPOSE

This analysis identifies the sources of underground waste water in the ESF and develops the required capacity, piping main size, and general layout of the system to collect and transfer waste water from the ESF to the surface water disposal system. As used in this analysis, the term "waste water" includes both naturally-occurring ground water inflows and water discharged from ESF construction, testing, and operation activities.

Revision 1 incorporates the comments received from the Management Review and Technical Review during August 1991.

2.0 METHOD

Waste water quantities from each source will be estimated based on design assumptions. The collection method for each source of waste water will be described. An appropriate underground storage (sump) volume and related pump capacities will be determined. From the resulting flow rate required to be transferred to the surface the piping main size will be determined. The general system layout will be represented schematically.

3.0 DESIGN INPUTS

3.1 The underground waste water collection system shall provide for control, handling, collection, treatment (as required), and transfer of waste water and ground water inflow to the surface waste water system. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 PC1a)

3.2 Gravity drainage, storage, and pumping systems, with adequate capacity and control measures, shall be designed and constructed for the control and transfer of underground water to the surface to ensure worker protection and to preclude adverse effects on in-situ site characterization testing or the ability of the site to meet performance objectives. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 PC1b)

a. Water handling and control underground shall be designed for all credible inflows, including inflow from penetration of fault structures or from perched water horizons, use of fire protection sprinklers, and from water line breakage.

b. The storage and pumping system shall have the capacity to accommodate a peak rate of 250 gpm or a steady flow of 20 gpm.

c. Adequate piping shall be provided to carry water from underground pump station(s) to the surface.

d. Pumping systems with adequate capacity shall be available.

e. The underground waste water collection system shall have full operating redundancy or shall have storage capacity to allow installation of spares in order to limit possible impacts on the isolation capability of the site.

3.3 The underground waste water collection system shall control standing water and air/water contact surfaces where ventilation air will be flowing in order to control humidity in air and to maintain the quality of the ventilation air being supplied. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 PC1c)

a. Control of humidity in the underground ventilation air shall be facilitated by reducing all underground (shaft, ramp, and test level) air/water contacts to the lowest practical level.

3.4 The underground waste water collection system shall utilize materials of construction that are resistant to erosive and corrosive effects, if economically practicable; otherwise, suitable monitoring and treatment facilities for credible groundwater inflows shall be available to control possible contamination and to prevent damage to pumping/piping systems from erosion or corrosion by waterborne particulates. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 PC1d)

3.5 Fluids recovered during construction operations shall be disposed of in such a way to avoid potential for performance impacts. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 PC1e)

3.6 The drainage and pumping systems shall accommodate measurement of the water as required. (YMP/CC-0013 5/31/91 ESFDR 1.2.6.7.6 PC1f)

3.7 The underground wastewater collection system shall be designed to prevent damage caused by water hammer and other destructive events. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.7.6 CA)

3.8 The design of the underground facility shall provide for control of water or gas intrusion. (YMP/CC-0013 Rev 5/31/91 ESFDR 1.2.6.8 CE v,vi)

a. Fluids recovered during testing operations shall be disposed of in such a way as to avoid potential for performance impacts.

b. Excess water shall be removed.

4.0 CODES AND STANDARDS

4.1 American National Standards Institute (ANSI)

ANSI B31.3-90 Chemical Plant and Refinery Piping

5.0 REFERENCE MATERIAL

5.1 Vendor Data

5.2 Crane Technical Paper #410 (Crane Co., 1988)

6.0 ASSUMPTIONS

6.1 (Section 9.1.1) Based on previous mining experience, waste water generated by tunneling of ramps, drift excavation, drill/blast, and testing will be no more than 25% of the water supplied to these operations as estimated in Tables 1 and 2 of ST-ME-001, "Underground Water Distribution System." The remaining water supplied will be in the muck carried to the surface by the conveyor/haulage system. (Verification not required)

6.2 (Section 9.1.2) Waste water generated by ground water inflow, including fault zone and perched waters, will be at a peak rate of 250 gpm or a steady flow of 20 gpm as stated in Section 3.2b. The peak rate will be assumed to occur for 1 hour, until the flow is stopped or reduced, and will be assumed as a possibility at any excavation or testing site. The steady rate will be assumed as a cumulative amount, generated throughout the ESF. (Verification not required)

6.3 (Section 9.1.3) The waste water generated from fire protection system actuation will be the entire accumulation from a design fire protection flowrate (700 gpm, as determined in ST-ME-001, "Underground Water Distribution System") occurring at the lowest planned ESF level (North end, Calico Hills Main Drift) for a duration of 1 hour. (Verification not required)

6.4 (Section 9.1.4) The waste water generated from a water line breakage will be the entire contents from a break at the low end of the volumetrically largest water pipe segment in the ESF. Water pipe segments will be established by placement of automatic excess-flow control valves as indicated in the attached schematic diagram. Flooding hazards will be considered in a safety analysis to be performed as part of the Title II design process. (Verification not required)

6.5 (YMP-025-2-MECH-P103) The installation of mine waste water system piping will follow the progress of Tunnel Boring Machine (TBM) excavation in each ramp. The system will be utilized during construction as described in ST-MN-020, "ESF Preliminary Excavation Plan." (Verification not required)

7.0 COMPUTER PROGRAM

None

8.0 UNITS

English Engineering System

9.0 CALCULATIONS/ANALYSIS

9.1 The assumptions of Section 6.0 lead to the following estimates of each source of waste water:

9.1.1 Applying the values of ST-ME-001 Tables 1 and 2 per Section 6.1; one tunneling operation (one TBM and one 2-drill rock bolter/jumbo) generates:

(25 ft dia. bore) .25(140 + 36) = 44 gpm waste water

(18 ft dia. bore) .25(76 + 36) = 28 gpm waste water

one drill/blast operation generates:

0.25(57) = 14 gpm waste water

one testing operation (1 large core and 1 small core) generates:

0.25(42) = 10.5 gpm waste water

9.1.2 A penetration of perched or fault zone ground water during excavation or testing (core drilling) generates a finite volume of:

250 gpm (60 min) = 15,000 gal

A continuous ground water inflow of 20 gpm is accumulated throughout the ESF.

9.1.3 As defined in Section 6.3, an event that actuates the fire protection system will generate a finite volume of waste water:

700 gpm (60 min) = 42,000 gal

9.1.4 The design water line break as defined in Section 6.4 would occur in the 8-inch water supply main in the South ramp, just upstream of the automatic excess flow valve located at the wye intersection. This subjects the volumetrically largest 8" piping segment in the ESF (9400 L.F.) to drainage down the ramp.

For 8" SCH 40 pipe, the volume/unit length is:

2.6 gal/L.F.

The waste water volume generated is:

9400 (2.6) = 24,440 gal

9.2 Collection of waste water is by methods specific to the quantity of water generated:

9.2.1 The waste water generated by water supplied to sites of excavation and testing activity (estimated in Section 9.1.1) are smaller quantities than the other sources and are intermittent with the activity schedule. Collection of these 10 gpm to 44 gpm flows is by a compressed air driven diaphragm pump at each site. The Wilden M-2 (approx. 30 gpm at 90 ft head, Appendix A-1) is a typical unit. This pump could discharge directly into a pipe leading the water via a collection header into the storage sump.

Under current plans, the location of the highest pressure head for the collection pump (diaphragm) is the extreme end of the Topopah Spring East Drift:

Elevation, intersection TS main/east drifts	=	3383′
Elevation, end of TS east drift	=	3192
		191′
Flow friction to intersection (3250 L.F. of 3" pipe @ 30 gpm, App. A-2)	=	3.7′
Pressure Head	=	195 ft.

Beyond the intersection of the TS Main and East Drifts, the gradient is negative and the water will gravity drain into a sump located at Elev. 3100′. Air diaphragm pumps are available with 195 ft or more discharge head. However, the volume of the 3" collection pipe to the intersection (3250 L.F.) is 1250 gallons. To accomplish repairs or maintenance on the collection pipe some or all of this water volume must be drained to the end of the drift making it necessary to have a tank volume available in the drift. This tank can be used in conjunction with routine waste water collection by having the diaphragm pump discharge into it rather than the pipe. A smaller, more portable diaphragm pump is then applicable for collection. A larger capacity submersible pump placed in the tank is used to empty the tank when full. Skid-mounting allows the tank to be moved down the drift, following excavation activity.

The arrangement of a collection tank with a larger capacity (relative to the diaphragm pumps) pump inside allows settling of suspended solids prior to pumping waste water into the collection piping. Combined with the higher flowrate of the larger pump, the arrangement reduces clogging of the collection piping and thus, is used in upsloping as well as downsloping drifts.

The tank must have sufficient reserve volume, even when full of collected waste water, to accommodate the volume of water in the collection pipe in the event of line breakage or repair. As an estimate, the minimum tank volume is twice the volume needed for pipe drainage:

$$2\ (1250) = 2500 \text{ gal}$$

9.2.2 Peak flows of waste water occurring naturally at perched horizons or fault zones are collected by the same equipment used in excavation and testing (Section 9.2.1). Discharging into the collection tank, the air diaphragm pump may see a typical pressure head of 15 - 20 ft. From the Wilden M-1 data (Appendix A-1) this equates to a flow rate of approximately 36 gpm. For the estimated 250 gpm peak flows:

$$\frac{250}{36} \approx 7 \text{ collection pumps required}$$

The minimum capacity of the submersible pump in the collection tank must then be 250 gpm against the highest planned collection pipe pressure head (end of TS east drift):

Elevation change to drift intersection = (from Section 9.2.1)	92′
Flow friction to intersection = (3250 L.F. of 3" pipe @ 250 gpm)	192′
	+284 ft

9.1.2 A penetration of perched or fault zone ground water during excavation or testing (core drilling) generates a finite volume of:

250 gpm (60 min) = 15,000 gal

A continuous ground water inflow of 20 gpm is accumulated throughout the ESF.

9.1.3 As defined in Section 6.3, an event that actuates the fire protection system will generate a finite volume of waste water:

700 gpm (60 min) = 42,000 gal

9.1.4 The design water line break as defined in Section 6.4 would occur in the 8-inch water supply main in the South ramp, just upstream of the automatic excess flow valve located at the wye intersection. This subjects the volumetrically largest 8" piping segment in the ESF (9400 L.F.) to drainage down the ramp.

For 8" SCH 40 pipe, the volume/unit length is:

2.6 gal/L.F.

The waste water volume generated is:

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9.2.1 The waste water generated by water supplied to sites of excavation and testing activity (estimated in Section 9.1.1) are smaller quantities than the other sources and are intermittent with the activity schedule. Collection of these 10 gpm to 44 gpm flows is by a compressed air driven diaphragm pump at each site. The Wilden M-2 (approx. 30 gpm at 90 ft head, Appendix A-1) is a typical unit. This pump could discharge directly into a pipe leading the water via a collection header into the storage sump.

Under current plans, the location of the highest pressure head for the collection pump (diaphragm) is the extreme end of the Topopah Spring East Drift:

Elevation, intersection TS main/east drifts	= 3383′
Elevation, end of TS east drift	= 3192
	191′
Flow friction to intersection (3250 L.F. of 3" pipe @ 30 gpm, App. A-2)	= 3.7′
Pressure Head	= 195 ft.

Beyond the intersection of the TS Main and East Drifts, the gradient is negative and the water will gravity drain into a sump located at Elev. 3100′. Air diaphragm pumps are available with 195 ft or more discharge head. However, the volume of the 3" collection pipe to the intersection (3250 L.F.) is 1250 gallons. To accomplish repairs or maintenance on the collection pipe some or all of this water volume must be drained to the end of the drift making it necessary to have a tank volume available in the drift. This tank can be used in conjunction with routine waste water collection by having the diaphragm pump discharge into it rather than the pipe. A smaller, more portable diaphragm pump is then applicable for collection. A larger capacity submersible pump placed in the tank is used to empty the tank when full. Skid-mounting allows the tank to be moved down the drift, following excavation activity.

The arrangement of a collection tank with a larger capacity (relative to the diaphragm pumps) pump inside allows settling of suspended solids prior to pumping waste water into the collection piping. Combined with the higher flowrate of the larger pump, the arrangement reduces clogging of the collection piping and thus, is used in upsloping as well as downsloping drifts.

The tank must have sufficient reserve volume, even when full of collected waste water, to accommodate the volume of water in the collection pipe in the event of line breakage or repair. As an estimate, the minimum tank volume is twice the volume needed for pipe drainage:

$$2\ (1250) = 2500 \text{ gal}$$

9.2.2 Peak flows of waste water occurring naturally at perched horizons or fault zones are collected by the same equipment used in excavation and testing (Section 9.2.1). Discharging into the collection tank, the air diaphragm pump may see a typical pressure head of 15 - 20 ft. From the Wilden M-1 data (Appendix A-1) this equates to a flow rate of approximately 36 gpm. For the estimated 250 gpm peak flows:

$$\frac{250}{36} \approx 7 \text{ collection pumps required}$$

The minimum capacity of the submersible pump in the collection tank must then be 250 gpm against the highest planned collection pipe pressure head (end of TS east drift):

Elevation change to drift intersection = 92′ (from Section 9.2.1)	
Flow friction to intersection (3250 L.F. of 3" pipe @ 250 gpm)	= 192′
	+284 ft

From the drift intersection to the TS level sump:

Elevation change	= -284′
Flow friction to sump (4750 L.F. of 3" pipe @ 250 gpm)	= +282′
	-2 ft additional head req'd
Total Head	284 ft

A discharge head of 284 ft, then, is sufficient for any collection tank submersible pump. The FLYGT #251 (Appendix A-1) is typical of the applicable submersible pumps, having a discharge of 115 gpm at 285 ft head. Two of these units are used for the peak (250 gpm) ground water flow with the remaining 20 gpm absorbed by the tank volume over the assumed one hour duration (Section 6.2).

Collection of the 20 gpm steady ground water flow is by gravity drainage of the waste water in covered trenches throughout the ESF. Covers on these trenches are perforated to admit inflow at any location. The waste water is diverted by these trenches in each ramp and drift to a sump on each ESF level.

9.2.3 Water discharged by the fire protection system is collected in the nearest sump by gravity drainage along the ramp/drift trench and floor.

9.2.4 Waste water created by a line break is collected in the nearest sump by gravity drainage similar to fire protection discharge.

9.3 A waste water storage volume (sump) is necessary in the ESF to provide:

An accumulation point for small waste water flows throughout the ESF, to allow pumping to the surface by high flowrate pumps.

A receiver for sudden, large waste water flows such as from fire protection or line breakage.

A settling area, to allow deposition of suspended solids in waste water (treatment) prior to pumping. Treatment extends the operating life of the high discharge head pumps necessary to deliver waste water to the surface, these pumps being significantly more expensive than the other pumps utilized in the ESF.

Because the ESF consists of two levels (Topopah Spring and Calico Hills) not interconnected by a gravity drain path, two sumps, one on each level are required.

9.3.1 Sizing of sump volume is based on required capacity to receive the largest single water inflow (from line break or fire protection). The largest generation of waste water occurs in the design fire protection event (Section 9.1.3):

Inflow volume = 42,000 gal

To maintain low humidity in the ESF, it is likely the sump will be generally maintained at low levels. Therefore, an ullage factor of 10% is sufficient to account for water already in the sump at the time of the inflow:

Sump volume = 42,000 + 0.1 (42,000)
= 46,200 gallons = 6,191 cu. ft.

This volume determination is applicable for both sumps.

9.3.2 Sump locations are at the lowest points in the main drifts of each level:

North end, Topopah Spring Main Drift = Elev. 3100 ft.
North end, Calico Hills Main Drift = Elev. 2702 ft.

9.4 Selection of pumps to deliver waste water from the sumps to the surface facilities is based on the following considerations:

minimum desired flow rate
discharge head required
appropriate pump type

9.4.1 The minimum desired flow rate is one that will prevent overflow of an already full sump while the design condition peak ground water flow (Section 6.2) is occurring.

minimum desired flow rate = 250 gpm

9.4.2 The discharge head required is the sum of static head (elevation head) and dynamic head from flow friction.

Table 1*

Elevation Head (Ft water)

	To North Portal	To South Portal
From TS sump	+587	+830
From CH sump	+985	+1228

With a 250 gpm flow rate, flow friction for a given material is dependent on pipe size. The dynamic head is the flow friction taken linearly over the effective length of pipe run:

Table 2

Actual Length of Pipe Run (L.F.)*

	To North Portal	To South Portal
From TS sump	6,478	19,787
From CH sump	10,788	26,682

* To estimate effective length of pipe run (which accounts for fitting losses), values are increased by 10%.

Pipe size is determined by a trial process where the smallest size pipe is selected that yields a reasonable value for dynamic head. For 6" diameter SCH 40 pipe, the friction factor is 0.195 ft water/100 L.F.. This yields:

Table 3

Dynamic Head Loss (ft water)

	To North Portal	To South Portal
From TS sump	13.9	42.4
From CH sump	23.1	57.2

For a 4" diameter pipe the friction factor increases 7.5 times (unacceptable). An 8" diameter pipe reduces flow friction by 4 times (not necessary considering the values involved). A 6" pipe is the optimal size.

Combining the data of Tables 1 and 3:

Table 4

Discharge Head Required (Ft water)

	To North Portal	To South Portal
From TS sump	601	872
From CH sump	1008	1285

Given the discharge head as the principal criteria, the logical primary waste water discharge paths are the routes to the North Portal. So, pump selection is based on achieving 250 gpm only to the North Portal, with a lesser maximum flow rate to the South Portal acceptable. The redundant flow paths as required by Section 3.2e are still available.

The substantial (67%) increase in discharge head required at the CH sump compared to the TS sump represents fewer selection options and a larger, more expensive pump(s) for CH level. Staging the CH sump discharge path to the TS sump instead of directly to the surface results in the following:

Via North Ramp

Elevation Head (CH sump to Y-intersection)	= 454 ft.
Friction Head to intersection (5,091 L.F. + 10%) x 0.195 ft/100 L.F.	= 11 ft.
Discharge Head Required CH sump to TS sump	= 465 ft.

Via South Ramp

Elevation Head (CH sump to Y-intersection)	= 1096 ft.
Friction Head to intersection (18,364 L.F. + 10%) x 0.195 ft/100 L.F.	= 39 ft.
Discharge Head Required CH sump to TS sump	= 1135 ft.

Compared to the data in Table 4, sending CH sump discharge to the TS sump reduces required discharge head by 54% via the North Ramp but only by 12% via the South Ramp. Pump discharge head for the CH sump is based on staging to the TS sump via the North Ramp as the primary discharge path. The pump selected will not be able to transfer water to the TS sump via the South Ramp. To obtain system redundancy at the CH level, one of the following will be addressed in Title II work:

- A vertical pipe to TS level, bypassing the intersection.
- An intermediate staging sump with additional pump(s) in the CH South Ramp.
- Higher head pumps.

The waste water system design utilizes two identical pumps at each sump (for redundancy). Also, pumps for both sumps are identical (for cost economics), so four similar pumps are used. The discharge head required for all pumps is based on the primary (250 gpm) flow path having the highest head; TS sump to North Portal.

Discharge Head required @ 250 gpm = 601 ft. water
= 261 psig

For pumping the TS sump via the alternate discharge path to the South Portal, a minimum flow rate of 20 gpm, based on the requirements of Section 3.2b, is chosen:

Discharge Head required @ 20 gpm = 872 ft. water
= 377 psig

9.4.3 There are five generic types of pumps capable of the required discharge head and flow rate.

a. A multi-stage centrifugal, high pressure pump: These are skid mounted with coupled motor and pump.

b. A multi-stage centrifugal submersible, medium pressure pump: These are built to stack in series to produce the high head pressure needed.

c. A multi-stage centrifugal submersible, high pressure pump: This large pump is capable of high head pressure in one submersible unit.

d. Slurry type, centrifugal pumps: These pumps are available only in medium pressure, rubber lined pumps, that must be coupled in series to produce the required head pressure. These units are skid mounted.

e. Piston type pumps used in oil field service: These pumps are high pressure, skid mounted, but very large.

Pumps of type (b) and (d) are not considered as both require stacking or coupling of multiple units to achieve the discharge head requirements. The space needed is excessive for these units. In addition, pumps of type (d) require the last unit to have a variable speed drive. A multiple unit system is less reliable than a single unit since multiple motors and couplings create a higher risk of failure.

The remaining three types of pumps (a,c,e) all deliver the high head pressure using one unit, but vary considerably in other characteristics. The piston type slurry pump (e) meets all the pressure and volume criteria, but carries a larger horsepower requirement (350 Hp). It is normally powered by a diesel engine, but can be powered by electric motor through a gearbox speed changer at the expense of added space and heat (compared to submersible pumps which transfer heat to the fluid being pumped). Due to the positive displacement nature of these pumps, a

manual reset relief valve would be required to prevent damage to discharge piping should blockage due to sludge, or accidental valve closure. A centrifugal pump can operate for short durations under blocked conditions with no overpressure problems. The piston pumps are about double the weight of the other two pumps. From the preceding, piston pumps (e) are not considered further.

When compared to a non-submersible centrifugal pump type (a), a submersible centrifugal type (c) is not limited by suction or priming. Generated heat from the motor of the submersible unit is rejected into the waste water instead of the ESF spaces. The submersible unit is flood-proof during adverse events and generally, submersible units are more frequently available in models which are designed to tolerate suspended solids (i.e., sand, grit) in the pumped media.

Based on the discussion of this section, multi-stage centrifugal submersible pumps are used at each ESF sump.

10.0 RECOMMENDATIONS:

Based on the discussion of Section 9.0, the arrangement of the ESF waste water collection system as depicted in the attached schematic flow diagram is recommended. The system piping consists of 6" SCH 40 discharge mains and 3" SCH 40 collection pipes. Waste water is collected by 36 gpm air-powered diaphragm pumps discharging into 2500 gal tanks with a 115 gpm @ 285 ft head submersible pump inside. Collected waste water is delivered to 42,000 gal sumps at the low points of the TS and CH main drifts. Sumps are pumped to the surface waste water facilities by multi-stage centrifugal submersible pumps delivering at least 250 gpm @ 601 ft head.

APPENDIX A

A-1 Vendor Data Sheets

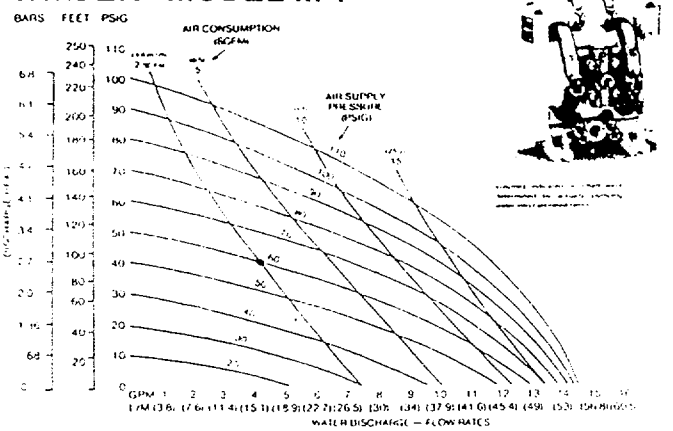
A-2 Pipe Flow Friction

A-1 Vendor Data Sheets

Wilden Diaphragm Pump M-2

Flygt Submersible Pump #251

WILDEN® MODEL M-1®

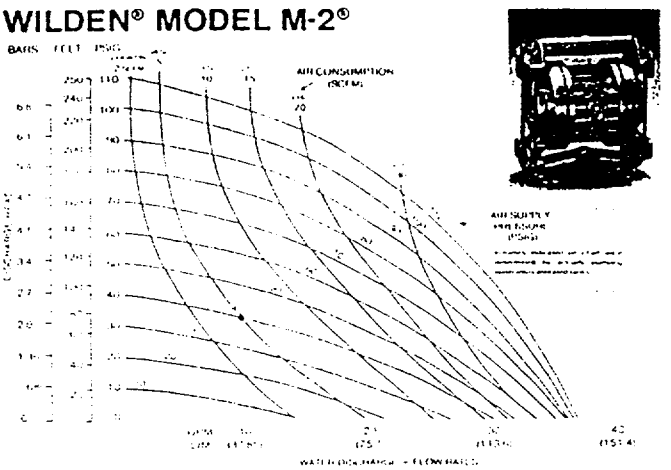


Height ..... 8½" Air Inlet ... ¼" Female NPT Suction Lift ... POLY. 15' Dry
Width ..... 8" Inlet ..... ½" Female NPT POLY. 25' Wet
Depth ..... 6½" Outlet ..... ½" Female NPT TEFLON 8' Dry
Weight ..... POLY. 8 lbs. Max. Size Solids ... 1/16" Dia. TEFLON 25' Primed

Example: *To pump 4 gpm against a discharge pressure of 40 psig requires 60 psig and 9 scfm air consumption. (See dot on chart.)*

Caution: Do not exceed 100 psig air supply pressure.

WILDEN® MODEL M-2®



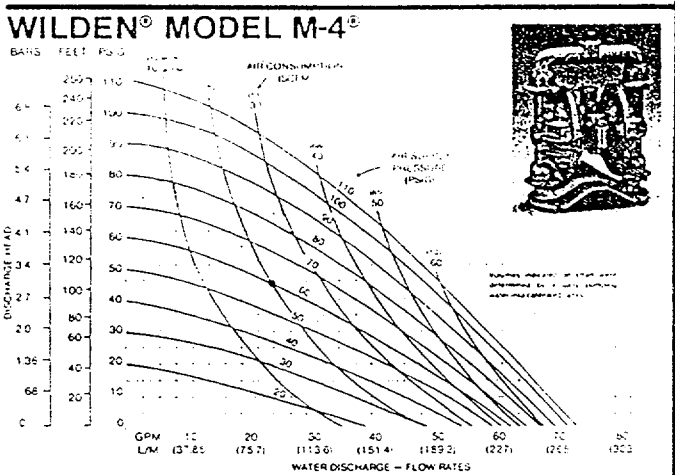
Height ..... 10½" Air Inlet ..... ¼" NPT Suction Lift ..... 18' Dry
Width ..... 10½" Inlet ..... 1" Male NPT 25' Wet
Depth ..... 7" Outlet ..... ¾" Male NPT Weight: ..... ALUM. 22 lbs.
Max. Size Solids ... ⅛" Dia. SS/HASTELLOY 35 lbs.

Example: *To pump 10 gpm against a discharge pressure of 50 psig requires 40 psig and 5 scfm air consumption. (See dot on chart.)*

Note: For M-2 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-2 pumps with Teflon diaphragms: 10 ft. dry, 25 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® MODEL M-4®



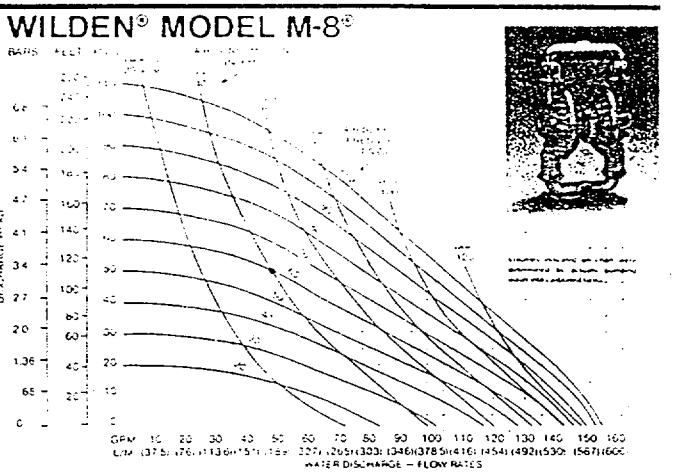
Height ..... 16" Air Inlet ..... ⅜" NPT Suction Lift ..... 22' Dry
Width ..... 14¼" Inlet ..... 1½" Female NPT 27' Wet
Depth ..... 11¾" Outlet ..... 1¼" Male NPT Weight: ..... ALUM. 35 lbs.
Max. Size Solids ... 3/16" Dia. IRON/S.S. 52 lbs.

Example: *To pump 22.5 gpm against a discharge pressure of 45 psig requires 60 psig and 20 scfm air consumption. (See dot on chart.)*

Note: For M-4 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-4 pumps with Teflon diaphragms: 12 ft. dry, 25 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® MODEL M-8®



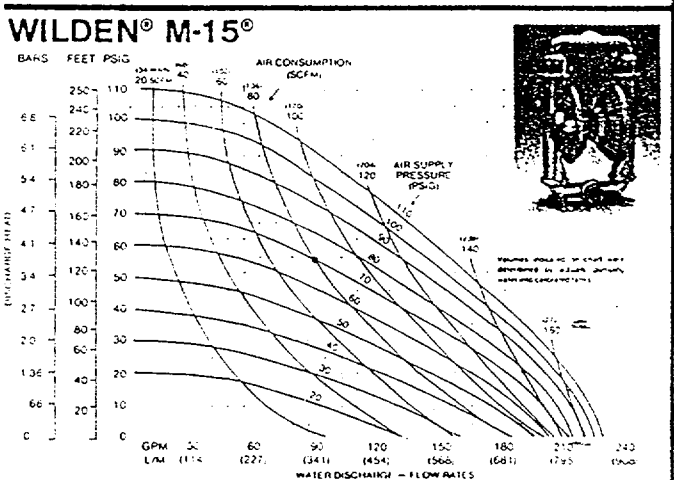
Height ..... 26¼" Air Inlet ..... ½" NPT Suction Lift ..... 20' Dry
Width ..... 15¾" Inlet ..... 2" Male NPT 25' Wet
Depth ..... 13¼" Outlet ..... 2" Male NPT Weight: ..... ALUM. 65 lbs.
Max. Size Solids ... ¼" Dia. IRON/S.S. 110 lbs.

Example: *To pump 47 gpm against a discharge pressure of 50 psig requires 60 psig and 40 scfm air consumption. (See dot on chart.)*

Note: For M-8 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-8 pumps with Teflon diaphragms: 12 ft. dry, 18 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® M-15®



Height ..... 32¾" Air Inlet ..... ½" NPT Weight: ..... ALUM. 120 lbs.
Width ..... 20" Inlet ..... 3" Male NPT IRON/S.S. 195 lbs.
Depth ..... 16" Outlet ..... 3" Male NPT Suction Lift ..... 20' Dry
Max. Size Solids ... ⅜" Dia. 25' Wet

Example: *To pump 90 gpm against a discharge pressure of 55 psig requires 70 psig and 80 scfm air consumption. (See dot on chart.)*

Note: For M-15 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-15 pumps with Teflon diaphragms: 12 ft. dry, 18 ft. wet.

In addition to those pumps listed, Wilden also offers:

The model M20. This pump offers flows to 320 gpm. Available in cast iron wetted construction only. The pump is manufactured with 4" American Standard Pipe Flange, 125 lb. class. The M20 offers the same ease of maintenance as our standard pump line.

The model M8 High Pressure Pump. This unit is capable of pumping product against 650 ft. of head pressure. Available in stainless steel wetted construction with Saniflex diaphragms only.

Please contact the factory for additional information regarding our new pump models.

WILDEN PUMP & ENGINEERING CO.

22069 Van Buren Street / P.O. Box 845
Colton, California 92324
714 / 422-1700
Telex: 676-452

Wilden recommends that in order to insure pump integrity, titability, and performance — replacement parts be Wilden replacement parts. We cannot guarantee the quality or reliability of after-market "will fit" parts.

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BS

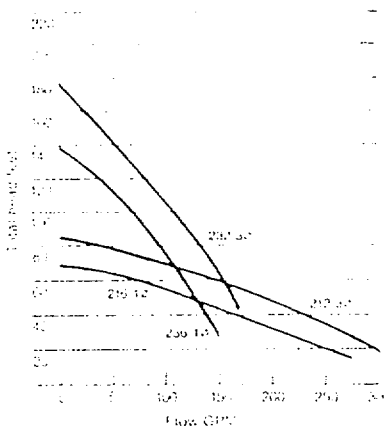
Dewatering

Semi-open multi-vane impeller made of abrasion-resistant steel (60 Rc Hardness).

Slim Portables

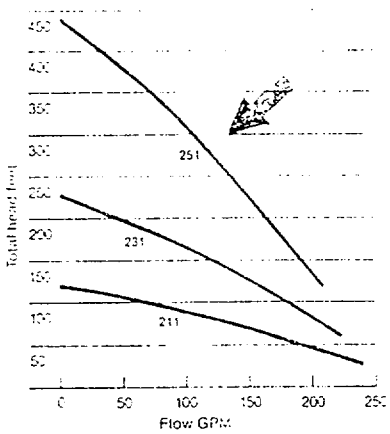
BS 2071

Service:	60 Hz 1Ø & 3Ø
Voltage:	230 & 230/460 or 575 V
HP rating:	4.2 & 5.9
RPM:	3450
Pump dimensions:	7¼" W (max.) x 27" H (max.)
Min. opening pump clears:	8" x 8" rect. or 8" dia.
Versions:	2" High head Imp. Code 232 3Ø Imp. Code 236 1Ø 3" High volume Imp. Code 212 3Ø Imp. Code 216 1Ø
Max. weight (lbs.):	67
Special features:	Integral cooling system. Pilot thermal sensors embedded in stator.



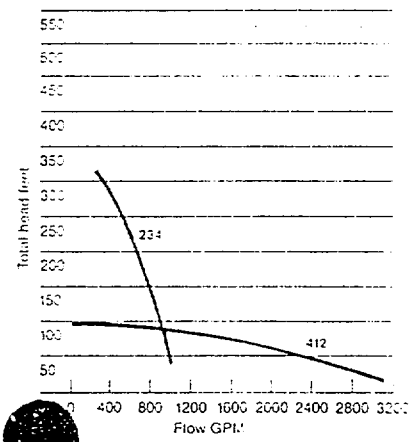
BS 2084

Service:	60 Hz 3Ø
Voltage:	230/460 or 575 V
HP rating:	6.3, 12 and 22
RPM:	3400
Pump dimensions:	9⅞" W (max.) x 38⅞" H (max.)
Min. opening pump clears:	12" x 12" rect. or 12" dia.
Versions:	3" High head Imp. Code 251, 22 HP 3" Std. performance Imp. Code 231, 12 HP 4" High volume Imp. Code 211, 6.3 HP
Max. weight (lbs.):	230
Special features:	Integral cooling system. Available in permissible variant.



BS 2201

Service:	60 Hz 3Ø
Voltage:	460 or 575 V
HP rating:	50 and 56
RPM:	HH 3450; HV 1760
Pump dimensions:	HH 17" W x 41⅜" H HV 19" W x 45⅜" H
Min. opening pump clears:	22" x 22" rect. or 22" dia.
Versions:	4" High head Imp. Code 234 6" High volume Imp. Code 412
Max. weight (lbs.):	HH 530; HV 628
Special features:	Integral cooling system. Pilot thermal sensors embedded in stator. Available in permissible variant.



A-2 Pipe Flow Friction

Table B-14 from Crane Co. Technical Paper #410

Flow of Water Through Schedule 40 Steel Pipe

Discharge		Pressure Drop per 100 feet and Velocity in Schedule 40 Pipe for Water at 60 F.																			
		Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop
Gallons per Minute	Cubic Ft. per Second	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.
		1/8"		1/4"		3/8"		1/2"		3/4"		1"		1 1/4"		1 1/2"			
.2	0.000446	1.13	1.86	0.616	0.359														
.3	0.000668	1.69	4.22	0.924	0.903	0.504	0.159	0.317	0.061										
.4	0.000891	2.26	6.98	1.23	1.61	0.672	0.345	0.422	0.086										
.5	0.00111	2.82	10.5	1.54	2.39	0.840	0.539	0.528	0.167	0.301	0.033								
.6	0.00134	3.39	14.7	1.85	3.29	1.01	0.751	0.633	0.240	0.361	0.041								
.8	0.00178	4.52	25.0	2.46	5.44	1.34	1.25	0.844	0.405	0.482	0.102								
1	0.00223	5.65	37.2	3.08	8.28	1.68	1.85	1.06	0.600	0.602	0.155	0.371	0.048						
2	0.00446	11.29	134.4	6.16	30.1	3.36	6.58	2.11	2.10	1.20	0.526	0.743	0.164	0.429	0.044				
3	0.00668			9.25	64.1	5.04	13.9	3.17	4.33	1.81	1.09	1.114	0.336	0.644	0.090	0.473	0.043		
4	0.00891			12.33	111.2	6.72	23.9	4.22	7.42	2.41	1.83	1.49	0.565	0.858	0.150	0.630	0.071		
5	0.01114	2"				8.40	36.7	5.28	11.2	3.01	2.75	1.86	0.835	1.073	0.223	0.788	0.104		
6	0.01337	0.574	0.044	2 1/2"		10.08	51.9	6.33	15.8	3.61	3.84	2.23	1.17	1.29	0.309	0.946	0.145		
8	0.01782	0.765	0.073			13.44	91.1	8.45	27.7	4.82	6.60	2.97	1.99	1.72	0.518	1.26	0.243		
10	0.02228	0.956	0.108	0.679	0.046			10.56	42.4	6.02	9.99	3.71	2.99	2.15	0.774	1.58	0.365		
15	0.03342	1.43	0.224	1.02	0.094	3"				9.03	21.6	5.57	6.36	3.22	1.63	2.37	0.755		
20	0.04456	1.91	0.375	1.36	0.158	0.868	0.056	3 1/2"		12.04	37.8	7.43	10.9	4.29	2.78	3.16	1.28		
25	0.05570	2.39	0.561	1.68	0.234	1.08	0.083	0.872	0.041	4"		9.28	16.7	5.37	4.22	3.94	1.93		
30	0.06684	2.87	0.786	2.01	0.327	1.30	0.114	0.974	0.056			11.14	23.8	6.44	5.92	4.73	2.72		
35	0.07798	3.35	1.05	2.35	0.436	1.52	0.151	1.14	0.071	0.872	0.041	12.99	32.2	7.51	7.90	5.52	3.64		
40	0.08912	3.83	1.35	2.68	0.556	1.74	0.192	1.30	0.095	1.00	0.052	14.85	41.5	8.59	10.24	6.30	4.65		
45	0.1003	4.30	1.67	3.02	0.668	1.95	0.239	1.46	0.117	1.13	0.064			9.67	12.80	7.09	5.85		
50	0.1114	4.78	2.03	3.35	0.839	2.17	0.288	1.62	0.142	1.25	0.076	5"		10.74	15.66	7.88	7.15		
60	0.1337	5.74	2.87	4.02	1.18	2.60	0.406	1.95	0.204	1.50	0.107			12.89	22.2	9.47	10.21		
70	0.1560	6.70	3.84	4.69	1.59	3.04	0.540	2.27	0.261	1.75	0.143	1.12	0.047			11.05	13.71		
80	0.1782	7.65	4.97	5.36	2.03	3.47	0.687	2.60	0.334	2.00	0.180	1.28	0.060			12.62	17.59		
90	0.2005	8.60	6.20	6.03	2.53	3.91	0.861	2.92	0.416	2.25	0.224	1.44	0.074	6"		14.20	22.0		
100	0.2228	9.56	7.59	6.70	3.09	4.34	1.05	3.25	0.504	2.50	0.272	1.60	0.090	1.11	0.036	15.78	26.9		
125	0.2785	11.97	11.76	8.38	4.71	5.43	1.61	4.06	0.769	3.13	0.415	2.01	0.135	1.39	0.055	19.72	41.4		
150	0.3342	14.36	16.70	10.05	6.69	6.51	2.24	4.87	1.08	3.75	0.580	2.41	0.190	1.67	0.077				
175	0.3899	16.75	22.3	11.73	8.97	7.60	3.00	5.68	1.44	4.42	0.774	2.81	0.253	1.94	0.102				
200	0.4456	19.14	28.8	13.42	11.68	8.68	3.87	6.49	1.85	5.04	0.985	3.21	0.323	2.22	0.130	8"			
225	0.5013	...	...	15.09	14.63	9.77	4.83	7.30	2.32	5.67	1.23	3.61	0.401	2.50	0.162	1.44	0.043		
250	0.557	...	...	...	...	10.85	5.93	8.12	2.84	6.30	1.46	4.01	0.495	2.78	0.195	1.60	0.051		
275	0.6127	...	...	...	...	11.94	7.14	8.93	3.40	6.93	1.79	4.41	0.583	3.06	0.234	1.76	0.061		
300	0.6684	...	...	...	...	13.00	8.36	9.74	4.02	7.56	2.11	4.81	0.683	3.33	0.275	1.92	0.072		
325	0.7241	...	...	...	...	14.12	9.89	10.53	4.69	8.19	2.47	5.21	0.797	3.61	0.320	2.08	0.083		
350	0.7798			...	...	...	...	11.36	5.41	8.82	2.84	5.62	0.919	3.89	0.367	2.24	0.095		
375	0.8355			...	...	...	...	12.17	6.18	9.45	3.25	6.02	1.05	4.16	0.416	2.40	0.108		
400	0.8912			...	...	...	...	12.98	7.03	10.08	3.68	6.42	1.19	4.44	0.471	2.56	0.121		
425	0.9469			...	...	...	...	13.80	7.89	10.71	4.12	6.82	1.33	4.72	0.529	2.73	0.136		
450	1.003	10"		...	...	...	...	14.61	8.80	11.34	4.60	7.22	1.48	5.00	0.590	2.89	0.151		
475	1.059	1.93	0.054			...	...	...	...	11.97	5.12	7.62	1.64	5.27	0.653	3.04	0.165		
500	1.114	2.03	0.059			...	...	...	...	12.60	5.65	8.02	1.81	5.55	0.720	3.21	0.182		
550	1.225	2.24	0.071			...	...	...	...	13.85	6.79	8.82	2.17	6.11	0.861	3.53	0.219		
600	1.337	2.44	0.083			...	...	...	...	15.12	8.04	9.63	2.55	6.66	1.02	3.85	0.258		
650	1.448	2.64	0.097	12"		...	...	...	...	...	...	10.43	2.98	7.22	1.18	4.17	0.301		
700	1.560	2.85	0.112	2.01	0.047						...	11.23	3.43	7.78	1.35	4.49	0.343		
750	1.671	3.05	0.127	2.15	0.054	14"					...	12.03	3.92	8.33	1.55	4.81	0.392		
800	1.782	3.25	0.143	2.29	0.061						...	12.83	4.43	8.88	1.75	5.13	0.443		
850	1.894	3.46	0.160	2.44	0.068	2.02	0.042				...	13.64	5.00	9.44	1.96	5.45	0.497		
900	2.005	3.66	0.179	2.58	0.075	2.13	0.047				...	14.44	5.58	9.99	2.18	5.77	0.554		
950	2.117	3.86	0.198	2.72	0.083	2.25	0.052				...	15.24	6.21	10.55	2.42	6.09	0.613		
1 000	2.228	4.07	0.218	2.87	0.091	2.37	0.057	16"			...	16.04	6.84	11.10	2.68	6.41	0.675		
1 100	2.451	4.48	0.260	3.15	0.110	2.61	0.068				...	17.65	8.23	12.22	3.22	7.05	0.807		
1 200	2.674	4.88	0.306	3.44	0.128	2.85	0.080	2.18	0.042		...	...	...	13.33	3.81	7.70	0.948		
1 300	2.896	5.29	0.355	3.73	0.150	3.08	0.093	2.36	0.048		...	...	...	14.43	4.45	8.33	1.11		
1 400	3.119	5.70	0.409	4.01	0.171	3.32	0.107	2.54	0.055					15.55	5.13	8.98	1.28		
1 500	3.342	6.10	0.466	4.30	0.195	3.56	0.122	2.72	0.063	18"				16.66	5.85	9.62	1.46		
1 600	3.565	6.51	0.527	4.59	0.219	3.79	0.138	2.90	0.071					17.77	6.61	10.26	1.65		
1 800	4.010	7.32	0.663	5.16	0.276	4.27	0.172	3.27	0.088	2.52	0.050			19.99	8.37	11.54	2.08		
2 000	4.456	8.14	0.808	5.73	0.339	4.74	0.209	3.63	0.107	2.80	0.060	20"		22.21	10.3	12.82	2.55		
2 500	5.570	10.17	1.24	7.17	0.515	5.93	0.321	4.54	0.163	3.50	0.091					16.03	3.94		
3 000	6.684	12.20	1.76	8.60	0.731	7.11	0.451	5.45	0.232	4.20	0.129	3.46	0.075	24"		19.24	5.59		
3 500	7.798	14.24	2.38	10.03	0.982	8.30	0.607	6.35	0.312	5.02	0.173	4.04	0.101			22.44	7.56		
4 000	8.912	16.27	3.08	11.47	1.27	9.48	0.787	7.26	0.401	5.74	0.222	4.62	0.129	3.19	0.052	25.65	9.80		
4 500	10.03	18.31	3.87	12.90	1.60	10.67	0.990	8.17	0.503	6.46	0.280	5.20	0.162	3.59	0.065	28.87	12.2		
5 000	11.14	20.35	4.71	14.33	1.95	11.85	1.21	9.08	0.612	7.17	0.340	5.77	0.199	3.98	0.079	...	...		
6 000	13.37	24.41	6.74	17.20	2.77	14.23	1.71	10.89	0.877	8.61	0.483	6.91	0.280	4.79	0.111	...	...		
7 000	15.60	28.49	9.11	20.07	3.74	16.60	2.31	12.71	1.18	10.04	0.652	8.08	0.376	5.59	0.150	...	...		
8 000	17.82	...	...	22.93	4.84	18.96	2.99	14.52	1.51	11.47	0.839	9.23	0.488	6.38	0.192	...	...		
9 000	20.05	...	...	25.79	6.09	21.34	3.76	16.34	1.90	12.91	1.05	10.39	0.608	7.18	0.242	...	...		
10 000	22.28	...	...	28.66	7.46	23.71	4.61	18.15	2.34	14.34	1.28	11.54	0.739	7.98	0.294	...	...		
12 000	26.74	...	...	34.40	10.7	28.45	6.59	21.79	3.33	17.21	1.83	13.85	1.06	9.58	0.416	...	...		
14 000	31.19	...	...	...	...	33.19	8.89	25.42	4.49	20.08	2.45	16.16	1.43	11.17	0.562	...	...		
16 000	35.65	...	...	...	...	...	...	29.05	5.83	22.95	3.18	18.47	1.85	12.77	0.723	...	...		
18 000	40.10	...	...	...	...	...	...	32.68	7.31	25.82	4.03	20.77	2.32	14.36	0.907	...	...		
20 000	44.56	...	...	...	...	...	...	36.31	9.03	28.69	4.93	23.08	2.86	15.96	1.12	...	...		

For pipe lengths other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table . . . for 300 feet, three times the given value, etc.

Velocity is a function of the cross sectional flow area; thus, it is constant for a given flow rate and is independent of pipe length.

For calculations for pipe other than Schedule 40, see explanation on next page.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-ME-011 Rev: 0

WBS No. 1.2.6.6	PRINT NAME	SIGNATURE	TITLE	DA
ORIGINATOR:	DANIEL A. VERONICA	Daniel A. Veronica	SR. MECH. ENGR.	7/18
CHECKER:	BERT H. ANZAI	Bert H. Anzai	SR. ENGR. II	7/1
APPROVAL - LDE:	NA	NA	NA	N
APPROVAL - SCDM:	JAMES D. GRENIA	James D. Grenia	DESE / SCDM MGR.	7/2
QA CONCURRENCE:	PAUL B HALE	Paul B Hale	SR QA SPECIALIST	8-20

SUBJECT: UNDERGROUND SUPPORT SYSTEMS

TITLE: COMPRESSED AIR DISTRIBUTION SYSTEM

QAG Reference: RSN-GR-013, Rev. 0

1.0 PURPOSE:

This analysis identifies and evaluates the compressed air system demand requirements, and determines the size of piping necessary to distribute compressed air within the Exploratory Studies Facility (ESF).

2.0 METHOD:

This analysis will be prepared by identifying the compressed air demand of each operation related to ESF construction, testing and operation. The planned schedule of those operations will be used to develop a value for the design compressed air demand. From the volumetric flow requirements to meet the design demand value, an appropriate pipe size for the compressed air mains will be determined.

3.0 DESIGN INPUTS:

3.1 The compressed air system shall provide compressed air throughout the designated areas of the ESF with the flow rates and pressure to support construction and operations of the facilities, site characterization testing requirements, and drilling requirements including additional drift excavation. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.2.6 PC1a)

3.2 Compressed air shall be conditioned as required and maintained at a quantity to meet drilling and test apparatus requirements. Suitable filtering shall be provided where oil-free air is required. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.2.6 PC1b)

3.3 The design shall include an air compressor(s) sized to meet the requirements of the ESF construction, testing, and operations. The design shall consider modularity of the system to accommodate variable loads and system maintenance. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.2.6 PC1c)

3.4 All compressed air used during operation and construction of the ESF shall be provided with chemical tracers unless exempted by the ESF Test Manager. All tracers and substances added shall be approved per ESFDR Section 1.2.6.0, Constraint Ciii. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.2.6 PC1d)

3.5 Compressed air shall be distributed at a quantity and pressure sufficient to meet underground ESF construction, operations, and site characterization testing requirements. The compressed air distribution system shall also be sufficient to meet drilling requirements during ESF operations to support additional drift excavation. (YMP/CC-0013, Revision 5/31/91, ESFDR 1.2.6.7.7 PC1)

4.0 CODES AND STANDARDS:

4.1 American National Standards Institute (ANSI)

ANSI B31.3-90 Chemical Plant and Refinery Piping

5.0 REFERENCE MATERIAL:

5.1 Vendor Data Sheets: Atlas Copco H235 Jumbo with COP 1238 Drill; Longyear - 38 diamond core drill; Tarve and Watson HDC-750-BB-360 Pump

5.2 SME Mining Engineering Handbook - Volume 1; 1st Edition (American Institute of Mining, Metallurgical and Petroleum Engineers, 1973)

5.3 Mining Engineering Handbook; 3rd Edition (Wiley, 1945)

5.4 Standard Handbook of Engineering Calculations; 2nd Edition (McGraw-Hill, 1985)

5.5 Plant Engineering Handbook; 2nd Edition (McGraw-Hill, 1959)

5.6 Crane Technical Paper #410 (Crane Co., 1988)

6.0 ASSUMPTIONS:

6.1 (YMP-025-2-MECH-PI05) To provide reliable compressed air distribution and system redundancy, compressed air from both ramps shall be distributed to the Topopah Spring level and Calico Hills level. (Verification not required)

6.2 (Section 9.7) The load factor for compressed air consumption will be 1.0. A load factor of 1.0 implies continuous service. (Verification not required)

6.3 (Section 9.6) The leakage rate for compressed air will be 10% of demand. (Verification not required)

6.4 (Section 9.9) Compressed air supply pressure will be 125 psig at the compressor discharge. This assumption permits use of two existing GFE Ingersoll-Rand SSR-2000-1500H Rotary-Screw Air Compressors of 1500 acfm capacity at 125 psig. Four more compressors of similar specifications will be purchased, allowing a design which employs three compressors at each ESF portal for system maintenance and reliability. (Verification required in Title II design)

6.5 (Section 9.9) At least one anticipated piece of pneumatic equipment, the Ingersoll-Rand DHD-112 Rock Drill, requires more than 125 psig supply pressure (Ref. Appendix A-1). Where equipment requires a higher supply pressure, the pressure will be increased locally by a boost compressor. (Verification not required)

6.6 (Table 1) Compressed air requirements of surface facilities are small enough to be satisfied by individual compressors placed locally and do not require distribution from the ESF compressed air system. (Verification required in Title II Design)

6.7 (Section 9.8) The design case for compressed air distribution is for the piping in one ramp to deliver the design flowrate (developed in this study) at 100 psig to the most remote location likely to occur during the construction phase. This case is assumed because after the construction phase, compressed air at any location in the ESF will be delivered by piping in both ramps, presenting a less restrictive situation. Such an assumption implies the main drifts will be completed before any significant amount of branch drifting takes place, which is consistent with ST-MN-020 "ESF Preliminary Excavation Plan." (Verification not required)

6.8 (Section 9.8) Main drift construction will be completed (Section 6.7) by a meeting of opposing TBMs, assumed to occur near the middle of the drift. (Verification not required)

7.0 COMPUTER PROGRAM:

None

8.0 UNITS:

English Standard Units

9.0 CALCULATIONS/ANALYSIS:

The compressed air demand varies depending on the equipment spreads employed at various phases on construction, testing and operation. The system will be designed to meet the consumption of the phase with the highest demand, based on current equipment usage plans.

9.1 The compressed air demand for the various phases of activity is shown in Table 1:

TABLE 1

Equipment Air Usage (Per Operation)

Operation/Equipment	Quantity	Unit Flow (SCFM)	Total Demand (SCFM)
Tunneling TS and CH Ramps (from either portal)			
Rock Bolter/Jumbo (2 drills/each)	2	N/A	0
TBM	2	N/A	0
			0 SCFM
Drill and Blast (Alcove/Intersection)			
Jumbo-Electro-Hydraulic (1 Jumbo - 3 Drills)	3	N/A	0
Blast Face Spray	1	300	300
Blow Pipe	1	376	376
Diaphragm Pump	1	12	12
			688 SCFM
Drift Excavation			
Mobile Miner/Road Header	1	N/A	0
			0 SCFM
Testing (1 large hole site and 1 small hole simultaneously)			
Core Drill (Large)	1	1320*	1320
Core Drill (Small)	1	400**	400
Diaphragm Pump	4	12	48
Impact Wrench	4	30	120
			1888 SCFM

Notes:

* Typical for I-R DHD-112
** Typical for Longyear 65

9.2 A large hole drill jumbo such as an Ingersoll-Rand CMM-2 will be used for testing (core drilling). It is anticipated that the CMM-2 will be adapted to use an electric motor to power the hydraulic system, thus eliminating any air consumption for the jumbo. Large diameter pneumatic down-hole drills such as the Ingersoll-Rand DHD-112 (Appendix A-1) are expected to be used with the CMM-2. Pneumatic drills such as the Watson HDC-750 or Longyear 65 will be employed for smaller core drilling (Appendix A-1).

9.3 The air demand for impact wrenches is determined from Appendix A-2. The air demand for a diaphragm pump typical of the capacity required is shown in Appendix A-3. A blast face spray device like the one shown in Appendix A-3 uses air and water to create a fog for dust suppression. The air consumption is estimated using the information shown in Appendix A-3. To insure full consideration, 300 scfm is used for Table 1. It is anticipated that only one blast face spray will be in use per blasting operation. The blowpipe airflow requirements can be estimated by determining the discharge of air through a pipe with a 1/2-inch orifice at 90 psig. The airflow discharge rate is 376 scfm as shown in Appendix A-4.

9.4 Considering the four operations outlined in Table 1, it is conceivable that, at some point in the ESF construction and testing activities, a combination of these operations would be necessary simultaneously in each access ramp. To accommodate maximum system utilization, the apparent design value for air demand would be the sum of one drill and blast operation and one testing operation in each ramp:

$$688 + 1888 = 2576 \text{ scfm}$$

However, the 698 scfm for the drill/blast operation is necessary only for a very short duration (minutes) relative to the core drilling (hours). Testing operations could be temporarily suspended to permit blasting, saving 26% (688/2576 X 100) of required compressed air capacity. The demand for testing then soley determines the airflow capacity for the compressed air distribution system design:

$$\text{Equipment Air Demand} = 1888 \text{ scfm} \approx 2000 \text{ scfm}$$

9.5 The compressed air demand for equipment in Table 1 is stated at standard conditions (scfm) and thus remains the same regardless of the altitude of the equipment. However, the air volume required by the compressor to deliver an equivalent amount of air at the operating pressure of the equipment will increase linearly with the altitude of the compressor intake. Compensation of the effect of site elevation will be dealt with when the compressor equipment is selected during Title II design.

9.6 Leakage of compressed air from couplings at the supply to equipment will effectively increase air demand by 10%:

2000 scfm + 0.1 (2000) = 2200 scfm

2200 scfm is the design airflow for each ESF ramp piping main.

9.7 Design air demand is the equipment air demand (including leakage) times the load factor:

2200 scfm (1.0) = 2200 scfm

9.8 Sizing of piping for the compressed air mains is based on providing the design airflow to a location in the ESF that represents the most remote location in the ESF compressed air piping main. Based on a meeting of the opposing TBMs approximately in the middle of the Calico Hills (CH) main drift (Section 6.8), the run to the most remote location in the piping main will be from the Tonopah Springs (TS) South Portal to the middle of the CH Main Drift.

TS South Portal to T-Intersection	7835 ft
CH South Ramp	8072 ft
To Midpoint CH Main Drift	5318 ft
	21,225 ft

To allow for various fittings and components which will be incorporated in Title II design, a factor of 10% in equivalent pipe length is added:

21,225 + 0.1 (21,225) = 23,348 ft

9.9 To insure proper operation of pneumatic equipment the required airflow must be available at a satisfactory pressure. This pressure is conservatively assumed to be 100 psig. Based on a 125 psig compressor discharge pressure the resulting maximum allowable pressure loss through the 23,348 ft equivalent length is 25 psi.

9.10 Piping size for the compressed air distribution system can be estimated by a trial process utilizing the known maximum allowable pressure loss with the table of Appendix A-5. If a 6" SCH 40 pipe size is assumed initially, the value for 2200 scfm is found by interpolation:

$$f = 0.094 + \frac{2200-2000}{2500-2000}(0.143-0.094)$$

$$f = 0.114 \text{ psi/100 ft}$$

Correcting to 130 degrees Fahrenheit air at 125 psig

$$F = 0.114 \frac{(100 + 14.7)}{(125 + 14.7)} \frac{460 - 130}{520} = 0.106 \text{ psi/100 ft}$$

For L = 23,348 ft; Pressure Loss = 24.7 psi

Since the 24.7 psi loss is slightly less than 25 psi maximum allowed, a 6" diameter pipe is the optimal choice for the main.

10.0 Recommendation

Based on the design criteria, assumptions and demand requirements, it is recommended that compressed airflow value of 2200 scfm at each ESF ramp be used to develop the compressed air distribution system. The appropriate pipe size for each main is 6" diameter SCH 40.

APPENDIX A

A-1 VENDOR DATA SHEETS

A-2 PNEUMATIC TOOL AIR CONSUMPTION RATES

A-3 BLASTFACE SPRAY DEVICE

A-4 BLOWPIPE DEVICE

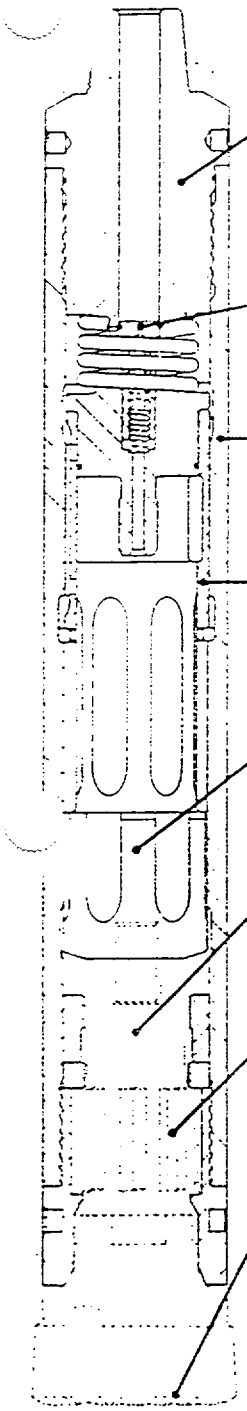
A-5 PIPE FLOW FRICTIONAL LOSS

A-1 VENDOR DATA SHEETS

INGERSOLL-RAND DHD-112

LONGYEAR 65

WILDEN DIAPHRAGM PUMP



Drill backhead has 6 5/8" reg. API thread for connecting the downhole drill to the drill pipe or steel. Four holes in the O.D. permit a hydraulic wrench to be used for disassembly.

Water check valve automatically seals the drill when the air is shut off, limiting ground water back-up into the drill.

Renewal wear sleeve, non-ported for long life, has milled slots that permit the use of a hydraulic disassembly wrench.

Internal cylinder is hardened and reversible to minimize wear. Long bearing surface keeps it aligned within the wear sleeve.

The piston functions as a sliding valve to control the operating cycle of the drill, without any separate valves or valve chest assembly.

Continuous hole cleaning is accomplished by the drill exhaust air which passes out through the center hole in the bit.

Patented pin drive system: Polymer pins between bit and chuck splines eliminate metal-to-metal contact and help prevent galling, minimizing the possibility of shank failure.

Ingersoll-Rand button bits are precision engineered to match the performance requirements of the DHD-112 downhole drill.

U.S. patents—4084646, 3517754
Canadian patent—942286 (1974)

Most complete line of downhole drills

Ingersoll-Rand offers the widest choice of downhole drills, including the world's largest—the Superdrill for holes up to 30" (762 mm) diameter. A complete line of valveless hammers use high-pressure air for fast, efficient penetration in hardest rock.

Drill	Bit diameters	Air pressures
[illegible]-340A	4½-4½" (105-114 mm)	90-250 psig (5.6-24.6 kg/cm²)
	5½-5½" (130-140 mm)	90-250 psig (5.6-24.6 kg/cm²)
[illegible]	6-6½" (152-165 mm)	150-250 psig (10.5-24.6 kg/cm²)
D[illegible]	7¾-10⅝" (200-270 mm)	90-250 psig (5.6-17.6 kg/cm²)
DHD-[illegible]	11¾-17½" (300-444 mm)	90-200 psig (5.6-14 kg/cm²)
DHD-12[illegible]	24" (610 mm)	100-150 psig (7-10.5 kg/cm²)
DHD-130A	30" (762 mm)	100-150 psig (7-10.5 kg/cm²)

Here's why the DHD-112 gives you top performance at rock bottom cost.

The drill's 8½" (216 mm) bore and 3.9" (100 mm) stroke enable it to deliver 1080 rock shattering blows per minute at 200 psi (1379 kPa). And to keep it up, 'round the clock if necessary, day after day.

DHD-112 Specifications

	U.S.	Metric
Hole diameter	11¾" to 17½"	301 to 444
Cylinder bore	8½"	215.9 mm
Stroke	4"	100 mm
Blows per minute at		
125 psig (862 kPa)	930	930
150 psig (1034 kPa)	990	990
175 psig (1206 kPa)	1030	1030
200 psig (1379 kPa)	1080	1080
Air consumption (minimum with plugged orifice)		
125 psig (862 kPa)	680 cfm	19.3 m³/min
150 psig (1034 kPa)	870 cfm	24.6 m³/min
175 psig (1206 kPa)	1080 cfm	30.6 m³/min
200 psig (1379 kPa)	1320 cfm	37.4 m³/min
Overall Length (with 12¼", 311 mm bit)		
Bit retracted	83"	2110 mm
Bit extended	85"	2161 mm
Outside diameter	10¾"	274 mm
Weight (less bit)	1375 lb.	623.7 kg
Button Bit Data		
Bit diameter	11¾"	301 mm
Overall length*	29¼"	739 mm
Weight, net	328 lb.	149 kg
Weight, boxed	378 lb.	171 kg
Bit diameter	12¼"	311 mm
Overall length*	27 1/16"	687 mm
Weight, net	349 lb.	158.3 kg
Weight, boxed	399 lb.	181 kg
Bit diameter	15"	381 mm
Overall Length*	28 9/16"	725 mm
Weight	477 lb.	216.4 kg
Weight, boxed	547 lb.	248.1 kg
Bit diameter	17½"	444 mm
Overall length*	28 9/16"	725 mm
Weight, net	661 lb.	300 kg
Weight, boxed	714 lb.	322 kg

*Does not include exhaust tube which projects 2-1/16" (52.4 mm) from the shank end of each bit.

ACCESSORIES
Hydraulic disassembly wrench (#50896604)
Hydraulic bit tube expander (#50796630)

Nothing contained in this brochure is intended to extend any warranty or representation, expressed or implied, regarding the products described herein. Any such warranties or other terms and conditions of sale of products shall be governed by Ingersoll-Rand's standard terms and conditions of sale for such products, which are available upon request.

4051 S. 76th E. AVE
TULSA, OK 74145
PHONE # (918) 627-4500

Ingersoll-Rand Co.
Rock Drill Division
Phillipsburg, NJ 08865

INGERSOLL-RAND
DRILLING EQUIPMENT

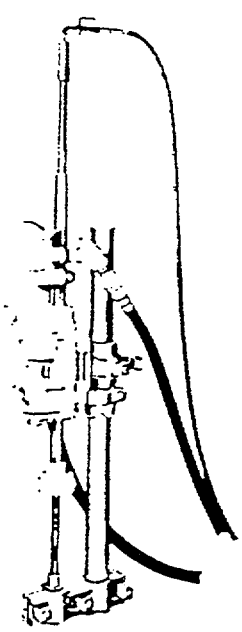
Longyear 65 Diamond Core Drill

Lightweight ▪ Powerful ▪ Air-Driven

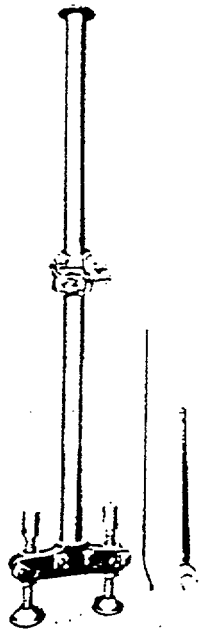
The Longyear 65 has all the job-proven features which make it one of the world's most widely used, lightweight diamond core drills.

Its minimal weight, 200 lb (91 kg) and length, 42.5 in (1080 mm) make it easy to move and set up in small working spaces.

The powerful 20 hp (15 kW) reversible air motor provides a smooth, sustained drive for faster penetration.



GROUT PIPE CLAMP includes column pipe, saddle clamp, safety collar and bushing. TWO SIZES AVAILABLE: For 1.5 in (38 mm) or 2 in (51 mm) grout pipe and for 3 in (76 mm) grout pipe.



3.5 in (89 mm) DOUBLE SCREW COLUMN with jaw-type saddle, safety collar, wrench and jack bar. Side arm also available.

DRILLING DEPTH GUIDELINES

360° angle range capability

	ft	m		ft	m
EW-EX	600	185	AQ	700	215
AW-AX	500	155	BQ	370	110
BW-BX	350	105	BCQ	430	130
NW-NX	300	90	NQ	320	100
LTK 46	800	245	NCQ	370	110

Actual capacities depend on in-hole and operating conditions and may vary from those shown.

Construction

High strength, thin wall steel housings make the Longyear 65 a fully enclosed, dust-proof oil tight lightweight unit. Extensive use of ball bearings throughout the drill coupled with an efficient spur gear drive in which all parts run in grease or oil to reduce wear and keep friction losses to a minimum.

Power

The high-torque, rotary vane type air motor develops sufficient power, is vibrationless and economical in air consumption. Flexibility of stepless throttle regulation and high output torque make for efficient drilling and maximum core recovery.

Drill rpm and Feed Screw Travel Rate

Input power and rpm from the air motor is diverted into two different sets of gears:

Drive Gears — rotate the feed screw. Feed screw or bit rpm is controlled by the air motor throttle — the faster the air motor rpm, the faster the drill rpm.

Three sets of drive gears provide different operational rpm ranges — 0-1500 rpm (standard), 0-1000 rpm (optional) and 0-3000 rpm (optional).

Feed Gears — rotate the feed nut key which, in turn, causes the feed screw to feed or retract. The feed rate is expressed as a ratio of drill (bit) rpm per inch of feed screw travel. Four feed gears per drill may be selected from 11 different gear choices — 140, 200, 300, 500 (standard) and 0, 50, 75, 100, 170, 800 and 1100 (optional).

The exact feed rates available may be determined from the chart shown on page 3.

Feed Screw Travel

The screw may normally be run a full 24 in (610 mm). A 26 in (660 mm) run is obtained by using the blast hole feed screw with a rod coupling replacing the chuck. The waterswivel is then connected directly to the feed screw. This conversion permits drilling with 2 ft (610 mm) rods in confined spaces. The reversible feature of the air motor is a time saver in this type of application since the rods, after the joint has been broken, may be unscrewed using the motor.

The feed screw easily accommodates an EW size core barrel so that the use of a short core barrel in starting holes in unnecessary.

CP-65 DATA SHEET

Specifications

Vane air motor, type: 6 blade, reversible
Power: 20 hp (15 kW)
Average air consumption @ pressure: 250 cfm @ 90 psi (7 m³/min @ .620 MPa)
Maximum air consumption @ pressure: 400 cfm @ 90 psi (11.2 m³/min @ .620 MPa)

DIMENSIONS	in	mm
Width	15.5	394
Height	12	305
Length	42.5	1080

NET WEIGHT	lb	kg
Standard drill with chuck	200	91
Standard drill with blast hole coupling	195	86
Drill equipped with 65 rod puller	290	132

BIT ROTATING SPEEDS	
Drive gear combinations	**rpm (nominal)**
Standard	0-1500
Optional	0-1000
Optional	0-3000

FEED SCREW		
I.D. of feed screw	in	mm
For coring applications	1.5	38
For blast hole applications	1.3	33
Normal feed length	24	610

Feed gears: Four feed gears may be selected from 11 different gear choices — Drill normally supplied with 140*, 200*, 300*, and 500* gears — optional gears: 0, 50*, 75*, 100*, 170*, 800* and 1100*.

*nominal

Accessories

	part number
Spare parts kit for 65 drill	38295
Spare parts kit for 65 air rod puller	38296
Water Swivel — high speed water swivel with pin thread for direct connection to feed screw — ⅜ in NPT hose connection.	44803
Water Swivel Adapter for 43 mm drill rods	67957
Water Swivel Adapter for EW drill rods	38129
Water Swivel Adapter for AW drill rods	44804
Water Swivel blast hole coupling (EW)	38194
Blast Hole feed screw	38204
Blast Hole feed screw coupling EW	38193
Blast Hole feed screw coupling AW	38192
Blast Hole barrel EX	38190
Blast Hole Barrel AX	38191
Pneumatic rod puller (EW)	38156
Pneumatic rod puller (AW)	38155
Column	38100
Column arm	38097
Grout pipe clamp 1.5 in (38 mm) and 2 in (51 mm)	38116
Grout pipe clamp 3 in (76 mm)	38157

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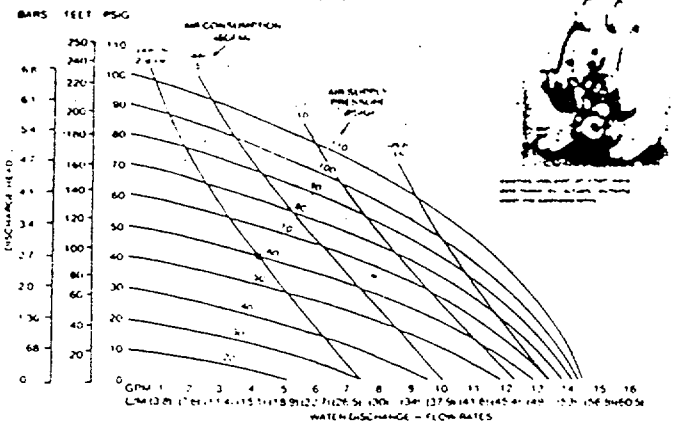
SPECIFICATIONS AND PERFORMANCE

WILDEN® MODEL M-1®

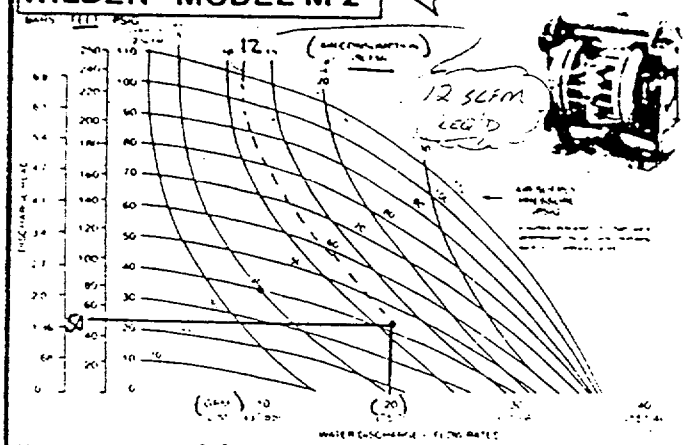


Height ..... 8½" Air Inlet ..... ¼" Female NPT Suction Lift ..... POLY 15' Dry
Width ..... 8" Inlet ..... ½" Female NPT POLY. 25' Wet
Depth ..... 6½" Outlet ..... ½" Female NPT TEFLON 8' Dry
Weight ..... POLY 8 lbs Max. Size Solids ... 1/16" Dia. TEFLON 25' Primed

Example: *To pump 4 gpm against a discharge pressure of 40 psig requires 60 psig and 2 scfm air consumption. (See dot on chart.)*

Caution: Do not exceed 100 psig air supply pressure.

WILDEN® MODEL M-2®



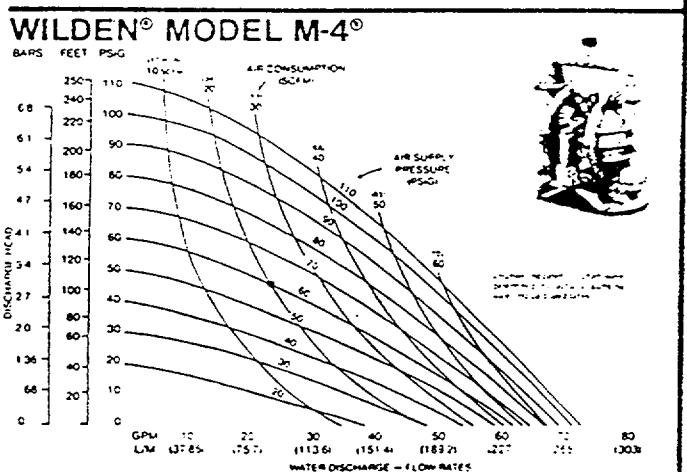
Height ..... 10½" Air Inlet ..... ¼" NPT Suction Lift ..... 18' Dry
Width ..... 10½" Inlet ..... 1" Male NPT 25' Wet
Depth ..... 7" Outlet ..... ¾" Male NPT Weight ..... ALUM. 22 lbs
Max. Size Solids ... ⅛" Dia. SS-HASTELLOY 35 lbs.

Example: *To pump 10 gpm against a discharge pressure of 35 psig requires 40 psig and 5 scfm air consumption. (See dot on chart.)*

Note: For M-2 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-2 pumps with Teflon diaphragms: 10 ft. dry, 25 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® MODEL M-4®



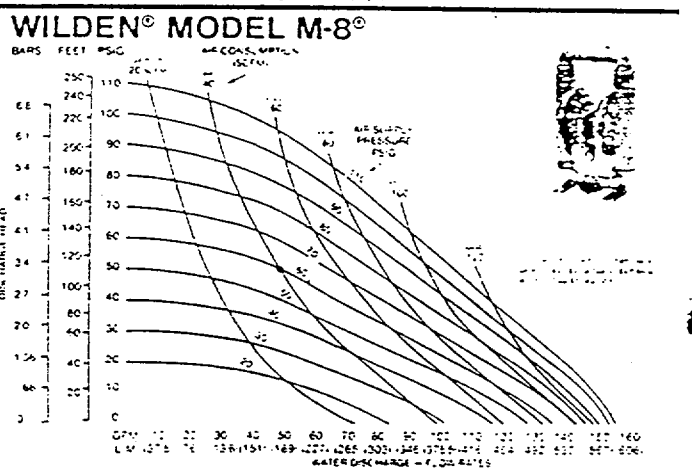
Height ..... 18" Air Inlet ..... ¾" NPT Suction Lift ..... 22' Dry
Width ..... 14¼" Inlet ..... 1½" Male NPT 27' Wet
Depth ..... 11¾" Outlet ..... 1¼" Male NPT Weight ..... ALUM. 35 lbs.
Max. Size Solids ... 3/16" Dia. IRON/S.S. 52 lbs.

Example: *To pump 22.5 gpm against a discharge pressure of 45 psig requires 60 psig and 20 scfm air consumption. (See dot on chart.)*

Note: For M-4 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-4 pumps with Teflon diaphragms: 12 ft. dry, 25 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® MODEL M-8®



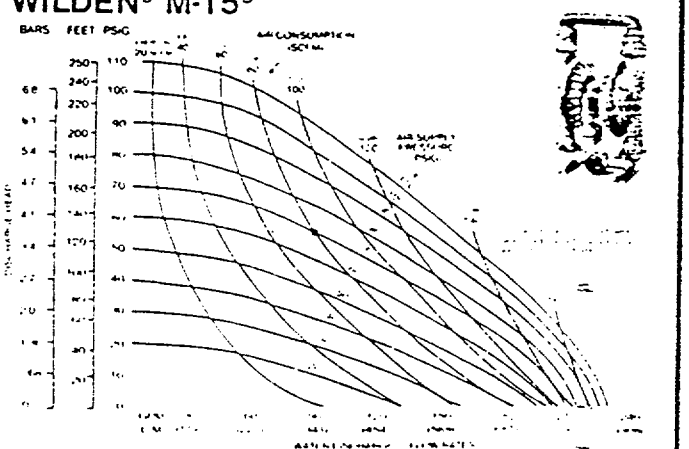
Height ..... 26¼" Air Inlet ..... ½" NPT Suction Lift ..... 20' Dry
Width ..... 15¾" Inlet ..... 2" Male NPT 25' Wet
Depth ..... 13¼" Outlet ..... 2" Male NPT Weight ..... ALUM. 65 lbs.
Max. Size Solids ... ¼" Dia. IRON/S.S. 110 lbs.

Example: *To pump 47 gpm against a discharge pressure of 50 psig requires 60 psig and 40 scfm air consumption. (See dot on chart.)*

Note: For M-8 pumps fitted with Teflon diaphragms reduce water discharge figures by 20%. Suction lift for M-8 pumps with Teflon diaphragms: 12 ft. dry, 18 ft. wet.

Caution: Do not exceed 125 psig air supply pressure.

WILDEN® M-15®



Height ..... 32¼" Air Inlet ..... ½" NPT Weight ALUM. 120 lbs
Width ..... 20" Inlet ..... 3" Male NPT IRON/S.S. 195 lbs
Depth ..... 18" Outlet ..... 3" Male NPT Suction Lift ..... 20' Dry
Max. Size Solids ... ¼" Dia. 25' Wet

Example: *To pump 90 gpm against a discharge pressure of 55 psig requires 70 psig and 80 scfm air consumption. (See dot on chart.)*

Caution: Do not exceed 125 psig air supply pressure.

Your local Wilden distributor is:

WILDEN PUMP & ENGINEERING CO.
22069 Van Buren Street / P.O. Box 845
Colton, California 92324
714/~~783-0621~~ (714) 422-1700
Telex: 676-452

Wilden recommends that in order to insure pump integrity, filability, performance, only genuine Wilden replacement parts be used.
We cannot guarantee the quality or reliability of after-market "will fit" parts.

A-2 AIR CONSUMPTION RATES FOR PNEUMATIC TOOLS/
ALLOWANCE FOR AIR LEAKAGE
(From Reference 5.4)

Calculation Procedure:

1. *Compute the required airflow rate*

List all the tools and devices in the compressed-air system that will consume air, Table 1. Then obtain from Table 2 the probable air consumption, cfm, of each tool. Enter this value in column 1, Table 1. Next, list the number of each type of tool that will be used in the system in column 2. Find the maximum probable air consumption of each tool by taking the product, line by line, of columns 1 and 2. Enter the result in column 3, Table 1, for each tool.

TABLE 2 Approximate Air Needs of Pneumatic Tools, Cfm

Grinders:	
6- and 8-in.-diameter wheels	50
2- and 2½-in.-diameter wheels	14–20
File and burr machines	18
Rotary sanders, 9-in.-diameter pads	55
Sand rammers and tampers:	
1 × 4 in. cylinder	25
1½ × 5 in. cylinder	28
1½ × 6 in. cylinder	39
Chipping hammers,	
10 to 13 lb	28–30
2 to 4 lb	12
Nut setters:	
To ⅝ in., 8 lb	20
½ to ¾ in., 18 lb	30
Paint spray	2–20
Plug drills	40–50
Riveters:	
3/16- to ½-in. rivets	12
Larger, weighing 18 to 22 lb	35
Rivet busters	35–39
Steel drills, rotary motors:	
To ¼ in., weighing 1½ to 4 lb	18–20
¼ to ½ in., weighing 6 to 8 lb	20–40
½ to ¾ in., weighing 9 to 14 lb	70
¾ to 1 in., weighing 25 lb	80
Wood borers to 1 in. diameter, weighing 14 lb	40

The air consumption values shown in column 3 represent the airflow rate required for continuous operation of each type and number of tools listed. However, few air tools operate continually. To provide for this situation a load factor is generally used when selecting an air compressor.

2. *Select the equipment load factor*

The equipment load factor = actual air consumption of the tool or device, cfm/full-load continuous air consumption of the tool or device, cfm. Load factors for compressed-air operated devices are usually less than 1.0.

Two variables are involved in the equipment load factor. The first is the *time factor*, or the percent of the total time the tool or device actually uses compressed air. The second is the *work factor*, or percent of maximum possible work output done by the tool. The load factor is the product of these two variables.

Determine the load factor for a given tool or device by consulting the manufacturer's engineering data, or by estimating the factor value by using previous experience as a guide. Enter the load factor in column 4, Table 1. The values shown represent typical load factors encountered in industrial plants.

3. *Compute the actual air consumption*

Take the product, line by line, of columns 3 and 4, Table 1. Enter the result, i.e., the probable air demand, cfm, in column 5, Table 1. Find the sum of the values in column 5, or 601 cfm. This is the probable air demand of the system.

4. *Apply allowances for leakage and future needs*

Most compressed-air system designs allow for 10 percent of the required air to be lost through leaks in the piping, tools, hoses, etc. Whereas some designers claim that allowing for leakage is a poor design procedure, observation of many installations indicates that air leakage is a fact of life and must be considered when designing an actual system

A-3 BLASTFACE SPRAY DEVICE
(From Reference 5.2)

unit available from a number of manufacturers. The effectiveness of this device is determined by the fineness of the mist or fog produced, and the "throw" and "spread" of the mixture. An unpublished report, covering tests made on 11 different types, indicated that the water consumption varied from 0.75 to 8.0 gpm; compressed air, 105 to 300 cfm (free air). It is apparent that a particular design should not be adopted as standard for use in all working places in all mines. A working area with little or no ventilation would benefit most from the unit providing the high rate of airflow. On the other hand, it would be poor engineering to waste expensive compressed air in a place well ventilated by conventional means. Similar reasoning may be applied to the utilization of the water delivered, particularly for blasts in drifts and raises vs. the larger ones in stopes involving much greater tonnages of broken material.

An important feature of the air-water nozzle is the manner in which the compressed air and water are blended before dispersal. The design should incorporate means precluding the drainage of water into the compressed-air line, particularly when the pressure of the latter is lower than that in the former. Two suitable types of nozzle are illustrated in the text published by the ILO,[32] and the details of a number of others are available on request from the Mines Accident Prevention Association of Ontario.[46]

The final step in the control of contaminants resulting from blasting is providing means to cleanse pollutants. A unique type of collector used in South Africa consists of a bed of vermiculite, treated with a solution of sodium carbonate and potassium permanganate, which removes the nitrous fumes, and a flannel filter for the collection of dust particles. After treatment, the air is returned to a fresh-air split where the dilution ratio is at least 5 to 1. Plant details are presented by Rabson.[47]

In the absence of a filtering system, blasting dust and fumes should be diluted and exhausted to surface via an untraveled route, preferably an upcast raise designed for that purpose. If this is not feasible, the blasting schedule should be arranged so that the vitiated air will pass through working places when the miners are absent. Failure to do this creates an undesirable health hazard and reduces production efficiency due to miners leaving their working places for the time necessary to clear the dust and fumes.

Mechanical Loading—Utilization of an air-water blast for a suitable period after blasting obviates the need for applying a water spray immediately before commencing the loading operation. On the other hand, if the rock pile has to be wetted by means of a hand-held hose, the quality of the environment will deteriorate considerably because the application of water under these conditions is similar to directing a stream into a barrel of flour.

Investigation of a rock pile after it apparently is soaked with water will reveal that the depth and extent of water penetration are shallow and limited. In other words, it is practically impossible to wet a pile of rock thoroughly by conventional spraying methods. As a result, dry dusty material is exposed continuously as the loading or scraping operation progresses. Under these circumstances, it is necessary to maintain a continuous mist or water spray at the point where new fragmental material is exposed. Use of a hand-held hose is not recommended, because the operator, on exposing new rock during the process of loading an ore carrier, may be tempted to complete the cycle before applying more water. Some success has been achieved by installing a nozzle spray on the front end of compressed-air-operated loading machines. A nozzle which provides a flat diverging stream of mist-size water droplets produces a good wetting action with minimum water consumption.

The scraping of rock in stopes and scram drifts produces large amounts of dust, particularly if the material is dry and the speed of the operation is high. A successful method of controlling this dust is to install a bar-type water spray where the scraper "bites" into the rock pile, with one or more additional nozzle-type sprays at intervals over the path followed by the scraper. A mist type of spray at the ore-pass or loading point will reduce dust dispersal and condition the rock

A-4 BLOWPIPE DEVICE
(From Reference 5.5)

ing. Therefore, it is essential for hose delivering bulk fuels to have a synthetic rubber tube and cover.

Whip Ends for Fuel Hose. Long-length fuel hose for home delivery usually fails at the end attached to the truck reel because of the severe bend the hose must take

Table 19-1. Discharge of Air through an Orifice

Receiver gauge pressure, lb	Diameter of orifice, in.											
	1/32	1/16	1/8	1/4	3/8	1/2	3/8	3/4	7/8	1	1 1/4	1 1/2
	Discharge of free air per min, cu ft											
2	0.15	0.65	5.44	9.7	21.9	39.0	61.0	87.6	119.5	156.0	242.0	350
5	0.24	0.97	3.86	15.4	34.6	61.6	96.5	133.0	189.0	247.0	384.0	550
10	0.34	1.36	5.45	21.8	49.0	87.0	136.0	196.0	267.0	350.0	543.0	780
15	0.42	1.67	6.65	26.7	60.0	107.0	167.0	240.0	326.0	427.0	665.0	960
20	0.48	1.93	7.70	30.8	69.0	123.0	189.0	277.0	378.0	494.0	770.0	
25	0.54	2.16	8.60	34.5	77.0	138.0	216.0	310.0	422.0	550.0	860.0	
30	0.63	2.52	10.0	40.0	90.0	161.0	252.0	362.0	493.0	645.0	1000.0	
35	0.71	2.80	11.20	44.7	100.0	179.0	280.0	400.0	550.0	715.0		
40	0.77	3.07	12.27	49.1	110.5	196.4	306.8	441.8	601.3	785.0		
45	0.84	3.36	13.40	53.8	121.0	215.0	336.0	482.0	658.0	860.0		
50	0.91	3.64	14.50	58.2	130.0	232.0	364.0	522.0	710.0	930.0		
60	1.05	4.20	16.80	67.0	151.0	268.0	420.0	604.0	822.0			
70	1.19	4.76	19.0	76.0	171.0	304.0	476.0	685.0	930.0			
80	1.33	5.32	21.20	85.0	191.0	340.0	532.0	765.0	1004.0			
90	1.47	5.87	23.50	94.0	211.0	376.0	587.0	843.0				
100	1.61	6.45	25.80	103.0	231.0	412.0	646.0	925.0				
125	1.97	7.85	31.40	125.0	282.0	502.0	785.0					

A-5 PIPE FLOW FRICTIONAL LOSS
(From Reference 5.6)

Flow of Air Through Schedule 40 Steel Pipe

For lengths of pipe other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table . . . for 300 feet, three times the given value, etc.

The pressure drop is also inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

Therefore, to determine the pressure drop for inlet or average pressures other than 100 psi and at temperatures other than 60 F, multiply the values given in the table by the ratio:

$$\left(\frac{100 + 14.7}{P + 14.7}\right)\left(\frac{460 + t}{520}\right)$$

where:

"P" is the inlet or average gauge pressure in pounds per square inch, and,

"t" is the temperature in degrees Fahrenheit under consideration.

The cubic feet per minute of compressed air at any pressure is inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

To determine the cubic feet per minute of compressed air at any temperature and pressure other than standard conditions, multiply the value of cubic feet per minute of free air by the ratio:

$$\left(\frac{14.7}{14.7 + P}\right)\left(\frac{460 + t}{520}\right)$$

Free Air q'_m Cubic Feet Per Minute at 60 F and 14.7 psia	Compressed Air Cubic Feet Per Minute at 60 F and 100 psig	Pressure Drop of Air In Pounds per Square Inch Per 100 Feet of Schedule 40 Pipe For Air at 100 Pounds per Square Inch Gauge Pressure and 60 F Temperature								
		1/8"	1/4"	3/8"	1/2"					
1	0.128	0.361	0.083	0.018						
2	0.256	1.31	0.285	0.064	0.020					
3	0.384	3.06	0.605	0.133	0.042	3/4"				
4	0.513	4.83	1.04	0.226	0.071					
5	0.641	7.45	1.58	0.343	0.106	0.027				
6	0.769	10.6	2.23	0.408	0.148	0.037	1"			
8	1.025	18.6	3.89	0.848	0.255	0.062	0.019			
10	1.282	28.7	5.96	1.26	0.356	0.094	0.029	1 1/4"	1 1/2"	
15	1.922	...	13.0	2.73	0.834	0.201	0.062			
20	2.563	...	22.8	4.76	1.43	0.345	0.102	0.026		
25	3.204	...	35.6	7.34	2.21	0.526	0.156	0.039	0.019	
30	3.845	...	...	10.5	3.15	0.748	0.219	0.055	0.026	
35	4.486	...	...	14.2	4.24	1.00	0.293	0.073	0.035	
40	5.126	...	...	18.4	5.49	1.30	0.379	0.095	0.044	
45	5.767	...	...	23.1	6.90	1.62	0.474	0.116	0.055	2"
50	6.408			28.5	8.49	1.99	0.578	0.149	0.067	0.019
60	7.690	2 1/2"		40.7	12.2	2.85	0.819	0.200	0.094	0.027
70	8.971			...	16.5	3.83	1.10	0.270	0.126	0.036
80	10.25	0.019		...	21.4	4.96	1.43	0.350	0.162	0.046
90	11.53	0.023		...	27.0	6.25	1.80	0.437	0.203	0.058
100	12.82	0.029	3"		33.2	7.69	2.21	0.534	0.247	0.070
125	16.02	0.044			...	11.9	3.39	0.825	0.380	0.107
150	19.22	0.062	0.021		...	17.0	4.87	1.17	0.537	0.151
175	22.43	0.083	0.028		...	23.1	6.60	1.58	0.727	0.205
200	25.63	0.107	0.036	3 1/2"	...	30.0	8.54	2.05	0.937	0.264
225	28.84	0.134	0.045	0.022		37.9	10.8	2.59	1.19	0.331
250	32.04	0.164	0.055	0.027		...	13.3	3.18	1.45	0.404
275	35.24	0.191	0.066	0.032		...	16.0	3.83	1.75	0.484
300	38.45	0.232	0.078	0.037		...	19.0	4.56	2.07	0.573
325	41.65	0.270	0.090	0.043	4"	...	22.3	5.32	2.42	0.673
350	44.87	0.313	0.104	0.050		...	25.8	6.17	2.80	0.776
375	48.06	0.356	0.119	0.057	0.030	...	29.6	7.05	3.20	0.887
400	51.26	0.402	0.134	0.064	0.034	...	33.6	8.02	3.64	1.00
425	54.47	0.452	0.151	0.072	0.038	...	37.9	9.01	4.09	1.13
450	57.67	0.507	0.168	0.081	0.042	...	...	10.2	4.59	1.26
475	60.88	0.562	0.187	0.089	0.047		...	11.3	5.09	1.40
500	64.08	0.623	0.206	0.099	0.052		...	12.5	5.61	1.55
550	70.49	0.749	0.248	0.118	0.062		...	15.1	6.79	1.87
600	76.90	0.887	0.293	0.139	0.073		...	18.0	8.04	2.21
650	83.30	1.04	0.342	0.163	0.086	5"	...	21.1	9.43	2.60
700	89.71	1.19	0.395	0.188	0.099	0.032		24.3	10.9	3.00
750	96.12	1.36	0.451	0.214	0.113	0.036		27.9	12.6	3.44
800	102.5	1.55	0.513	0.244	0.127	0.041		31.8	14.2	3.90
850	108.9	1.74	0.576	0.274	0.144	0.046		35.9	16.0	4.40
900	115.3	1.95	0.642	0.305	0.160	0.051	6"	40.2	18.0	4.91
950	121.8	2.18	0.715	0.340	0.178	0.057	0.023	...	20.0	5.47
1 000	128.2	2.40	0.788	0.375	0.197	0.063	0.025	...	22.1	6.06
1 100	141.0	2.89	0.948	0.451	0.236	0.075	0.030	...	26.7	7.29
1 200	153.8	3.44	1.13	0.533	0.279	0.089	0.035	...	31.8	8.63
1 300	166.6	4.01	1.32	0.626	0.327	0.103	0.041	...	37.3	10.1
1 400	179.4	4.65	1.52	0.718	0.377	0.119	0.047			11.8
1 500	192.2	5.31	1.74	0.824	0.431	0.136	0.054			13.5
1 600	205.1	6.04	1.97	0.932	0.490	0.154	0.061	8"		15.3
1 800	230.7	7.65	2.50	1.18	0.616	0.193	0.075			19.3
2 000	256.3	9.44	3.06	1.45	0.757	0.237	0.094	0.023		23.9
2 500	320.4	14.7	4.76	2.25	1.17	0.366	0.143	0.035	10"	37.3
3 000	384.5	21.1	6.82	3.20	1.67	0.524	0.204	0.051	0.016	
3 500	448.6	28.8	9.23	4.33	2.26	0.709	0.276	0.068	0.022	
4 000	512.6	37.6	12.1	5.66	2.94	0.919	0.358	0.088	0.028	
4 500	576.7	47.6	15.3	7.16	3.69	1.16	0.450	0.111	0.035	12".
5 000	640.8	...	18.8	8.85	4.56	1.42	0.552	0.136	0.043	0.018
6 000	769.0	...	27.1	12.7	6.57	2.03	0.794	0.195	0.061	0.025
7 000	897.1	...	36.9	17.2	8.94	2.76	1.07	0.262	0.082	0.034
8 000	1025	...	...	22.5	11.7	3.59	1.39	0.339	0.107	0.044
9 000	1153	...	...	28.5	14.9	4.54	1.76	0.427	0.134	0.055
10 000	1282	...	...	35.2	18.4	5.60	2.16	0.526	0.164	0.067
11 000	1410	...	...	...	22.2	6.78	2.62	0.633	0.197	0.081
12 000	1538	...	...	...	26.4	8.07	3.09	0.753	0.234	0.096
13 000	1666	...	...	...	31.0	9.47	3.63	0.884	0.273	0.112
14 000	1794	...	...	...	36.0	11.0	4.21	1.02	0.316	0.129
15 000	1922	...	...	...	...	12.6	4.84	1.17	0.364	0.148
16 000	2051	...	...	...	...	14.3	5.50	1.33	0.411	0.167
18 000	2307	...	...	...	...	18.2	6.96	1.68	0.520	0.213
20 000	2563	...	...	...	...	22.4	8.60	2.01	0.642	0.260
22 000	2820	...	...	...	...	27.1	10.4	2.50	0.771	0.314
24 000	3076	...	...	...	...	32.3	12.4	2.97	0.918	0.371
26 000	3332	...	...	...	...	37.9	14.5	3.49	1.12	0.435
28 000	3588	...	...	...	...	...	16.9	4.04	1.25	0.505
30 000	3845	...	...	...	...	...	19.3	4.64	1.42	0.520

Calculations for Pipe Other than Schedule 40

To determine the velocity of water, or the pressure drop of water or air, through pipe other than Schedule 40, use the following formulas:

$$v_a = v_{40}\left(\frac{d_{40}}{d_a}\right)^2$$

$$\Delta P_a = \Delta P_{40}\left(\frac{d_{40}}{d_a}\right)^5$$

Subscript "a" refers to the Schedule of pipe through which velocity or pressure drop is desired.

Subscript "40" refers to the velocity or pressure drop through Schedule 40 pipe, as given in the tables on these facing pages.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-025 Rev: 1

WBS No.	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	R.L. Coppage	R. Coppage	SR. MINE. ENGR	8/22/91
CHECKER:	W.R. Kennedy	WR Kennedy	SR. MINE. ENGR	8/22/91
APPROVAL - LDE:	B.T. Stanley	Bruce T. Stanley	Lead Mining Engr.	8/22/91
APPROVAL - SCDM:	B.R. Chytrowski	B.R. Chytrowski	SCDM	8/22/91
QA CONCURRENCE:	PAUL B. HALE	Paul B Hale	SR. QA SPECIALIST	8-22-91

SUBJECT: RAMP SIZING

TITLE: TS South Ramp Sizing Study

QAG Reference: RSN-GR-013, Rev.0

1.0 Purpose: The purpose of this study is to make a preliminary recommendation for the diameter of the TS South access ramp. The purpose of revision 1 is to incorporate the comments of the management review of August 12 to 16 1991.

2.0 Method: The approach will be to review requirements; propose a cross section arrangement which meets requirements;discuss how the proposed cross section size fulfills requirements; state conclusions; and recommend a cross section size.

3.0 Study Input-The following ESFDR sections are applicable to the TS south ramp sizing: The source of these inputs is YMP/CC-0013 ESFDR, Rev. 07-29-91 1.2.6.5

PC 1c.i,ii,iii,iv,v.; ie.; 1f.i,iv,; 1g., 1h. i,ii,; 1i,(ii),(iii); 2b.iv;2d.iii; 2i.vii; CA i; CB. ii; and 1.2.6.5.4. PC1c. FR-1, FR-2.

4.0 Codes and Standards-The following codes are applicable:

-30CFR57.9110 July 1, 1988 ed.

5.0 Assumptions-The following assumptions will be used in this study:

- All design input will be included in an approved Basis For Design.
- The site characterization testing program as described in volume 2 of YMP/CC-0013 ESFDR, Rev. 07-29-91 can be constructed and operated in a ramp cross section designed to support all other required functions.(see 9.2(1) page (3 of 6)

- Assume that the required diameter is the finished diameter. (see page 5 of 6)

- The largest equipment piece contemplated for passage down the south TS ramp is a 12' diameter main bearing for the 18 ft diameter TBM, which will be used to excavate the Calico Hills ramp. Special arrangements will be required for this one time occurance.

6.0 Reference Material-The following material was used as reference material during the preparation of this analysis:

- RSN ST-MN-010 Preliminary Transportation Analysis Rev.1 (p 61)

- RSN Drwg. no YMP-025-2-STRU-GA05 which presents a proposed typical South Ramp cross section.

- RSN calc. ST-MN-30,31, which are preliminary ventilation calculations.

- IC 1625 Tamondong to Grenia Dated 7-23-91 Size of Calico Hills north/south ramp and main drift.

- RSN YMP-025-2-MING-MI48, 51. These drawings show ventilation layouts.

7.0 Computer Codes- Not Applicable

8.0 Units- The numerical units used in this study will be English standard.

9.0 Analysis - The following analysis will follow the approach outlined in section 3.

9.1 Review of applicable requirements:

9.1.1 ESFDR Requirements- The ESFDR requirements cited in section 3 are those that govern the sizing of access ramps. These requirements can be paraphrased as follows:
- Testing needs must be considered.
- Personnel and equipment transportation needs must be considered.
- Space must be provided for ventilation and utilities.
- The ramp must be useful for emergency escape.
- The ramp opening must not adversely affect the waste isolation capability of the site.
- The ramp should be capable of repository incorporation at some future time if necessary.

9.1.2 Functional needs during ESF construction and operations- The Following functional needs were extracted from the cited references:

- RSN ST-MN-010 Preliminary Transportation Analysis:
  (1) A 36 inch wide belt conveyor is required for muck removal.

  (2) Rubber tired transporters of maximum 8 ft width may be used.

  (3) A nine(9) feet wide mechanical excavator may traverse the TS ramp on its way to the Calico Hills access.

- RSN calc. ST-MN-30 and 31, preliminary ventilation calculations:

  (1) A 72 inch diameter vent tube will be required in the ramp for a protracted period.

  (2) 400,000 cfm of exhaust ventilation air will have to pass through the TS South ramp during peak operation periods.
  (3) The air velocity in the ramp should not exceed 600 ft per minute. Dust control measures are required should this velocity be exceeded. Refer to ST-MN-031.

- RSN Drwg. YMP-025-2-STRU-GA05, general arrangement of the south ramp using the requirements.

  (1) The proposed ramp cross section layout reflects the roadway width requirements, the 30CFR57.9110 requirement to provide a 30 inch wide walkway and the need to place the conveyor on the rib of the excavation in accordance with the reasons stated in the cited IC 1625.

- The remaining references serve to support the information related above.

9.2 Proposed cross section general arrangement: Refer to RSN Drwg. YMP-025-2-STRU-GA05 an excerpt of which appears in fig.1. The proposed layout in fig. 1 satisfies the requirements stated in section 9.1.1 above as follows:

(1) Testing needs do not appear to influence the size of the cross section. Test alcoves of the size described in the ESFDR can be constructed in this cross section.

(2) The transportation of personnel needs are met by the fig. 1 layout by allowing the passage of an 8 feet wide personnel carrier to travel with sufficient clearance.

(3) The requirement for ventilation and utilities space is met by the layout shown in that (1) the required size vent tube is shown, (2) space is shown for the contemplated utilities, and (3) the unobstructed area of the cross section is sufficient for the contemplated intake or exhaust air flow.

(4) The roadway shown in the fig. 1 provides a means of emergency escape.

(5) The implications of cross section size on isolation capability are not known. A reasonable conclusion at this point is that the smallest cross section size which satisfies all the functions and requirements is the most desirable from the standpoint of isolation capability.

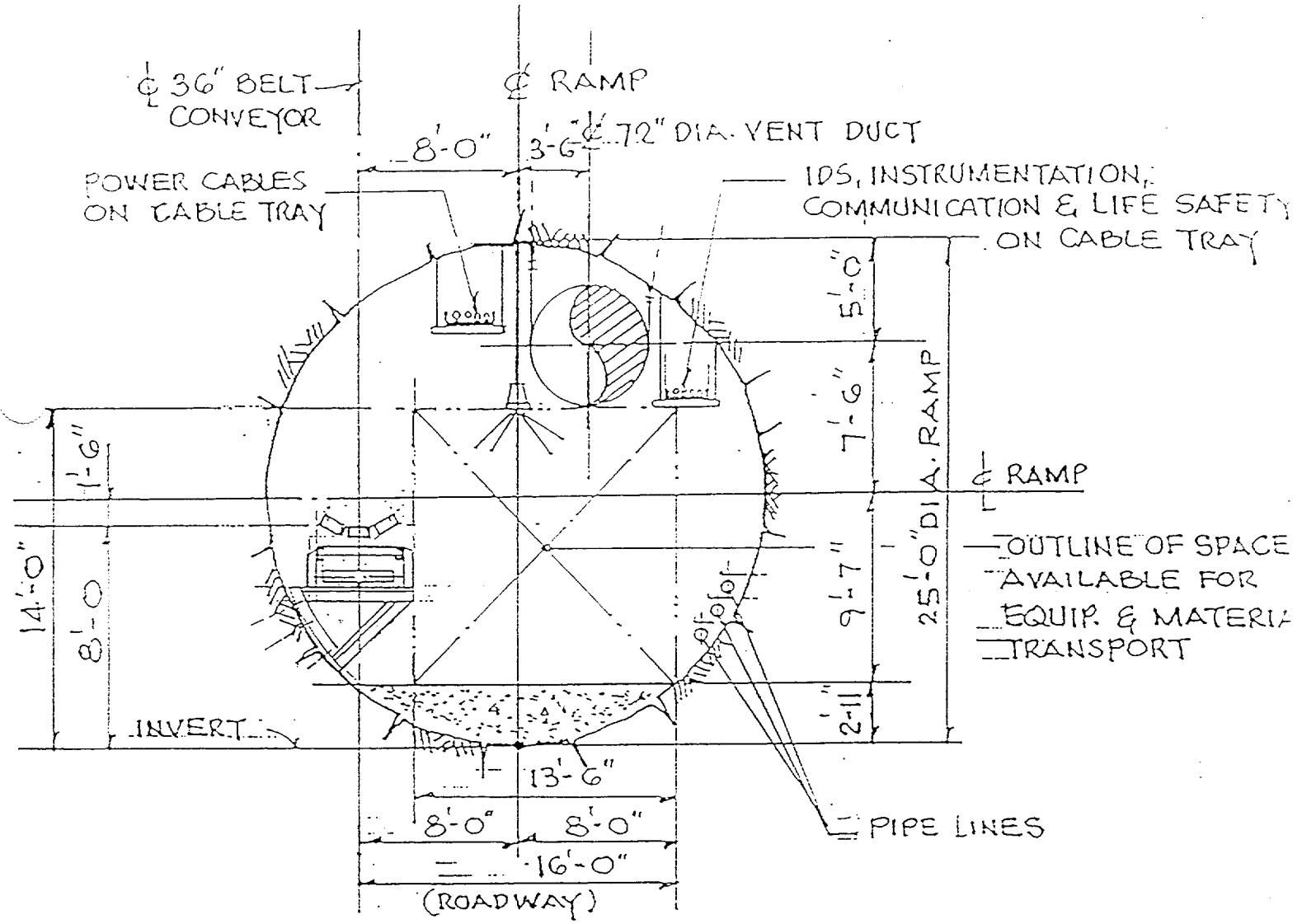
(6) The cross section size shown may or may not be suitable for incorporation into the repository, however, enlargement is possible if needed.

9.3 The functional requirements stated in section 9.1.2 above are satisfied by fig. 1 layout as follows:

(1) The 36 inch wide conveyor is present, the roadway width provides for a 8 ft wide vehicle and a 30 inch wide walkway or clearance on both sides. In addition, room exists for the passage of the mechanical excavator on an occasional basis.

(2) The 72 inch diameter exhaust vent duct is present, the clear cross section has approximately 400 square ft of area for air flow. Using the estimated ventilation air flow requirement of 400,000 cubic ft per minute this area will permit an approximate air flow velocity of 1000 ft per minute. One thousand feet per minute air flow velocity indicates the possibility that dust will be raised from the conveyor and the road surface. Methods for mitigating this condition should be investigated in order to avoid the need to either increase the cross section size or reduce the air flow volume to slow down the flow velocity.

Figure 1



SECTION

PROPOSED TS SOUTH RAMP CROSS SECTION

GENERAL ARRANGEMENT

(3) Ample space is provided for the utilities which are contemplated for installation in the ramp at this time.

(4) No impediments to the testing program as presently defined are apparent. The assumption that the testing program can be constructed and operated in a 25 feet diameter ramp cross section is supported by the proposed layout in fig 1 by providing space for relocation of utilities and vent duct to locations which would allow the development of test alcoves.

10.0 Conclusions: The following are conclusions based on the discussion above:

1. The 25 feet diameter circular cross section shown in fig 1 fulfills the requirements and functions found to be applicable to this analysis. The possible dust hazard caused by air velocities above 600 feet per minute must be mitigated in some manner.

2. Based on the ventilation studies cited, the 25 feet diameter is the minimum size cross section that should be considered at this time and only if suitable dust control methods are identified. Removal of obstructions in order to slow the air velocity would result in degradation of performance of the ramp in support of ESF operations.

3. Inspection of fig. 1 indicates that the cross section diameter is strongly influenced by the need to construct a flat roadway in the circular opening created by a TBM. Further analysis should be done in later design phases on the subject of roadway construction methods. If, for instance, it would be feasible and preferable to excavate a flat roadway rather than to backfill as shown then the diameter might be reduced.

11.0 Recommendation: For the purposes of the conceptual design effort plan to use a diameter of 25 feet for the TS South Access ramp. Continue to evaluate ESFDR revisions especially in the area of site characterization testing to assess the possible impact on the ramp cross section diameter. When equipment sizes, ventilation quantities,test alcove sizes and construction methods are defined in detail in title II, another analysis of the of the ramp cross section size should be considered.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-026 Rev: 1

Page 1 of 7

WBS No.	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	R.L.Coppage	R L Coppage	SR. MINE. ENGR.	8-22-91
CHECKER:	W.R.Kennedy	W R Kennedy	SR. MINE. ENGR	8-22-91
APPROVAL - LDE:	B.T. Stanley	Bruce T Stanley	Lead Mining Eng.	8-22-91
APPROVAL - SCDM:	B.R. Chytrowski	B.R. Chytrowski	SCDM	8-22-91
QA CONCURRENCE:	PAUL B. HALE	Paul B Hale	SR. QA Spec.	8-22-91

SUBJECT: Ramp Sizing

TITLE: Calico Hills South Ramp Sizing

QAG Reference: RSN-GR-013, REV 0

1.0 PURPOSE: The purpose of this analysis is to make a preliminary recommendation for the diameter of the Calico Hills South Access Ramp.
The purpose of Revision 1 is to incorporate the comments of the management review of August 12 to 16, 1991.

2.0 METHOD: The following procedure will be followed in this analysis:

- List the ESFDR Requirements for the ramp.
- List the functional requirements of the ramp as developed in the Alternative Studies.
- Refer to the Transportation Methods Analysis to determine the size and placement of equipment in the ramp cross-sectional space.
- Develop a proposed cross-sectional general arrangement which meets the basic requirements.
- Discuss the merits of the various features of the proposed cross-section as to how well each fulfills the functions assigned to the ramp.
- List the conclusions that may be drawn from the discussion of the merits of each option.
- Based on the conclusions reached, make a preliminary recommendation for the ramp diameter.

3.0 DESIGN INPUTS: The following ESFDR sections are pertinent to the sizing of the Calico Hills South Access ramp: The reference is YMP/CC-0013, ESFDR, Rev. 07-29-91,

1.2.6.5 FR-1
PC 1c.i,ii,iii,iv,v.; 1e., 1f.i,iv,; 1g., 1h.i,ii; 1i,(ii),(iii); 2d.iii;
C A i, C B. ii,
1.2.6.5.4. PC 1c.

4.0 CODES AND STANDARDS: The following codes are applicable:

30 CFR 57.9110 July 1, 1988 Edition

5.0 REFERENCE MATERIAL:

5.1 ST-MN-010, Rev. 1, 6-14-91, Jurani, Preliminary Transportation Methods Analysis, p 61.
5.2 FSN-AS-430, Rev. 2, Alternative Studies, Option B-7, Scen. 2. (Option 30).
5.3 ESFDR YMP/CC-0013, Rev 07/29/91, Vol. 2, pp 6-76, Test Planning and Location Information
5.4 IC-1625, Tamondong to Stanley, dated 7-23-91, Repositioning of Conveyor System in all Calico Hills Entry Openings thus Requiring Size Increase to 18 ft. diameter.
5.5 Drawings: YMP-025-2-Ming-MI-48,51,53 Rev A.

6.0 ASSUMPTIONS: The following assumptions have been used in the development of this analysis:

- All Design Input will be included in an approved Basis for Design

- The site characterization testing program as described in Volume 2 of YMP/CC-0013 ESFDR, Rev. 07-29-91 can be constructed and operated in a ramp cross section designed to support all other required functions.

- Assume that the required diameter is the finished diameter.

- The largest equipment piece contemplated for passage down the south Calico Hills ramp is a 9 feet wide mechanical excavator.

7.0 COMPUTER PROGRAM:

Not applicable.

8.0 UNITS: English Standard

9.0 ANALYSIS:

9.1 Review of the ESFDR requirements:

1. PC 1.c. basically requires that testing needs must be considered.

2. PC 1e requires that personnel transport needs be considered.

3. PC 1f,i,iv requires that the ramp be designed to accommodate the equipment contemplated for use.

4. PC 1g Covers utility accommodation.

5. PC 1h,i,ii Covers ventilation.

6. PC 1i requires that the ramp be capable of being used as an emergency escape way.

7. PC 2d iii requires that the opening configuration does not affect isolation capability.

8. CA i requires that testing flexibility be provided.

9. C B ii requires that the needs for site performance confirmation be provided for.

10. 1.2.6.5.4 PC 1c requires space for utilities.

9.2 Functional Requirements:

The following are the presently known functions of the Calico Hills South Access ramp:

1. To provide an access for personnel and equipment to the Calico Hills level from the TS South Access Ramp;

2. To provide exposure of the rock mass that lies between the MTL and the Calico Hills Level for scientific examination and evaluation;

3. To provide a pathway for ventilation airflow to support construction and testing operations in the Ramp and on the Calico Hills Level.

9.3 Refer to ST-MN-010, "Transportation Methods Analysis," which specifies the cross-sectional dimensions of the equipment that will be used in the Calico Hills operations. The largest sizes of the appropriate equipment will be used for the sake of conservatism and flexibility of operations scheduling. It is contemplated that a 9 ft wide mechanical excavator will traverse the ramp on an occasional basis. Section 5.3 of the cited study clearly indicates that a

minimum roadway width of 10.5 feet is required in order to provide room for equipment and the mandated walkway width of 2.5 feet.

9.4 The Alternative Studies program selected Option 30 for a Basis of Design. One of the important features was the use of TBM Excavation for the Calico Hills access ramp. This method, of course, produces a round cross-sectional shape which has some influence upon the ultimate size of the excavation because of the need to provide a flat roadway. This results in wasted space from utilizing equipment with basically rectangular cross-section in a circular shaped space.

9.5 Figure 1 illustrates how various equipment items and fixtures could be arranged in a 18 ft diameter ramp cross-section.

9.6 Discussion of ramp cross-section arrangement shown in Figure 1.

9.6.1 General statements:

(1) Placement of the conveyor on the rib of the ramp is a key feature in the cross-sectional arrangement. The placement of the conveyor on or near the roadway level influences the required diameter. The minimum roadway width and the width of the conveyor establishes the minimum ramp diameter.

(2) Alcoves may be constructed at various locations in the ramp. At this time sufficient flexibility as to excavation methods and procedures exists to permit the ramp size to be independent of side excavation activity.

(3) Ventilation air flow is another important influence on the ramp diameter. It will be shown below that the roadway width requirements are more important than ventilation in establishing the minimum ramp cross section diameter requirement.

9.6.2 How the Arrangement in Figure 1 meets the ESFDR Requirements:

1. Testing needs do not appear to influence the size of the cross-section. Test alcoves can be constructed in this cross-section.

2. The cited transportation study covers the personnel transport and equipment requirement. The cross-section allows the equipment specified in the transportation study to function.

3. The ventilation requirements (space and duct) are specified in the cited ventilation study. Figure 1 provides the required space.

4. Utilities and escapeway requirements are met by the space provided and the utility hangers shown.

5. The ramp meets the isolation requirement by providing a stable shape. The implications of the size on isolation capability are not known. A reasonable conclusion at this point is that the smallest cross section size which satisfies all the function and requirements is the most desirable from an isolation standpoint.

6. The needs for flexibility and performance confirmation are met by providing ample room for excavation and drilling equipment.

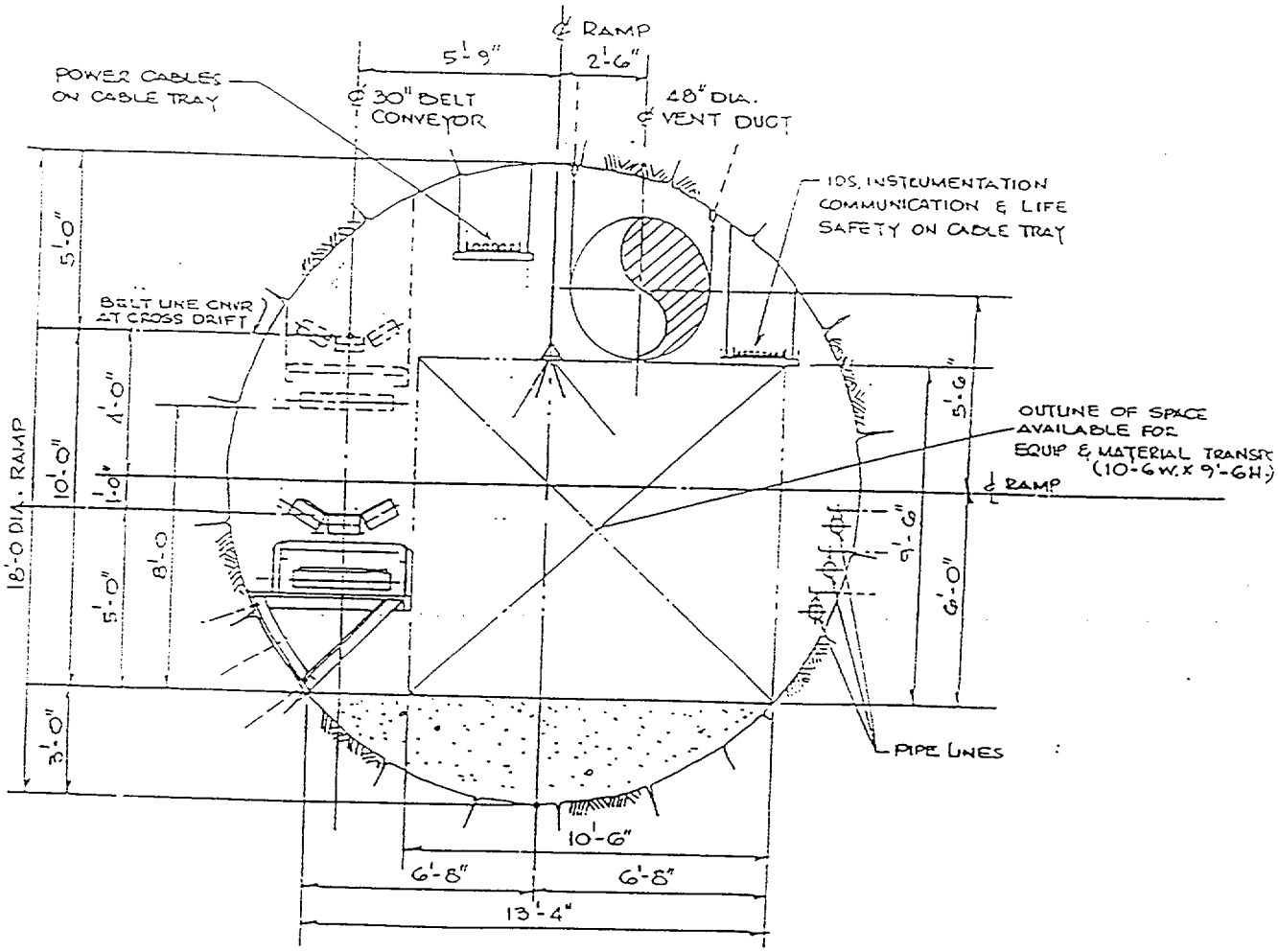
9.6.3 How Arrangement in Figure 1 Meets Functional Requirements:

1. Access for personnel and equipment: The arrangements shown in Figure 1 meets this functional requirement if the equipment fleet as defined in ST-MN-010 is utilized.

2. Rock mass exposure: Since mapping should be done ahead of installation of the permanent equipment shown in Figure 1 the mapping function has no influence on the ramp cross section size.

3. Ventilation: Refer to ST-MN-013, 014, and Drawing YMP-025-2-Ming-MI51. The ventilation air volume required to support the Calico Hills construction and testing is 115000 CFM. The function of providing enough space for ducting and intake air flow is shown to be satisfied by the arrangement shown in Figure 1. The approximate area for airflow in this cross section is 254 ft^2. The approximate air speed would be 453 ft/min. This air speed is within industry guidelines. Therefore ventilation requirements do not determine the cross section diameter.

FIGURE 1



TYPICAL 18'-0" DIA. RAMP CROSS-SECTION

CALICO HILLS RAMP CROSS SECTION

PRELIMINARY LAYOUT

USING MINIMUM REQUIRED SPACE FOR EQUIPMENT.

4. The arrangement shown in Figure 1 shows 9.5 ft of headroom which will facilitate the movement of the contemplated mechanical excavator and would permit sufficient clearance of the conveyor when excavating an alcove to minimize interference with the advancing TBM.

10. CONCLUSIONS AND RECOMMENDATIONS:

10.1 Conclusions: The foregoing discussion and the references cited lead to the following preliminary conclusions:

1. The ventilation, muck handling, and transportation equipment space requirements are the primary determinants for the ramp diameter because any restrictions on equipment size or operations will degrade system and program performance.

2. The Testing program scheduled to be done in the Calico Hills south ramp has no effect on the ramp cross section size.

3. All of the ESFDR requirements which affect ramp cross-section size are met by the proposed 18 ft. diameter arrangement shown in Figure 1.

10.2 Recommendation: On a preliminary basis, adopt a 18 ft. diameter for the cross-section of the Calico Hills South Access ramp. If changes in requirements and the scope of work on the Calico Hills level are made then additional analyses of the ramp size will be made. A detailed trade study would be justified when equipment and operations space needs are better defined in Title II engineering.

In addition, an analysis of alternative methods for construction of the flat roadway in a TBM driven ramp (i.e. built-up roadbed vs cutting a flat roadbed) should be performed since the cross section size is dependent on the roadway width.

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-030 Rev: 1

WBS No. 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	Romeo S. Jurani		Sr. Mining Engr.	8/22/91
CHECKER:	Mark J. Esp		Sr. Mining Engr.	8/22/91
APPROVAL - LDE:	Bruce T. Stanley		Ld. Mining Engr.	8/22/91
APPROVAL - SCDM:	Bolek R. Chytrowski		SCDM	8/22/91
QA CONCURRENCE:	Paul Hale		Sr. QA Specialist	8/22/91

SUBJECT: ESF VENTILATION

TITLE: Preliminary Ventilation Analysis
ESF Construction Phase

QAG Reference: RSN-GR-013, Rev. 0

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1. PURPOSE:

A) To determine the airflow requirement during the construction phase of the Exploratory Studies Facilities (ESF), before the north and south ramps are connected; and

B) To establish the preliminary size of the ventilation ducts, air quantity output, pressure, and motor horsepower of the axial fans needed during the ESF construction and initial testing activities.

Revision 1 is issued to incorporate the Management and Technical Review comments

2. METHOD:

The general mining plan and construction strategy are analyzed and provided with the appropriate ventilation airflows in accordance with the general mining industry practices and project requirement documents.

2.1. The ventilation practices of the mining industry are reviewed to determine the range of airflow velocities applicable to the ESF.

2.2. The air quantities to support the development and construction plans of the TS/CH North and South Ramps are calculated based on general mining industry practices. After the ramps are connected at the TS and CH levels, another mode of ventilation (flow-through) will be implemented as discussed in a separate study, # ST-MN-031, Preliminary Ventilation Analysis, Operation Phase.

2.3. A ventilation schematic is prepared to reflect the ESF construction model and calculate air resistances for each branch.

2.4. The approximate size of the rigid vent ducts and vane axial fans available in the market are installed in the model to produce a general arrangement plan. The established air quantities are to be induced to the working face by the fans through metallic vent ducts to handle either the fresh or the return air.

2.5. Based on the ESF construction model, a computer simulation of the ventilation system is generated using VNETPC Version 3.0 software.

2.6. Computer output which satisfies the estimated airflow requirement at the face is to be modeled. The corresponding leakages and fan power distribution along branches are to be tabulated and plotted. This data is the basis for the recommendation of this study.

3. DESIGN INPUT:

3.1. YMP/CC-0013 (ESFDR) Rev. 5/31/91 issued May 31, 1991.

Sec. 1.2.6.3.1/FR.1.
Provide a ventilation system to supply ventilation air to and exhaust ventilation from the subsurface workings to meet the needs of construction and operation of the underground site characterization and testing program.

Sec. 1.2.6.3.1/PC.1a.
The ventilation system shall supply and exhaust adequate quantities of air to and from underground working areas such that operator safety, health and productivity requirements are maintained.

Sec. 1.2.6.3.1/PC.1e.
The ventilation system shall minimize leakage to the extent practicable.

3.2 YMP/CC-0002 (RIB) Ver. 4, Rev. 4, issued April 8, 1991.

- Chapter 2, Section 4, Item 2, Table 1.
  Ramp or drift air velocity shall not exceed 1,500 ft./min.

4. CODES AND STANDARDS:

4.1 30 CFR 57, Revised July 1, 1988 (MSHA)
4.2 DOE Order #5480.4 with Change 2, issued 5/16/89
4.3 California Code 8 CAC 4.20 and 8 CAC 4.17, issued 7/11/81

5. REFERENCE MATERIAL:

A. RSN Report, ST-MN-010, Preliminary Underground Transportation Methods Analysis, Rev. 1, issued June 14, 1991.

B. RSN Report, ST-MN-020, ESF Preliminary Excavation Plan, Rev. 1, issued June 13, 1991.

C. Mine Ventilation and Air Conditioning, 1982, Second Edition, by Hartman, Mutmansky, and Wang.

D. Joy Axivane Fan Catalog # J 610 (Fan Curves as dated).

E. VNETPC Version 3.0 Software, Ventilation Simulation Program with Gas Distribution User's Manual, July, 1988.

F. VNETPC Ver. 3.0 Certified Input and Output Data
   - ACL 13, North Ramp System, issued 7/23/91.
   - ACL 12, South Ramp System, issued 7/23/91.

6. ASSUMPTIONS:

6.1. It is assumed that all input will be included in the approved Basis For Design (BFD)

6.2. For the purpose of general arrangement concept, the assumptions used are common mining engineering practices and are not subject to verification. The ESF construction ventilation system will not be used to support the repository facilities.

6.3. The report deals mostly with airflow distribution issues. Other related subjects such as heat loads and heat stress, fan noise, dust control, and environmental monitoring are to be addressed in a separate report.

7. COMPUTER PROGRAMS:

VNETPC Version 3.0, Ventilation Simulation Program with Gas Distribution Software. The following documentation are referred:

- North Ramp System - ACL Number: ACL-13
- South Ramp System - ACL Number: ACL-12
- Program Name: VNETPC Version 3.0
- Computer Type: Dell 325
- Software Design Description Waiver: SDDW-02, Rev. 00
- Software Validation Waiver: SVW-02, Rev. 00
- Hardware Certification Form Number: HCR-01-00
- Software Certification Form Number: SCF-02-00
- Refer to ACL 12 and 13 for Input/Output certification run
- Basis for Application: VNETPC Version 3.0 was developed to simulate underground mine ventilation. Refer software documentation SVVR - 02, Rev. 00, Test 3, for applicability.

8. UNITS USED: - English Standard (British if noted)

9. ANALYSIS:

9.1. Determining Air Velocity in ESF Work Place by Industry Practices

9.1.1. Survey of Air Velocity Used by Mining Operations

From the survey of operating mines as discussed on pages 401 through 406 of the Mine Ventilation and Air Conditioning by Hartman,

Mutmansky and Wang (Ref. C, p. 401-406), the following summary data is the minimum reported air velocity at the working face:

1.	Amax Climax	230 fpm
2.	Magma San Manuel	50
3.	NCCM Chingola	150
4.	Ranchers Exploration Johnny M....	100
5.	UN-Homestake Section 23	140
6.	UN-Homestake Section 13	80
7.	UN-Homestake Section 15	80
8.	UN-Homestake Section 25	80
9.	Mt Isa	80
10.	Magma Magma	600
11.	Hecla Lucky Friday	100
12.	Hecla Star	100
13.	Noranda Geco	150
14.	Cities Service Cherokee.....	120
15.	Cities Service Calloway.....	120
	Average Face Air Velocity.....	145 fpm

It is apparent that the figures show some commom face air velocity practice in the range from 100 to 150 fpm.

9.1.2. Establishing Face Air Velocity Trend

The average calculated air velocity of 145 fpm is an ideal practice as responded by mining operators. This is corroborated by ventilation experts (Ref. C, p. 394), who recommend stope air velocities to be in the range of 100 - 400

fpm as a design rule of thumb unless excess heat is a problem in the mine environment.

9.1.3. Face Air Velocity Recommendation and Precaution

For the purpose of general arrangement, a range of face air velocities between 140-150 fpm is recommended for the ESF construction and operation. It is cautioned however, that this recommendation will be reviewed and may be changed as needed. The mining industry may have successfully adapted an ideal face air velocity practice. It is not certain however, if any of these mines has a violation record cited by any government agency on account of insufficient ventilation due to the presence of diesel equipment, or high concentration of deleterious dust beyond the threshold limit values. Other factors not included in the survey were the use of diesel equipment, the impact of mining method such as the use of mechanical miners, the limited use of water for dust control and the severity presence of potential toxic respirable dust such as quartz, cristobalite and tridymite.

9.2. Determination of Air Quantity for ESF Construction

The design air quantity of the ventilation system will include reasonable leakages to yield the recommended air velocity range at the face of about 140 - 150 fpm. At 15% leakage factor, a net velocity range of (140/0.85 and 150/0.85) 165 - 176 fpm is used for the design calculation.

To support the ESF construction (Ref. A,B), and the initial site characterization (worst case), four drifts are advanced simultaneously at either the North or the South Ramp System, namely:

1. One 25 ft. dia. TS Ramp or TS Drift driven by a Tunnel Boring Machine.

2. One 18 ft. dia. CH Ramp or CH Drift driven by a Tunnel Boring Machine.

3. One TS Lateral Drift, 12 ft. x 20 ft.

4. One CH Lateral Drift, 9 ft. x 16 ft.

Table 9.2 shows the calculated data of air quantities with the 15% leakage factor. Projected air velocities when leakages are increased to 20% and 25% are also shown in the table. The total quantity required is about 188,500 cfm for construction of the north or south ramp respectively.

It is estimated that the air quantities in each of the four drifts will support a limited number of diesel equipment (100 cfm/BHP) to service the mining face and personnel.

The ESF will be developed mostly by mechanical miners with conveyor haulage system (Ref. A). Diesel ventilation therefore will not be the driving criterion in determining drift air quantity requirement.

TABLE 9.2 Air Quantity For ESF Construction

VENTILATION DATA

AIR QUANTITY DISTRIBUTION & PROJECTED DRIFT
AIR VELOCITY DURING CONSTRUCTION PHASE

TOTAL AIR SUPPLY = 188,500 cfm.

For North or South Development Activities

R.S. Jurani 7/17/91

TS LEVEL DEVELOPMENT	Volume in cfm	Cross Area* (Est. only) ft^2	Projected Max Drift Air Velocity (fpm)	Projected Air Velocity @ Face Less 15% Leakage (fpm)	Projected Air Velocity @ Face Less 20% Leakage (fpm)	Projected Air Velocity @ Face Less 25% Leakage (fpm)
TS Ramp or TS Main Drift	82,000	491 (25' dia)	167	142	134	125
TS Lateral (One Face)	40,000	20'x12'	167	142	133	125
TS Total=	122,000 cfm					

CH LEVEL DEVELOPMENT	Volume in cfm	Cross Area* (Est. only) ft^2	Projected Max Drift Air Velocity (fpm)	Projected Air Velocity @ Face Less 15% Leakage (fpm)	Projected Air Velocity @ Face Less 20% Leakage (fpm)	Projected Air Velocity @ Face Less 25% Leakage (fpm)
CH Ramp or CH Main Drift	42,500	254 (18' dia)	167	142	134	125
CH Lateral (One Face)	24,000	16'x 9'	167	142	133	125
CH Total=	66,500 cfm					

* Calculation of drift cross section in rectangular shape is not final and will be changed to realistic dimension once cutter head configuration of the mechanical miner is finalized.

9.3 Determining Fresh and Return Airways

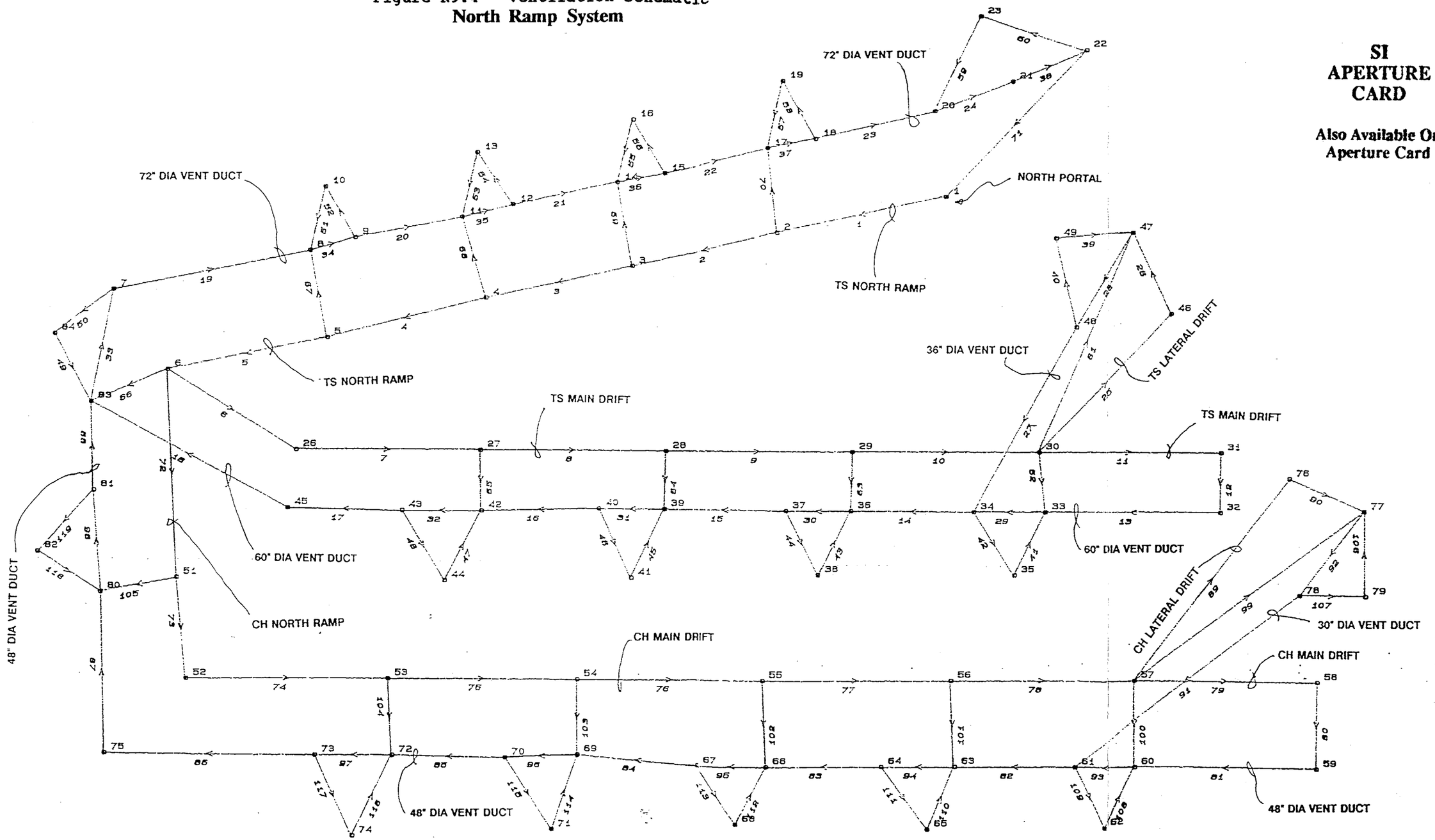
During the ESF construction by mechanical miners, dust will become airborne at the face of the advancing drift. The design of the ventilation system must capture the dust laden air at the face as soon as feasible and isolate the return air from the breathing zone of the workers who would be in any place along the ramp or drift. Subsequently or eventually, the dusty air will be cleaned and returned to the surface.

The set up will require the return air at the face to be directed to the ventilation ducts enclosed and away from the underground human environment. The airflow logically makes the ramp and drift the fresh air intake, and the vent duct the return airway. Vane axial fans in the ducts move the air.

9.4. Ventilation Schematic

A ventilation schematic representing the ESF construction phase together with the ventilation tubes and axial fans is as shown in Figure N9.4, North Ramp System for the north ramp activities and Figure S9.4, South Ramp System for the south ramp activities. The schematic establishes the junction numbers delineating ventilation branches.

Figure N9.4 Ventilation Schematic
North Ramp System



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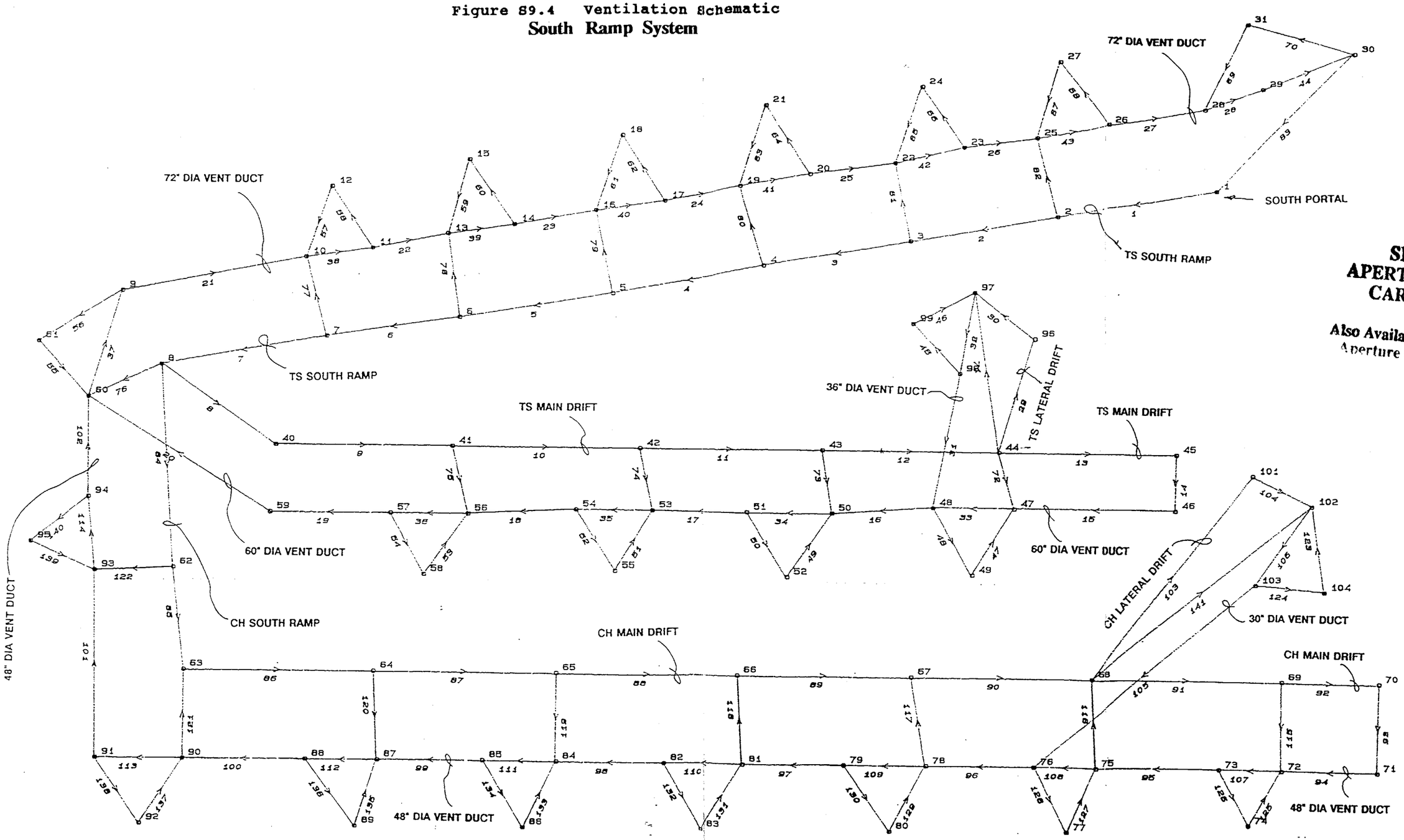
VENTILATION SCHEMATIC DELINEATING JUNCTION, BRANCH AND AIRFLOW DIRECTION

9112020061-09

Figure S9.4 Ventilation Schematic
South Ramp System



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VENTILATION SCHEMATIC DELINEATING JUNCTION, BRANCH AND AIRFLOW DIRECTION

9112020061-09/01

9.5. Estimation of Airway Resistances

Each branch airway is identified and supplied with the following ventilation data:

- Frictional coefficient factor x 10^{-10}, (K)
- Cross section area (A), ft^2
- Perimeter (P), ft
- Equivalent length (L), ft

The resistance of the airway (R) as VNETPC Software input (in PU units) is calculated as:

$$R = K \times P \times L / (52 \times A^3)$$

The data and calculations of the north and south ramp airway resistances are tabulated in Table N9.5, Resistance Calculation - North Ramp System, and Table S9.5, Resistance Calculation - South Ramp System.

Based upon good engineering judgement, the K factor used is 75 for the ramps or drifts and 15 for the ventilation ducts. Ventilation control resistance (PU units) equivalent is 250 for duct leakages and 600 for fan leakages.

TABLE N9.5 Resistance Calculation
North Ramp System

NORTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 1 of 3 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH L' (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
1	1	2	0.0012	75	490.8750	78.5400	1107	1218	TS North Ramp Intake-1st leg	1
2	2	3	0.0012	75	490.8750	78.5400	1107	1218	TS North Ramp Intake-2nd leg	2
3	3	4	0.0012	75	490.8750	78.5400	1107	1218	TS North Ramp Intake-3rd leg	3
4	4	5	0.0012	75	490.8750	78.5400	1107	1218	TS North Ramp Intake-4th leg	4
5	5	6	0.0012	75	490.8750	78.5400	1107	1218	TS North Ramp Intake-5th leg	5
6	6	26	0.0001	75	490.8750	78.5400	95	105	TS N Ramp below TS/CH Intersection	6
7	26	27	0.0009	75	490.8750	78.5400	850	935	TS N Ramp Curve	7
8	27	28	0.0014	75	490.8750	78.5400	1300	1430	TS Main Drift 1st leg	8
9	28	29	0.0014	75	490.8750	78.5400	1300	1430	TS Main Drift 2nd leg	9
10	29	30	0.0014	75	490.8750	78.5400	1300	1430	TS Main Drift 3rd leg	10
11	30	31	0.0015	75	490.8750	78.5400	1423	1565	TS Main Drift 4th leg	11
12	31	32	0.0329	15	19.6350	15.7080	50	55	TS Main Drift Vent Duct Intake 60"	12
13	32	33	0.9369	15	19.6350	15.7080	1423	1565	TS Main Drift Vent Duct 60" 4th	13
14	34	36	0.8560	15	19.6350	15.7080	1300	1430	TS Main Drift Vent Duct 60" 3rd	14
15	37	39	0.8560	15	19.6350	15.7080	1300	1430	TS Main Drift Vent Duct 60" 2nd	15
16	40	42	0.8560	15	19.6350	15.7080	1300	1430	TS Main Drift Vent Duct 60" 1st	16
17	43	45	0.5597	15	19.6350	15.7080	850	935	TS Main Drift Curve Vent Duct 60"	17
18	45	83	0.0626	15	19.6350	15.7080	95	105	TS N Ramp Curve Vent Duct 60"	18
19	7	8	0.2929	15	28.2744	18.8496	1107	1218	TS N Ramp Duct Exhaust-5th leg 72"	19
20	9	11	0.2929	15	28.2744	18.8496	1107	1218	TS N Ramp Duct Exhaust-4th leg 72"	20
21	12	14	0.2929	15	28.2744	18.8496	1107	1218	TS N Ramp Duct Exhaust-3rd leg 72"	21
22	15	17	0.2929	15	28.2744	18.8496	1107	1218	TS N Ramp Duct Exhaust-2nd leg 72"	22
23	18	20	0.2929	15	28.2744	18.8496	1107	1218	TS N Ramp Duct Exhaust-1st leg 72"	23
24	20	21	0.0529	15	28.2744	18.8496	200	220	TS North Collar Exhaust Duct	24
25	30	46	0.0098	75	280.0000	68.0000	2000	2200	TS Lateral Drift 14'X 20'	25
26	46	47	0.8467	15	7.0686	9.4248	100	110	Duct Intake of TS Lateral 36"	26
27	48	34	16.9349	15	7.0686	9.4248	2000	2200	Vent Tube of TS Lateral 36"	27
28	47	48	Fan Size 4	0	0.0000	0.0000	0	0	Fan Size 4	28
29	33	34	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	29
30	36	37	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	30
31	39	40	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	31
32	42	43	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	32
33	83	7	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	33
34	8	9	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	34
35	11	12	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	35
36	14	15	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	36
37	17	18	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	37
38	21	22	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	38
39	49	47	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	39
40	48	49	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	40

TABLE N9.5 Resistance Calculation
North Ramp System

NORTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 2 of 3 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft²	PERIMETER P (Ft)	ACTUAL LENGTH L' (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
41	35	33	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	41
42	34	35	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	42
43	38	36	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	43
44	37	38	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	44
45	41	39	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	45
46	40	41	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	46
47	44	42	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	47
48	43	44	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	48
49	84	83	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	49
50	7	84	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	50
51	10	8	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	51
52	9	10	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	52
53	13	11	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	53
54	12	13	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	54
55	16	14	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	55
56	15	16	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	56
57	19	17	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	57
58	18	19	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	58
59	23	20	Fan Leak R-S	0	0.0000	0.0000	0	0	Fan Leak R-S	59
60	22	23	Fan Leak R-S	0	0.0000	0.0000	0	0	Fan Leak R-S	60
61	30	47	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	61
62	30	33	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	62
63	29	36	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	63
64	28	39	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	64
65	27	42	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	65
66	6	83	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	66
67	5	8	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	67
68	4	11	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	68
69	3	14	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	69
70	2	17	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	70
71	22	1	Surf Con.	0	0.0000	0.0000	0	0	Surf Con.	71
72	6	51	0.0082	75	254.4696	56.5488	1500	1650	CH N Ramp (Upper 1)	72
73	51	52	0.0024	75	254.4696	56.5488	439	483	CH N Ramp (Upper 2)	73
74	52	53	0.0051	75	254.4696	56.5488	944	1038	CH N Ramp Curve	74
75	53	54	0.0086	75	254.4696	56.5488	1574	1731	CH N Ramp (Lower)	75
76	54	55	0.0086	75	254.4696	56.5488	1574	1731	CH N Main Drift 1st leg	76
77	55	56	0.0086	75	254.4696	56.5488	1574	1731	CH N Main Drift 2nd leg	77
78	56	57	0.0086	75	254.4696	56.5488	1574	1731	CH N Main Drift 3rd leg	78
79	57	58	0.0086	75	254.4696	56.5488	1574	1731	CH N Main Drift 4th leg	79
80	58	59	0.1005	15	12.5664	12.5664	50	55	CH N Main Vent Tube Intake 48"	80
81	59	60	3.1627	15	12.5664	12.5664	1574	1731	CH N Main Vent Tube 1st leg	81
82	61	63	3.1627	15	12.5664	12.5664	1574	1731	CH N Main Vent Tube 2nd leg	82

TABLE N9.5 Resistance Calculation
North Ramp System

NORTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 3 of 3 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH L' (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
83	64	66	3.1627	15	12.5664	12.5664	1574	1731	CH N Main Vent Tube 3rd leg	83
84	67	69	3.1627	15	12.5664	12.5664	1574	1731	CH N Main Vent Tube 4th leg	84
85	70	72	3.1627	15	12.5664	12.5664	1574	1731	CH N Ramp Vent Tube (Lower)	85
86	73	75	1.8968	15	12.5664	12.5664	944	1038	CH N Ramp Vent Tube (Curve)	86
87	75	80	0.8821	15	12.5664	12.5664	439	483	CH N Ramp Vent Tube (Upper 2)	87
88	81	83	3.0140	15	12.5664	12.5664	1500	1650	CH N Ramp Vent Tube (Upper 1)	88
89	57	76	0.0531	75	144.0000	50.0000	2000	2200	CH N Lateral Drift 16'x9'	89
90	76	77	2.1070	15	4.9087	7.8540	100	110	CH N Lateral Vent Tube Intake 30"	90
91	78	61	42.1394	15	4.9087	7.8540	2000	2200	CH N Lateral Vent Tube 30"	91
92	77	78	Fan Size 5	0	0.0000	0.0000	0	0	Fan Size 5	92
93	60	61	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	93
94	63	64	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	94
95	66	67	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	95
96	69	70	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	96
97	72	73	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	97
98	80	81	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	98
99	57	77	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	99
100	57	60	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	100
101	56	63	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	101
102	55	66	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	102
103	54	69	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	103
104	53	72	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	104
105	51	80	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	105
106	79	77	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	106
107	78	79	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	107
108	62	60	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	108
109	61	62	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	109
110	65	63	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	110
111	64	65	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	111
112	68	66	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	112
113	67	68	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	113
114	71	69	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	114
115	70	71	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	115
116	74	72	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	116
117	73	74	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	117
118	82	80	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	118
119	81	82	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	119

TABLE S9.5 Resistance Calculation
South Ramp System

SOUTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 1 of 4 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH L' (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
1	1	2	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-1st leg	1
2	2	3	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-2nd leg	2
3	3	4	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-3rd leg	3
4	4	5	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-4th leg	4
5	5	6	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-5th leg	5
6	6	7	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-6th leg	6
7	7	8	0.00118	75	490.8750	78.5400	1120	1232	TS South Ramp Intake-7th leg	7
8	8	40	0.00011	75	490.8750	78.5400	100	110	TS S Ramp below TS/CH Intersection	8
9	40	41	0.00127	75	490.8750	78.5400	1206	1327	TS S Ramp Curve	9
10	41	42	0.00140	75	490.8750	78.5400	1331	1464	TS Main Drift 1st leg	10
11	42	43	0.00140	75	490.8750	78.5400	1331	1464	TS Main Drift 2nd leg	11
12	43	44	0.00140	75	490.8750	78.5400	1331	1464	TS Main Drift 3rd leg	12
13	44	45	0.00140	75	490.8750	78.5400	1331	1464	TS Main Drift 4th leg	13
14	45	46	0.03292	15	19.6350	15.7080	50	55	TS Main Drift Vent Duct Intake 60"	14
15	46	47	0.87637	15	19.6350	15.7080	1331	1464	TS Main Drift Vent Duct 60" 4th	15
16	48	50	0.87637	15	19.6350	15.7080	1331	1464	TS Main Drift Vent Duct 60" 3rd	16
17	51	53	0.87637	15	19.6350	15.7080	1331	1464	TS Main Drift Vent Duct 60" 2nd	17
18	54	56	0.87637	15	19.6350	15.7080	1331	1464	TS Main Drift Vent Duct 60" 1st	18
19	57	59	0.79407	15	19.6350	15.7080	1206	1327	TS Main Drift Curve Vent Duct 60"	19
20	59	60	0.06584	15	19.6350	15.7080	100	110	TS S Ramp Curve Vent Duct 60"	20
21	9	10	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-7th leg 72"	21
22	11	13	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-6th leg 72"	22
23	14	16	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-5th leg 72"	23
24	17	19	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-4th leg 72"	24
25	20	22	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-3rd leg 72"	25
26	23	25	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-2nd leg 72"	26
27	26	28	0.29636	15	28.2744	18.8496	1120	1232	TS S Ramp Duct Exhaust-1st leg 72"	27
28	28	29	0.05292	15	28.2744	18.8496	200	220	TS South Collar Exhaust Duct	28
29	44	96	0.00983	75	280.0000	68.0000	2000	2200	TS Lateral Drift 14'x20'	29
30	96	97	0.84674	15	7.0686	9.4248	100	110	Duct Intake of TS Lateral 36"	30
31	98	48	16.93490	15	7.0686	9.4248	2000	2200	Vent Tube of TS Lateral 36"	31
32	97	98	Fan Size 4	0	0.0000	0.0000	0	0	Fan Size 4	32
33	47	48	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	33
34	50	51	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	34
35	53	54	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	35
36	56	57	Fan Size 2	0	0.0000	0.0000	0	0	Fan Size 2	36
37	60	9	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	37
38	10	11	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	38
39	13	14	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	39
40	16	17	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	40
41	19	20	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	41

TABLE S9.5 Resistance Calculation
South Ramp System

SOUTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 2 of 4 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
42	22	23	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	42
43	25	26	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	43
44	29	30	Fan Size 1	0	0.0000	0.0000	0	0	Fan Size 1	44
45	98	99	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	45
46	99	97	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	46
47	49	47	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	47
48	48	49	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	48
49	52	50	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	49
50	51	52	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	50
51	55	53	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	51
52	54	55	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	52
53	58	56	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	53
54	57	58	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	54
55	61	60	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	55
56	9	61	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	56
57	12	10	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	57
58	11	12	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	58
59	15	13	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	59
60	14	15	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	60
61	18	16	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	61
62	17	18	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	62
63	21	19	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	63
64	20	21	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	64
65	24	22	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	65
66	23	24	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	66
67	27	25	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	67
68	26	27	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	68
69	31	28	Fan Leak R-S	0	0.0000	0.0000	0	0	Fan Leak R-S	69
70	30	31	Fan Leak R-S	0	0.0000	0.0000	0	0	Fan Leak R-S	70
71	44	97	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	71
72	44	47	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	72
73	43	50	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	73
74	42	53	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	74
75	41	56	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	75
76	8	60	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	76
77	7	10	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	77
78	6	13	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	78
79	5	16	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	79
80	4	19	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	80
81	3	22	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	81
82	2	25	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	82
83	30	1	Surf Con.	0	0.0000	0.0000	0	0	Surf Con.	83

TABLE S9.5 Resistance Calculation
South Ramp System

SOUTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 3 of 4 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft²	PERIMETER P (Ft)	ACTUAL LENGTH (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
84	8	62	0.00906	75	254.4696	56.5488	1664	1830	CH S Ramp (Upper 1)	84
85	62	63	0.00906	75	254.4696	56.5488	1664	1830	CH S Ramp (Upper 2)	85
86	63	64	0.00514	75	254.4696	56.5488	944	1038	CH S Ramp Curve	86
87	64	65	0.00828	75	254.4696	56.5488	1520	1672	CH S Ramp (Lower 1)	87
88	65	66	0.00828	75	254.4696	56.5488	1520	1672	CH S Ramp (Lower 2)	88
89	66	67	0.00828	75	254.4696	56.5488	1520	1672	CH S Main Drift 1st leg	89
90	67	68	0.00828	75	254.4696	56.5488	1520	1672	CH S Main Drift 2nd leg	90
91	68	69	0.00828	75	254.4696	56.5488	1520	1672	CH S Main Drift 3rd leg	91
92	69	70	0.00828	75	254.4696	56.5488	1520	1672	CH S Main Drift 4th leg	92
93	70	71	0.10047	15	12.5664	12.5664	50	55	CH S Main Vent Tube Intake 48"	93
94	71	72	3.05423	15	12.5664	12.5664	1520	1672	CH S Main Vent Tube 4th leg	94
95	73	75	3.05423	15	12.5664	12.5664	1520	1672	CH S Main Vent Tube 3rd leg	95
96	76	78	3.05423	15	12.5664	12.5664	1520	1672	CH S Main Vent Tube 2nd leg	96
97	79	81	3.05423	15	12.5664	12.5664	1520	1672	CH S Main Vent Tube 1st leg	97
98	82	84	3.05423	15	12.5664	12.5664	1520	1672	CH S Ramp (Lower 2) Vent Tube	98
99	85	87	3.05423	15	12.5664	12.5664	1520	1672	CH S Ramp (Lower 1) Vent Tube	99
100	88	90	1.89684	15	12.5664	12.5664	944	1038	CH S Ramp Curve Vent Tube	100
101	91	93	3.34358	15	12.5664	12.5664	1664	1830	CH S Ramp (Upper 2) Vent Tube	101
102	94	60	3.34358	15	12.5664	12.5664	1664	1830	CH S Ramp (Upper 1) Vent Tube	102
103	68	101	0.05313	75	144.0000	50.0000	2000	2200	CH S Lateral Drift 16'x9'	103
104	101	102	1.05349	15	4.9087	7.8540	50	55	CH S Lateral Vent Tube Intake 30"	104
105	103	76	42.13944	15	4.9087	7.8540	2000	2200	CH S Lateral Vent Tube 30"	105
106	102	103	Fan Size 5	0	0.0000	0.0000	0	0	Fan Size 5	106
107	72	73	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	107
108	75	76	Fan Size 3	0	0.0000	0.0000	0		Fan Size 3	108
109	78	79	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	109
110	81	82	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	110
111	84	85	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	111
112	87	88	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	112
113	90	91	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	113
114	93	94	Fan Size 3	0	0.0000	0.0000	0	0	Fan Size 3	114
115	69	72	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	115
116	68	75	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	116
117	67	78	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	117
118	66	81	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	118
119	65	84	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	119
120	64	87	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	120
121	63	90	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	121
122	62	93	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	122
123	104	102	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	123

TABLE S9.5 Resistance Calculation
South Ramp System

SOUTH RAMP SYSTEM -CONSTRUCTION VENTILATION Page 4 of 4 R.S. Jurani 7/17/91

Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
124	103	104	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	124
125	74	72	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	125
126	73	74	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	126
127	77	75	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	127
128	76	77	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	128
129	80	78	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	129
130	79	80	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	130
131	83	81	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	131
132	82	83	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	132
133	86	84	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	133
134	85	86	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	134
135	89	87	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	135
136	88	89	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	136
137	92	90	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	137
138	91	92	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	138
139	95	93	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	139
140	94	95	Fan Leak .5R	0	0.0000	0.0000	0	0	Fan Leak .5R	140
141	68	102	Duct Leak R	0	0.0000	0.0000	0	0	Duct Leak R	141

9.6. Computer Simulation of ESF Ventilation (Construction Phase) by VNETPC Software

9.6.1. Vane axial fan catalogs are referred, and the fan units estimated to perform the airflow requirement are selected. Five sizes are analyzed on three fan models and each of their performance characteristics and curve data are shown on Figures 9.6.1A through 9.6.1E.

FIGURE 9.6.1A Fan Size No. 1

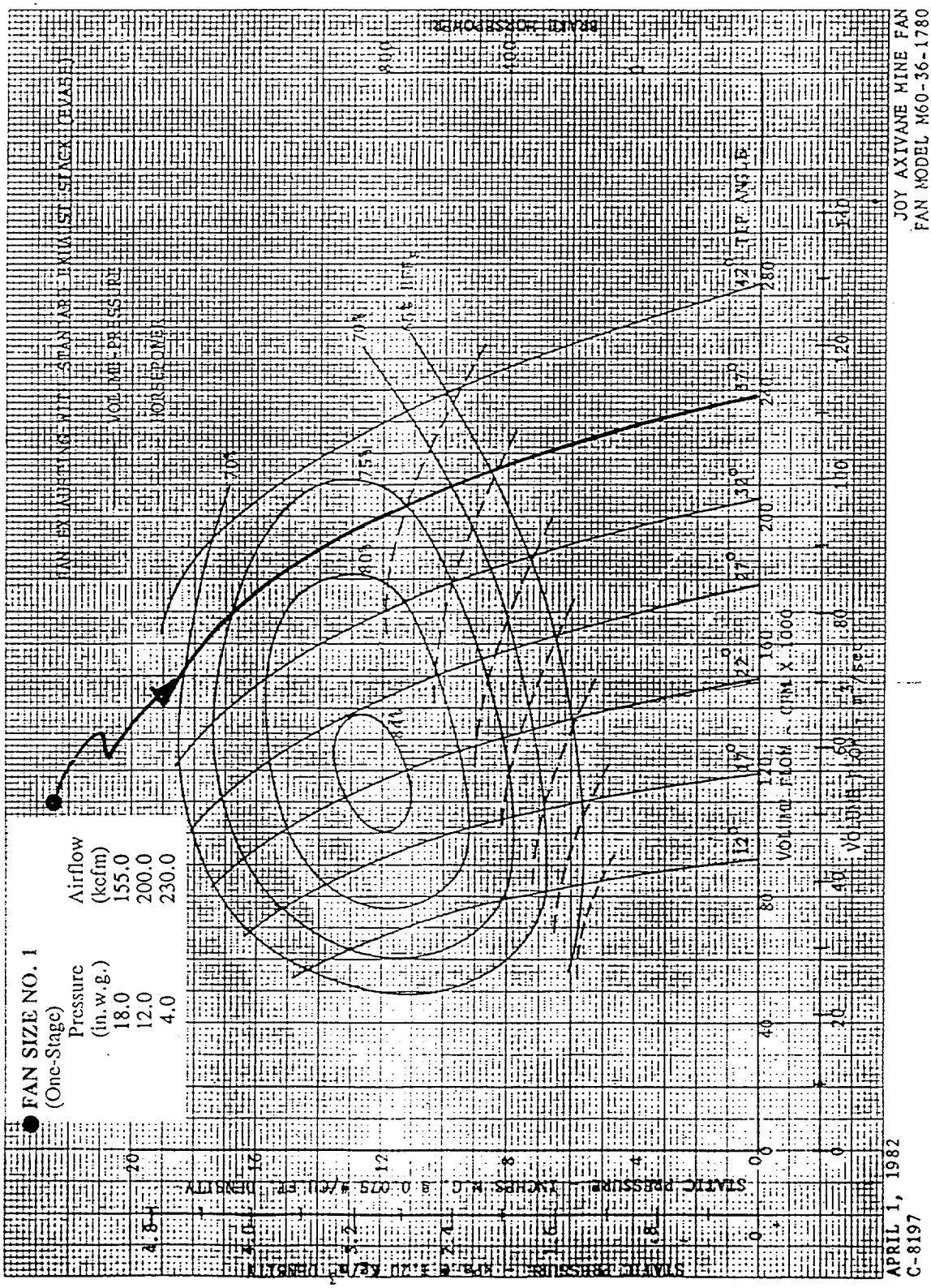


FIGURE 9.6.1B Fan Size No. 2

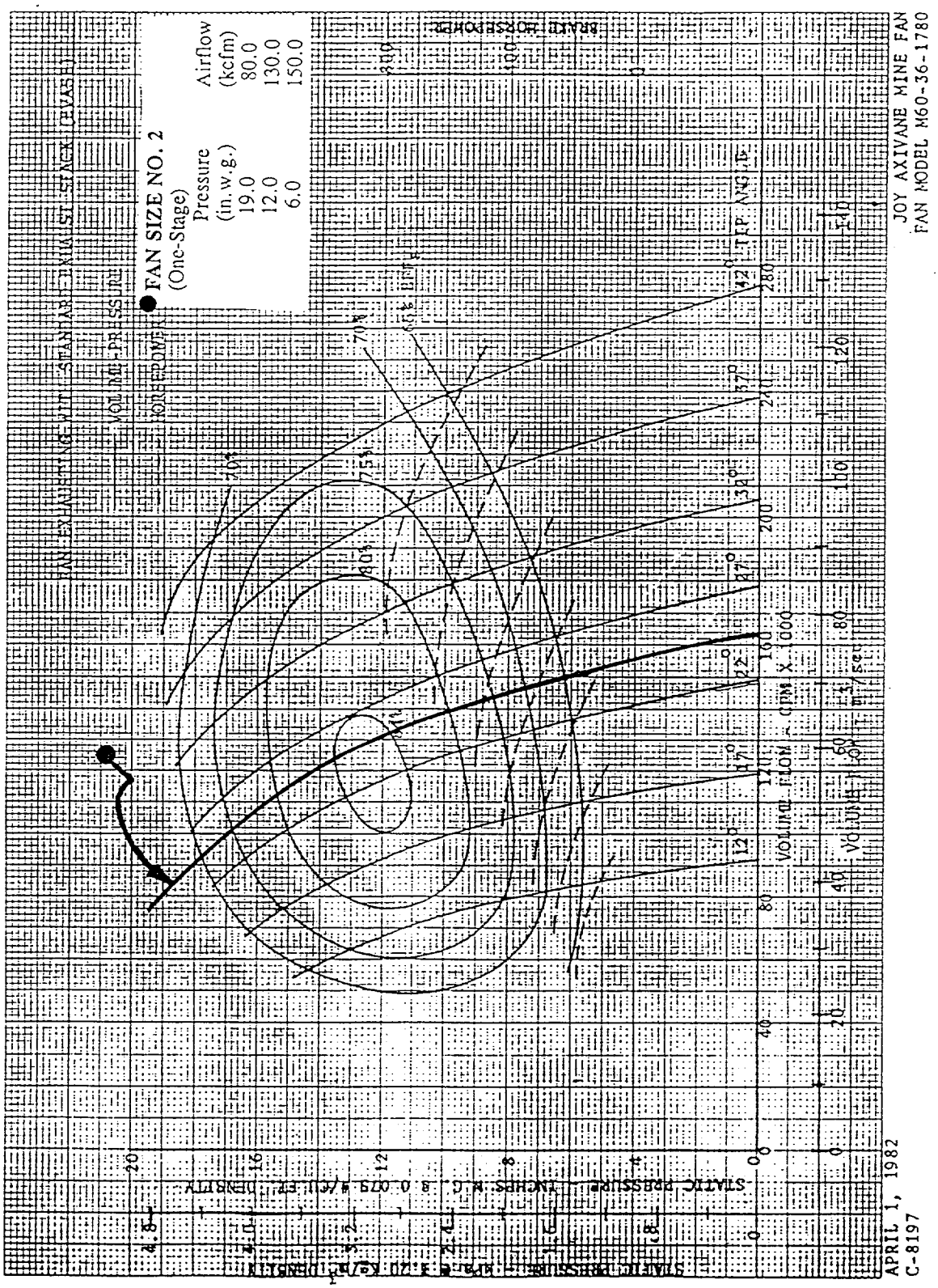
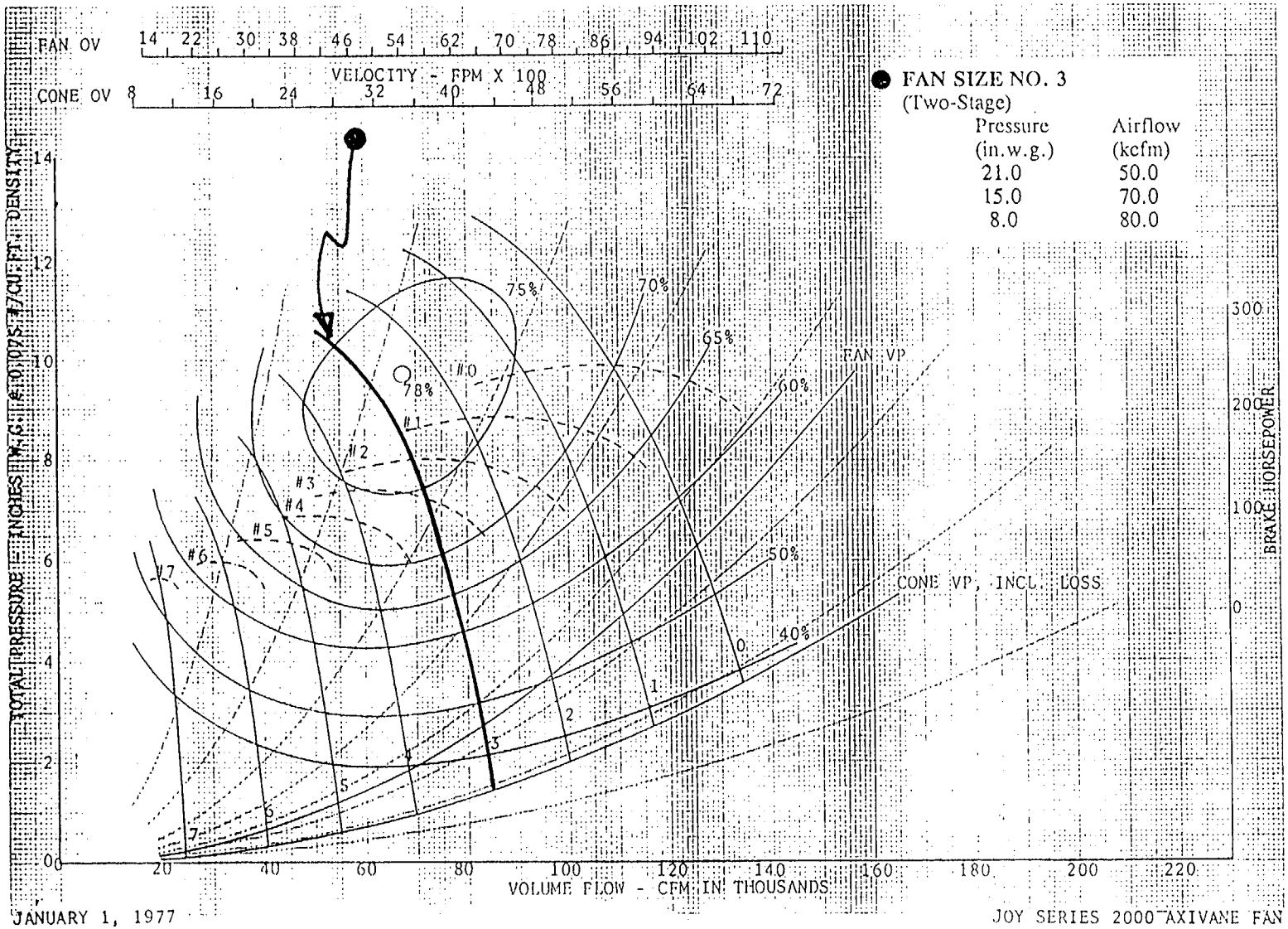
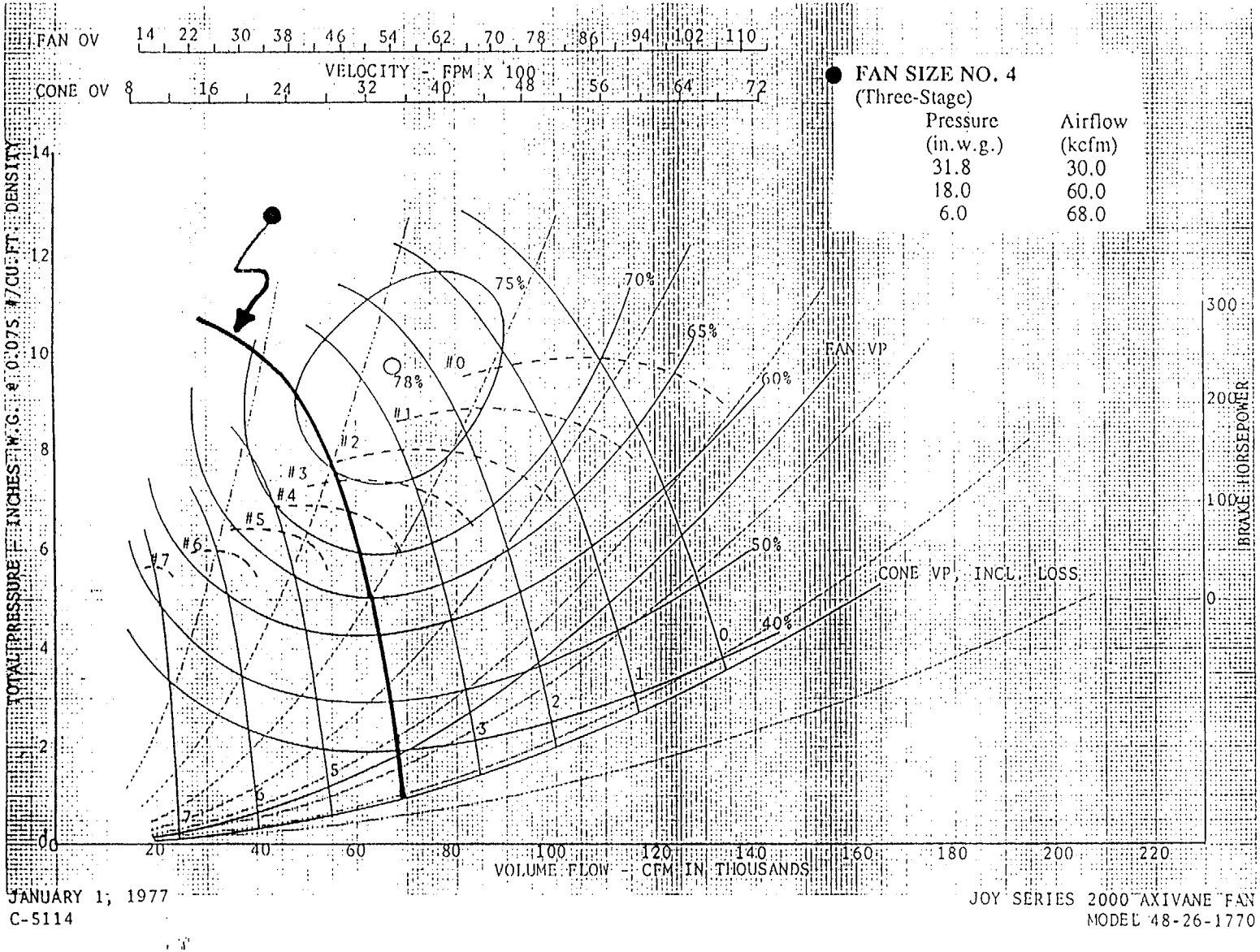


FIGURE 9.6.1C Fan Size No. 3



JANUARY 1, 1977
C-5114

JOY SERIES 2000 AXIVANE FAN
MODEL 48-26-1770

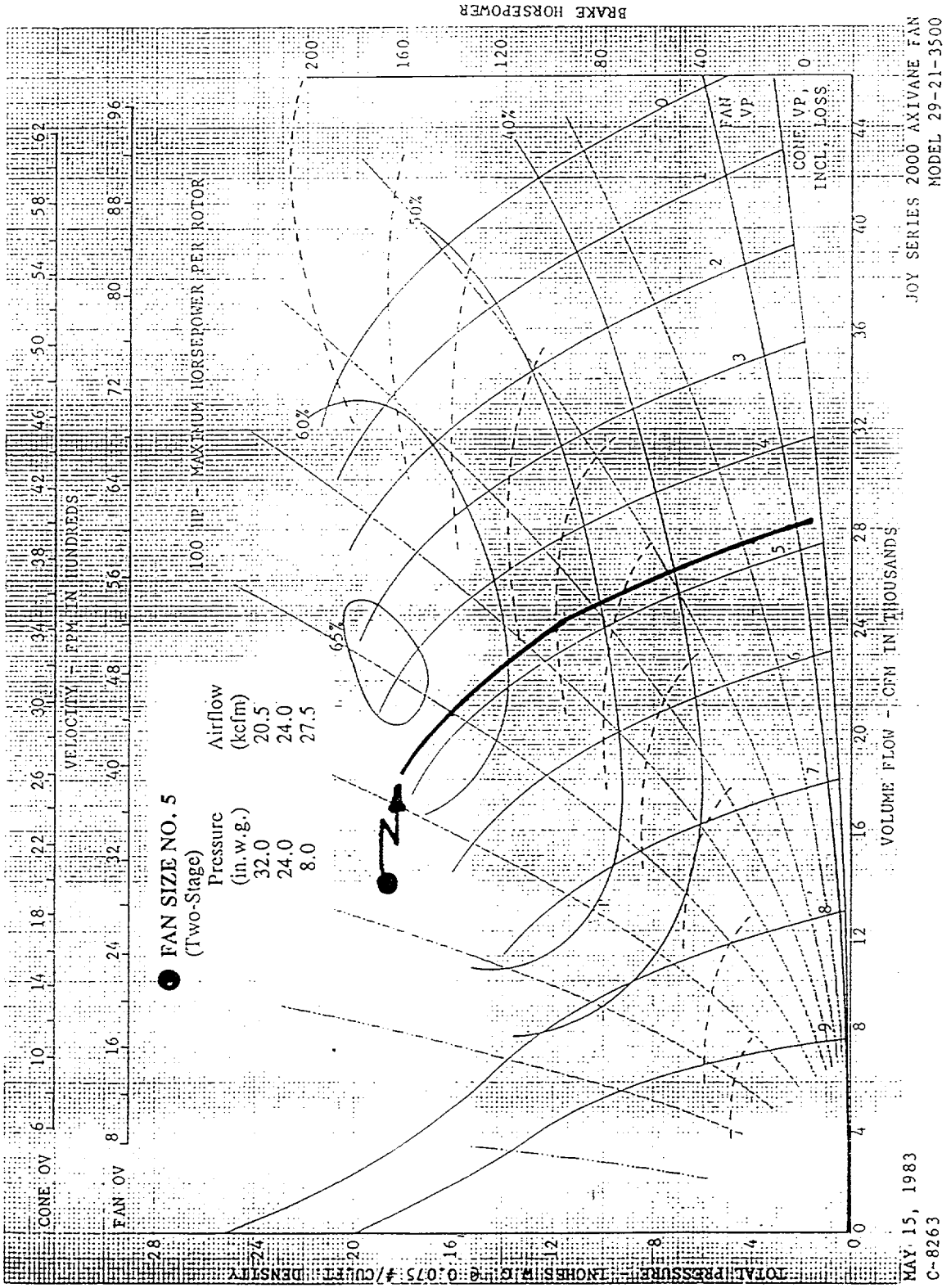


JANUARY 1, 1977
C-5114

JOY SERIES 2000 AXIVANE FAN
MODEL 48-26-1770

FIGURE 9.6.1D Fan Size No. 4

FIGURE 9.6.1E Fan Size No. 5



9.6.2. The ventilation schematic, resistance data and the fan sizes discussed in Sections 9.4, 9.5 and 9.6.1 are used as input of the VNETPC Software Codes (Ref. E).

All computer input is printed to check and compare the raw data in the computer to the original data gathered. These printouts are shown in Tables N9.6.2 and S9.6.2.

TABLE N9.6.2 VNETPC Computer Input
North Ramp System

VNETPC (Version 3.0)
07-23-1991
11:23:33

* DESCRIPTIVE DATA *

File Name: CAL030N
Network Title: ESF TITLE 1
Mine Name: YMP
Company Name: RAYTHEON SERVICES NEVADA
Comments: SUPPORT CALC-030N
British Units
Surface Reference Junction Number 1

* FAN DATA *

Average Efficiency of Fans is 60 %, Power Costs are 6.0 cents/kWh

Fan Ref No.	From	To	Operating Pressure (in.w.g)	No. of Char. Pts.
14	47	48	26.000	3
12	33	34	11.800	3
12	36	37	11.800	3
12	39	40	11.800	3
12	42	43	11.800	3
11	83	7	9.600	3
11	8	9	9.600	3
11	11	12	9.600	3
11	14	15	9.600	3
11	17	18	9.600	3
11	21	22	9.600	3
15	77	78	22.000	3
13	60	61	12.900	3
13	63	64	12.900	3
13	66	67	12.900	3
13	69	70	12.900	3
13	72	73	12.900	3
13	80	81	12.900	3

* FAN CHARACTERISTICS *

Fan 1	Pressure (in.w.g)	Airflow (kcfm)
	31.800	30.00
	18.000	60.00
	6.000	68.00

Fan 2	Pressure (in.w.g)	Airflow (kcfm)

TABLE N9.6.2 VNETPC Computer Input
North Ramp System

	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 3	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 4	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 5	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 6	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 7	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 8	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 9	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 10	Pressure (in.w.g)	Airflow (kcfm)

TABLE N9.6.2 VNETPC Computer Input
North Ramp System

	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 11	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 12	Pressure (in.w.g)	Airflow (kcfm)
	32.000	20.50
	24.000	24.00
	8.000	27.50
Fan 13	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 14	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 15	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 16	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 17	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 18	Pressure (in.w.g)	Airflow (kcfm)

TABLE N9.6.2 VNETPC Computer Input
North Ramp System

21.000	50.00
15.000	70.00
8.000	80.00

* BRANCH DATA *

```
*****************************************************************************
* BR Units: p- m.in.w.g  Q-kcfm R-   P.U.    k-lbf m^2/f^4 L-    ft          *
*****************************************************************************
```

No.	From	To	Resist.	Airflow	Press. drop	k	Length	Equiv. length	Area	Per
1	1	2	0.00117							
2	2	3	0.00117							
3	3	4	0.00117							
4	4	5	0.00117							
5	5	6	0.00117							
6	6	26	0.00010							
7	26	27	0.00090							
8	27	28	0.00137							
9	28	29	0.00137							
10	29	30	0.00137							
11	30	31	0.00150							
12	31	32	0.03292							
13	32	33	0.93694							
14	34	36	0.85596							
15	37	39	0.85596							
16	40	42	0.85596							
17	43	45	0.55966							
18	45	83	0.06255							
19	7	8	0.29292							
20	9	11	0.29292							
21	12	14	0.29292							
22	15	17	0.29292							
23	18	20	0.29292							
24	20	21	0.05292							
25	30	46	0.00983							
26	46	47	0.84674							
27	48	34	16.93490							
28	47	48	0.00000							
29	33	34	0.00000							
30	36	37	0.00000							
31	39	40	0.00000							
32	42	43	0.00000							
33	83	7	0.00000							
34	8	9	0.00000							
35	11	12	0.00000							
36	14	15	0.00000							
37	17	18	0.00000							
38	21	22	0.00000							
39	49	47	300.00000							
40	48	49	300.00000							
41	35	33	300.00000							

TABLE N9.6.2 VNETPC Computer Input

North Ramp System

42	34	35	300.00000
43	38	36	300.00000
44	37	38	300.00000
45	41	39	300.00000
46	40	41	300.00000
47	44	42	300.00000
48	43	44	300.00000
49	84	83	300.00000
50	7	84	300.00000
51	10	8	300.00000
52	9	10	300.00000
53	13	11	300.00000
54	12	13	300.00000
55	16	14	300.00000
56	15	16	300.00000
57	19	17	300.00000
58	18	19	300.00000
59	23	20	300.00000
60	22	23	300.00000
61	30	47	250.00000
62	30	33	250.00000
63	29	36	250.00000
64	28	39	250.00000
65	27	42	250.00000
66	6	83	250.00000
67	5	8	300.00000
68	4	11	300.00000
69	3	14	300.00000
70	2	17	300.00000
71	22	1	0.00001
72	6	51	0.00817
73	51	52	0.00239
74	52	53	0.00514
75	53	54	0.00857
76	54	55	0.00857
77	55	56	0.00857
78	56	57	0.00857
79	57	58	0.00857
80	58	59	0.10047
81	59	60	3.16274
82	61	63	3.16274
83	64	66	3.16277
84	67	69	3.16274
85	70	72	3.16274
86	73	75	1.89684
87	75	80	0.88211
88	81	83	3.01405
89	57	76	0.05313
90	76	77	2.10697
91	78	61	42.13944
92	77	78	0.00000
93	60	61	0.00000
94	63	64	0.00000
95	66	67	0.00000
96	69	70	0.00000
97	72	73	0.00000

TABLE N9.6.2 VNETPC Computer Input

North Ramp System

98	80	81	0.00000
99	57	77	250.00000
100	57	60	250.00000
101	56	63	250.00000
102	55	66	250.00000
103	54	69	250.00000
104	53	72	250.00000
105	51	80	250.00000
106	79	77	300.00000
107	78	79	300.00000
108	62	60	300.00000
109	61	62	300.00000
110	65	63	300.00000
111	64	65	300.00000
112	68	66	300.00000
113	67	68	300.00000
114	71	69	300.00000
115	70	71	300.00000
116	74	72	300.00000
117	73	74	300.00000
118	82	80	300.00000
119	81	82	300.00000

TABLE S9.6.2 VNETPC Computer Input
South Ramp System

VNETPC (Version 3.0)
07-23-1991
11:34:15

* DESCRIPTIVE DATA *

File Name: CALO30S
Network Title: ESF TITLE 1
Mine Name: RAYTHEON SERVICES NEVADA
Company Name: YMP
Comments: SUPPORT CALC-030S
British Units
Surface Reference Junction Number 1

* FAN DATA *

Average Efficiency of Fans is 60 %, Power Costs are 6.0 cents/kWh

Fan Ref No.	From	To	Operating Pressure (in.w.g)	No. of Char. Pts.
14	97	98	26.000	3
12	47	48	11.800	3
12	50	51	11.800	3
12	53	54	11.800	3
12	56	57	11.800	3
11	60	9	9.600	3
11	10	11	9.600	3
11	13	14	9.600	3
11	16	17	9.600	3
11	19	20	9.600	3
11	22	23	9.600	3
11	25	26	9.600	3
11	29	30	9.600	3
15	102	103	22.000	3
13	72	73	12.900	3
13	75	76	12.900	3
13	78	79	12.900	3
13	81	82	12.900	3
13	84	85	12.900	3
13	87	88	12.900	3
13	90	91	12.900	3
13	93	94	12.900	3

* FAN CHARACTERISTICS *

Fan 1	Pressure (in.w.g)	Airflow (kcfm)
	31.800	30.00
	18.000	60.00

TABLE S9.6.2 VNETPC Computer Input
South Ramp System

	6.000	68.00
Fan 2	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 3	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 4	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 5	Pressure (in.w.g)	Airflow (kcfm)
	19.000	80.00
	12.000	130.00
	6.000	150.00
Fan 6	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 7	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 8	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 9	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00

TABLE S9.6.2 VNETPC Computer Input
South Ramp System

	4.000	230.00
Fan 10	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 11	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 12	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 13	Pressure (in.w.g)	Airflow (kcfm)
	18.000	155.00
	12.000	200.00
	4.000	230.00
Fan 14	Pressure (in.w.g)	Airflow (kcfm)
	32.000	20.50
	24.000	24.00
	8.000	27.50
Fan 15	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 16	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00
Fan 17	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00

TABLE S9.6.2 VNETPC Computer Input
South Ramp System

	8.000	80.00

Fan 18	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00

Fan 19	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00

Fan 20	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00

Fan 21	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00

Fan 22	Pressure (in.w.g)	Airflow (kcfm)
	21.000	50.00
	15.000	70.00
	8.000	80.00

* BRANCH DATA *

```
*****************************************************************************
* BR Units: p- m.in.w.g  Q-kcfm R-   P.U.    k-lbf m^2/f^4 L-    ft          *
*****************************************************************************
```

No.	From	To	Resist.	Airflow	Press. drop	k	Length	Equiv. length	Area	Per
1	1	2	0.00118							
2	2	3	0.00118							
3	3	4	0.00118							
4	4	5	0.00118							
5	5	6	0.00118							
6	6	7	0.00118							
7	7	8	0.00118							
8	8	40	0.00011							
9	40	41	0.00127							

TABLE S9.6.2 VNETPC Computer Input

South Ramp System

10	41	42	0.00140
11	42	43	0.00140
12	43	44	0.00140
13	44	45	0.00140
14	45	46	0.03292
15	46	47	0.87637
16	48	50	0.87637
17	51	53	0.87637
18	54	56	0.87637
19	57	59	0.79407
20	59	60	0.06584
21	9	10	0.29636
22	11	13	0.29636
23	14	16	0.29636
24	17	19	0.29636
25	20	22	0.29636
26	23	25	0.29636
27	26	28	0.29636
28	28	29	0.05292
29	44	96	0.00983
30	96	97	0.84674
31	98	48	16.93490
32	97	98	0.00000
33	47	48	0.00000
34	50	51	0.00000
35	53	54	0.00000
36	56	57	0.00000
37	60	9	0.00000
38	10	11	0.00000
39	13	14	0.00000
40	16	17	0.00000
41	19	20	0.00000
42	22	23	0.00000
43	25	26	0.00000
44	29	30	0.00000
45	98	99	300.00000
46	99	97	300.00000
47	49	47	300.00000
48	48	49	300.00000
49	52	50	300.00000
50	51	52	300.00000
51	55	53	300.00000
52	54	55	300.00000
53	58	56	300.00000
54	57	58	300.00000
55	61	60	300.00000
56	9	61	300.00000
57	12	10	300.00000
58	11	12	300.00000
59	15	13	300.00000
60	14	15	300.00000
61	18	16	300.00000
62	17	18	300.00000
63	21	19	300.00000
64	20	21	300.00000
65	24	22	300.00000

TABLE S9.6.2 VNETPC Computer Input

South Ramp System

66	23	24	300.00000
67	27	25	300.00000
68	26	27	300.00000
69	31	28	300.00000
70	30	31	300.00000
71	44	97	250.00000
72	44	47	250.00000
73	43	50	250.00000
74	42	53	250.00000
75	41	56	250.00000
76	8	60	250.00000
77	7	10	250.00000
78	6	13	250.00000
79	5	16	250.00000
80	4	19	250.00000
81	3	22	250.00000
82	2	25	250.00000
83	30	1	0.00000
84	8	62	0.00906
85	62	63	0.00906
86	63	64	0.00514
87	64	65	0.00828
88	65	66	0.00828
89	66	67	0.00828
90	67	68	0.00828
91	68	69	0.00828
92	69	70	0.00828
93	70	71	0.10047
94	71	72	3.05423
95	73	75	3.05423
96	76	78	3.05423
97	79	81	3.05423
98	82	84	3.05423
99	85	87	3.05423
100	88	90	1.89684
101	91	93	3.34358
102	94	60	3.34358
103	68	101	0.05313
104	101	102	1.05349
105	103	76	42.13944
106	102	103	0.00000
107	72	73	0.00000
108	75	76	0.00000
109	78	79	0.00000
110	81	82	0.00000
111	84	85	0.00000
112	87	88	0.00000
113	90	91	0.00000
114	93	94	0.00000
115	69	72	250.00000
116	68	75	250.00000
117	67	78	250.00000
118	66	81	250.00000
119	65	84	250.00000
120	64	87	250.00000
121	63	90	250.00000

TABLE S9.6.2 VNETPC Computer Input
South Ramp System

122	62	93	250.00000
123	104	102	300.00000
124	103	104	300.00000
125	74	72	300.00000
126	73	74	300.00000
127	77	75	300.00000
128	76	77	300.00000
129	80	78	300.00000
130	79	80	300.00000
131	83	81	300.00000
132	82	83	300.00000
133	86	84	300.00000
134	85	86	300.00000
135	89	87	300.00000
136	88	89	300.00000
137	92	90	300.00000
138	91	92	300.00000
139	95	93	300.00000
140	94	95	300.00000
141	68	102	300.00000

9.6.3. Ventilation controls such as doors, regulators, stoppings, dampers, etc. are assigned with an approximate branch line resistance to control the airflow in a specific branch.

9.6.4. The ventilation simulation program is run in accordance with the software instruction manual (Ref. E).

9.6.5. The airflow output is compared with the predetermined airflow requirement (design goal) of the system. Initially, if the run is not satisfactory, the preceding steps are repeated by trying another set of fan curves and ventilation control resistances until the design goals are satisfied.

9.6.6. The north and south ramp systems have satisfactory computer run with airflow quantity plotted as shown in Figures N9.6.6 and S9.6.6, respectively. The computer simulation has detailed output shown in Tables N9.6.6 and S9.6.6. The tables show the branch airflow, pressure, resistance, and air horsepower needed.

The computer output has the following airflow summary:

North Ramp System

	Air Volume (cfm)
a) TS North Ramp or TS Main Drift... (25 ft dia. face)	82,400

b) TS Lateral Drift..... 29,600
(12 ft. x 20 ft)

Total potential air for
TS level distribution..... 112,000

c) CH North Ramp or CH Main Drift... 43,700
(18 ft dia. face)

d) CH Lateral Drift..... 15,300
(9 ft. x 16 ft)

Total potential air for
CH level distribution..... 59,000

South Ramp System

Air Volume (cfm)

a) TS South Ramp or TS Main Drift... 81,800
(25 ft dia. face)

b) TS Lateral Drift..... 29,300
(12 ft. x 20 ft)

Total potential air for
TS level distribution..... 111,100

c) CH South Ramp or CH Main Drift... 50,300
(18 ft dia. face)

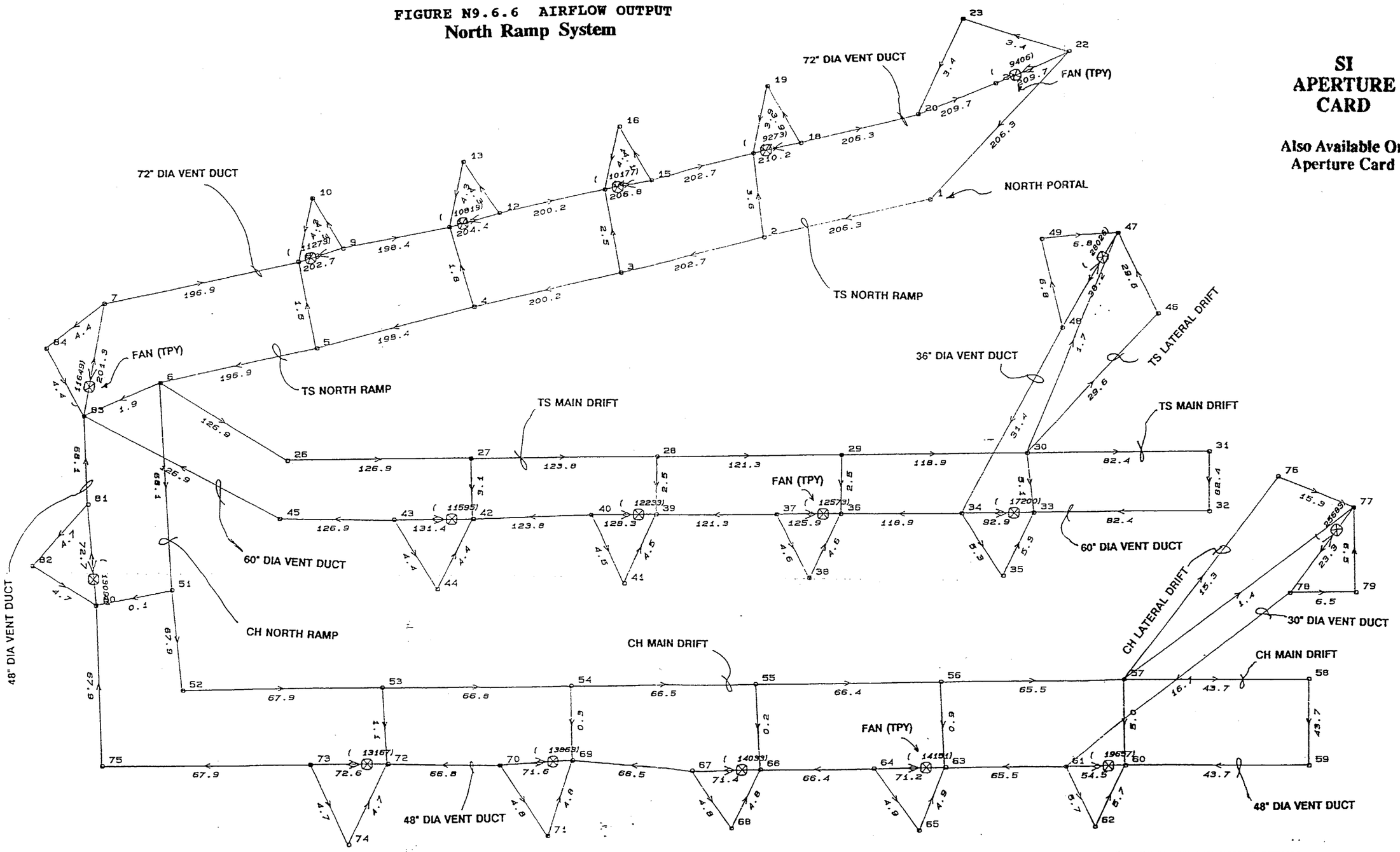
d) CH Lateral Drift..... 14,600
(9 ft. x 16 ft)

Total potential air for
CH level distribution..... 64,900

Some of these numbers are lower than the corresponding numbers in Table 9.2 because the numbers in that Table include leakage, while the above numbers are based on the actual network model.

A satisfactory computer run is gaged mainly on the combined potential ventilating air that could be made available at the TS or CH faces. Regulating actual airflow to direct specific air quantity to a particular face will be left to field tune-up.

FIGURE N9.6.6 AIRFLOW OUTPUT
North Ramp System

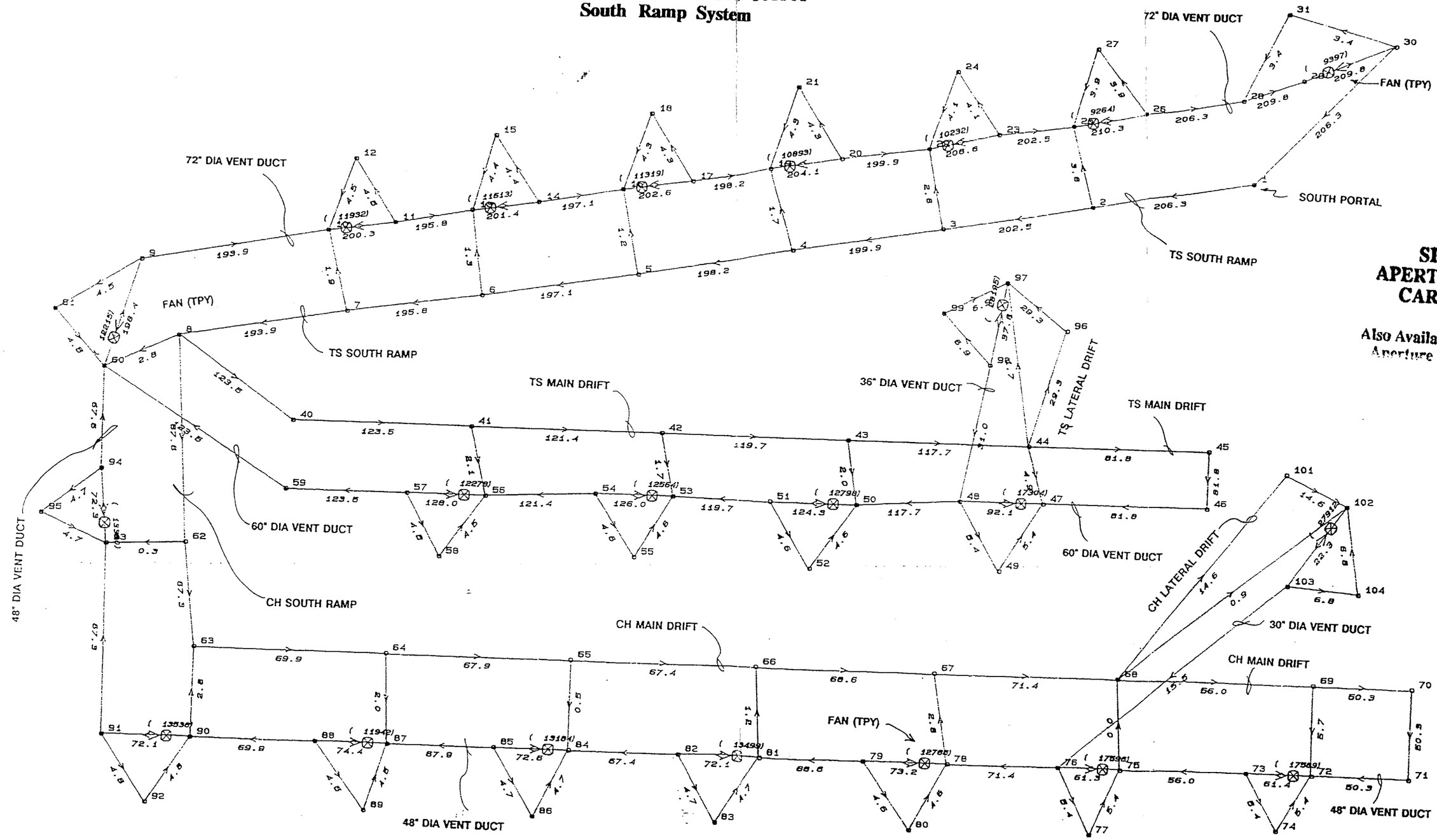


VENTILATION COMPUTER SIMULATION SHOWING AIRFLOW QUANTITY (CFM x 1000) ALONG BRANCHES

SI APERTURE CARD

Also Available On Aperture Card

FIGURE S9.6.6 AIRFLOW OUTPUT
South Ramp System



SI APERTURE CARD

Also Available On Aperture Card

VENTILATION COMPUTER SIMULATION SHOWING AIRFLOW QUANTITY (CFM x 1000) ALONG BRANCHES

TABLE N9.6.6 VNETPC Computer Output
North Ramp System

VNETPC (Version 3.0)
11:19:43
07-23-1991

Output File Name: OUTPUT.TMP
Network File Name: CAL030N
Network Title: ESF TITLE 1
Mine Name: YMP
Company: RAYTHEON SERVICES NEVADA
Comments: SUPPORT CALC-030N

**** OUTPUT DATA ****

Annual costs are based on electricity charges of 6.0 cents per kWh and fan efficiencies of 60.0%
Cost given for an NVP represents money saved by natural ventilation

*** Fan Operating Points ***

Fan No.	Ref	From	To	Pressure in.w.g.	Quantity kcfm	Air Power hp	Op.Cost $/year
1	14	47	48	28.026	38.20	168.71	110210
2	12	33	34	17.199	92.86	251.65	164389
3	12	36	37	12.573	125.90	249.44	162940
4	12	39	40	12.233	128.33	247.37	161591
5	12	42	43	11.595	131.35	239.98	156764
6	11	83	7	11.649	201.31	369.53	241390
7	11	8	9	11.273	202.73	360.11	235237
8	11	11	12	10.819	204.43	348.51	227659
9	11	14	15	10.177	206.83	331.69	216671
10	11	17	18	9.273	210.22	307.18	200659
11	11	21	22	9.405	209.73	310.82	203035
12	15	77	78	25.682	23.26	94.14	61496
13	13	60	61	19.657	54.47	168.73	110219
14	13	63	64	14.150	71.21	158.78	103721
15	13	66	67	14.033	71.38	157.84	103106
16	13	69	70	13.864	71.62	156.47	102210
17	13	72	73	13.167	72.62	150.67	98420
18	13	80	81	13.093	72.72	150.04	98010

*** Branch Data ***

Branch	From	To	Press.Dp m.in.wg.	Airflow kcfm	Resist. P.U.	AP Loss hp	Op.Cost $/year
1	1	2	49	206.29	0.00117	1.6	1040
2	2	3	48	202.72	0.00117	1.5	1002
3	3	4	46	200.18	0.00117	1.5	948
4	4	5	46	198.39	0.00117	1.4	939
5	5	6	45	196.91	0.00117	1.4	912

TABLE N9.6.6 VNETPC Computer Output

North Ramp System

6	6	26	1	126.95	0.00010	0.0	13
7	26	27	14	126.95	0.00090	0.3	183
8	27	28	21	123.81	0.00137	0.4	268
9	28	29	20	121.32	0.00137	0.4	250
10	29	30	19	118.87	0.00137	0.4	232
11	30	31	10	82.37	0.00150	0.1	85
12	31	32	223	82.37	0.03292	2.9	1891
13	32	33	6356	82.37	0.93694	82.5	53889
14	34	36	12094	118.87	0.85596	226.5	147980
15	37	39	12599	121.32	0.85596	240.9	157340
16	40	42	13121	123.81	0.85596	256.0	167222
17	43	45	9019	126.95	0.55966	180.4	117855
18	45	83	1008	126.95	0.06255	20.2	13172
19	7	8	11357	196.91	0.29292	352.4	230188
20	9	11	11528	198.39	0.29292	360.4	235414
21	12	14	11738	200.18	0.29292	370.3	241866
22	15	17	12037	202.72	0.29292	384.5	251168
23	18	20	12465	206.29	0.29292	405.2	264687
24	20	21	2327	209.73	0.05292	76.9	50235
25	30	46	8	29.63	0.00983	0.0	24
26	46	47	743	29.63	0.84674	3.5	2266
27	48	34	16664	31.37	16.93490	82.4	53807
28	47	48	0	38.20	0.00000	0.0	0
29	33	34	0	92.86	0.00000	0.0	0
30	36	37	0	125.90	0.00000	0.0	0
31	39	40	0	128.33	0.00000	0.0	0
32	42	43	0	131.35	0.00000	0.0	0
33	83	7	0	201.31	0.00000	0.0	0
34	8	9	0	202.73	0.00000	0.0	0
35	11	12	0	204.43	0.00000	0.0	0
36	14	15	0	206.83	0.00000	0.0	0
37	17	18	0	210.22	0.00000	0.0	0
38	21	22	0	209.73	0.00000	0.0	0
39	49	47	14013	6.83	300.00000	15.1	9858
40	48	49	14013	6.83	300.00000	15.1	9858
41	35	33	8599	5.35	300.00000	7.3	4739
42	34	35	8599	5.35	300.00000	7.3	4739
43	38	36	6286	4.58	300.00000	4.5	2962
44	37	38	6286	4.58	300.00000	4.5	2962
45	41	39	6116	4.52	300.00000	4.4	2843
46	40	41	6116	4.52	300.00000	4.4	2843
47	44	42	5797	4.40	300.00000	4.0	2623
48	43	44	5797	4.40	300.00000	4.0	2623
49	84	83	5824	4.41	300.00000	4.0	2642
50	7	84	5824	4.41	300.00000	4.0	2642
51	10	8	5636	4.33	300.00000	3.8	2515
52	9	10	5636	4.33	300.00000	3.8	2515
53	13	11	5409	4.25	300.00000	3.6	2364
54	12	13	5409	4.25	300.00000	3.6	2364
55	16	14	5088	4.12	300.00000	3.3	2157
56	15	16	5088	4.12	300.00000	3.3	2157

TABLE N9.6.6 VNETPC Computer Output

North Ramp System

57	19	17	4636	3.93	300.00000	2.9	1876
58	18	19	4636	3.93	300.00000	2.9	1876
59	23	20	3539	3.43	300.00000	1.9	1251
60	22	23	3539	3.43	300.00000	1.9	1251
61	30	47	752	1.73	250.00000	0.2	134
62	30	33	6590	5.13	250.00000	5.3	3483
63	29	36	1504	2.45	250.00000	0.6	380
64	28	39	1550	2.49	250.00000	0.6	397
65	27	42	2459	3.14	250.00000	1.2	794
66	6	83	907	1.90	250.00000	0.3	178
67	5	8	660	1.43	300.00000	0.2	101
68	4	11	961	1.79	300.00000	0.3	177
69	3	14	1927	2.54	300.00000	0.8	503
70	2	17	3835	3.58	300.00000	2.2	1412
71	22	1	0	206.29	0.00001	0.0	0
72	6	51	37	68.05	0.00817	0.4	259
73	51	52	11	67.93	0.00239	0.1	77
74	52	53	23	67.93	0.00514	0.2	161
75	53	54	38	66.82	0.00857	0.4	261
76	54	55	37	66.54	0.00857	0.4	253
77	55	56	37	66.36	0.00857	0.4	253
78	56	57	36	65.47	0.00857	0.4	243
79	57	58	16	43.74	0.00857	0.1	72
80	58	59	192	43.74	0.10047	1.3	865
81	59	60	6052	43.74	3.16274	41.7	27251
82	61	63	13556	65.47	3.16274	139.8	91354
83	64	66	13925	66.36	3.16277	145.6	95111
84	67	69	14004	66.54	3.16274	146.8	95922
85	70	72	14119	66.82	3.16274	148.7	97104
86	73	75	8753	67.93	1.89684	93.7	61205
87	75	80	4070	67.93	0.88211	43.6	28460
88	81	83	13958	68.05	3.01405	149.7	97774
89	57	76	12	15.30	0.05313	0.0	19
90	76	77	493	15.30	2.10697	1.2	776
91	78	61	11780	16.72	42.13944	31.0	20274
92	77	78	0	23.26	0.00000	0.0	0
93	60	61	0	54.47	0.00000	0.0	0
94	63	64	0	71.21	0.00000	0.0	0
95	66	67	0	71.38	0.00000	0.0	0
96	69	70	0	71.62	0.00000	0.0	0
97	72	73	0	72.62	0.00000	0.0	0
98	80	81	0	72.72	0.00000	0.0	0
99	57	77	505	1.42	250.00000	0.1	74
100	57	60	6260	5.00	250.00000	4.9	3225
101	56	63	196	0.89	250.00000	0.0	18
102	55	66	8	0.19	250.00000	0.0	0
103	54	69	18	0.27	250.00000	0.0	0
104	53	72	312	1.12	250.00000	0.1	36
105	51	80	3	0.12	250.00000	0.0	0
106	79	77	12841	6.54	300.00000	13.2	8648
107	78	79	12841	6.54	300.00000	13.2	8648

TABLE N9.6.6 VNETPC Computer Output
North Ramp System

108	62	60	9828	5.72	300.00000	8.9	5790
109	61	62	9828	5.72	300.00000	8.9	5790
110	65	63	7075	4.86	300.00000	5.4	3537
111	64	65	7075	4.86	300.00000	5.4	3537
112	68	66	7016	4.84	300.00000	5.3	3493
113	67	68	7016	4.84	300.00000	5.3	3493
114	71	69	6932	4.81	300.00000	5.3	3430
115	70	71	6932	4.81	300.00000	5.3	3430
116	74	72	6583	4.68	300.00000	4.9	3174
117	73	74	6583	4.68	300.00000	4.9	3174
118	82	80	6546	4.67	300.00000	4.8	3148
119	81	82	6546	4.67	300.00000	4.8	3148

Number of Iterations = 51

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	-49	3	-97	4	-143
5	-189	6	-234	7	10508	8	-849
9	10424	10	4787	11	-1104	12	9714
13	4305	14	-2024	15	8153	16	3064
17	-3884	18	5389	19	752	20	-7076
21	-9405	22	0	23	-3539	26	-235
27	-249	28	-270	29	-290	30	-309
31	-319	32	-542	33	-6898	34	10301
35	1701	36	-1794	37	10779	38	4492
39	-1820	40	10413	41	4296	42	-2708
43	8887	44	3089	45	-133	46	-317
47	-1060	48	26966	49	12953	51	-271
52	-282	53	-305	54	-343	55	-380
56	-417	57	-453	58	-469	59	-661
60	-6713	61	12944	62	3115	63	-613
64	13537	65	6462	66	-388	67	13644
68	6628	69	-361	70	13503	71	6571
72	-617	73	12549	74	5956	75	3796
76	-465	77	-958	78	24724	79	11883
80	-276	81	12817	82	6270	83	-1141
84	4683						

**** NETWORK EXERCISE COMPLETE ****

TABLE S9.6.6 VNETPC Computer Output
South Ramp System

VNETPC (Version 3.0)
11:30:20
07-23-1991

Output File Name: OUTPUT.TMP
Network File Name: CAL030S
Network Title: ESF TITLE 1
Mine Name: RAYTHEON SERVICES NEVADA
Company: YMP
Comments: SUPPORT CALC-030S

**** OUTPUT DATA ****

Annual costs are based on electricity charges of 6.0 cents per kWh and fan efficiencies of 60.0%
Cost given for an NVP represents money saved by natural ventilation

*** Fan Operating Points ***

Fan No.	Ref	From	To	Pressure in.w.g.	Quantity kcfm	Air Power hp	Op.Cost $/year
1	14	97	98	28.195	37.83	168.09	109804
2	12	47	48	17.304	92.11	251.16	164068
3	12	50	51	12.798	124.30	250.66	163741
4	12	53	54	12.564	125.96	249.38	162903
5	12	56	57	12.278	128.01	247.66	161779
6	11	60	9	12.215	198.38	381.85	249435
7	11	10	11	11.932	200.25	376.51	245951
8	11	13	14	11.613	201.45	368.64	240807
9	11	16	17	11.319	202.55	361.27	235995
10	11	19	20	10.893	204.15	350.42	228904
11	11	22	23	10.232	206.63	333.15	217622
12	11	25	26	9.264	210.26	306.93	200495
13	11	29	30	9.397	209.76	310.60	202893
14	15	102	103	27.912	22.29	98.03	64034
15	13	72	73	17.589	61.37	170.09	111106
16	13	75	76	17.596	61.35	170.09	111109
17	13	78	79	12.765	73.19	147.22	96169
18	13	81	82	13.499	72.14	153.46	100242
19	13	84	85	13.184	72.59	150.81	98514
20	13	87	88	11.942	74.37	139.94	91414
21	13	90	91	13.538	72.09	153.78	100455
22	13	93	94	13.380	72.31	152.46	99594

*** Branch Data ***

Branch	From	To	Press.Dp m.in.wg.	Airflow kcfm	Resist. P.U.	AP Loss hp	Op.Cost $/year

TABLE S9.6.6 VNETPC Computer Output
South Ramp System

1	1	2	50	206.33	0.00118	1.6	1062
2	2	3	48	202.50	0.00118	1.5	1001
3	3	4	47	199.89	0.00118	1.5	967
4	4	5	46	198.21	0.00118	1.4	939
5	5	6	45	197.05	0.00118	1.4	913
6	6	7	45	195.79	0.00118	1.4	907
7	7	8	44	193.87	0.00118	1.3	878
8	8	40	1	123.48	0.00011	0.0	13
9	40	41	19	123.48	0.00127	0.4	241
10	41	42	20	121.39	0.00140	0.4	250
11	42	43	20	119.68	0.00140	0.4	246
12	43	44	19	117.72	0.00140	0.4	230
13	44	45	9	81.80	0.00140	0.1	76
14	45	46	220	81.80	0.03292	2.8	1853
15	46	47	5864	81.80	0.87637	75.6	49378
16	48	50	12145	117.72	0.87637	225.3	147168
17	51	53	12552	119.68	0.87637	236.7	154626
18	54	56	12913	121.39	0.87637	247.0	161346
19	57	59	12108	123.48	0.79407	235.6	153901
20	59	60	1003	123.48	0.06584	19.5	12749
21	9	10	11139	193.87	0.29636	340.3	222289
22	11	13	11360	195.79	0.29636	350.5	228946
23	14	16	11507	197.05	0.29636	357.3	233398
24	17	19	11643	198.21	0.29636	363.6	237545
25	20	22	11841	199.89	0.29636	373.0	243632
26	23	25	12152	202.50	0.29636	387.8	253292
27	26	28	12616	206.33	0.29636	410.2	267938
28	28	29	2328	209.76	0.05292	76.9	50264
29	44	96	8	29.27	0.00983	0.0	24
30	96	97	725	29.27	0.84674	3.3	2184
31	98	48	16252	30.98	16.93490	79.3	51825
32	97	98	0	37.83	0.00000	0.0	0
33	47	48	0	92.11	0.00000	0.0	0
34	50	51	0	124.30	0.00000	0.0	0
35	53	54	0	125.96	0.00000	0.0	0
36	56	57	0	128.01	0.00000	0.0	0
37	60	9	0	198.38	0.00000	0.0	0
38	10	11	0	200.25	0.00000	0.0	0
39	13	14	0	201.45	0.00000	0.0	0
40	16	17	0	202.55	0.00000	0.0	0
41	19	20	0	204.15	0.00000	0.0	0
42	22	23	0	206.63	0.00000	0.0	0
43	25	26	0	210.26	0.00000	0.0	0
44	29	30	0	209.76	0.00000	0.0	0
45	98	99	14097	6.86	300.00000	15.2	9947
46	99	97	14097	6.86	300.00000	15.2	9947
47	49	47	8652	5.37	300.00000	7.3	4783
48	48	49	8652	5.37	300.00000	7.3	4783
49	52	50	6399	4.62	300.00000	4.7	3042
50	51	52	6399	4.62	300.00000	4.7	3042
51	55	53	6282	4.58	300.00000	4.5	2959

TABLE 89.6.6 VNETPC Computer Output

South Ramp System

52	54	55	6282	4.58	300.00000	4.5	2959
53	58	56	6139	4.52	300.00000	4.4	2859
54	57	58	6139	4.52	300.00000	4.4	2859
55	61	60	6107	4.51	300.00000	4.3	2836
56	9	61	6107	4.51	300.00000	4.3	2836
57	12	10	5966	4.46	300.00000	4.2	2739
58	11	12	5966	4.46	300.00000	4.2	2739
59	15	13	5806	4.40	300.00000	4.0	2629
60	14	15	5806	4.40	300.00000	4.0	2629
61	18	16	5659	4.34	300.00000	3.9	2530
62	17	18	5659	4.34	300.00000	3.9	2530
63	21	19	5446	4.26	300.00000	3.7	2389
64	20	21	5446	4.26	300.00000	3.7	2389
65	24	22	5116	4.13	300.00000	3.3	2175
66	23	24	5116	4.13	300.00000	3.3	2175
67	27	25	4632	3.93	300.00000	2.9	1874
68	26	27	4632	3.93	300.00000	2.9	1874
69	31	28	3534	3.43	300.00000	1.9	1249
70	30	31	3534	3.43	300.00000	1.9	1249
71	44	97	733	1.71	250.00000	0.2	129
72	44	47	6095	4.94	250.00000	4.7	3098
73	43	50	956	1.96	250.00000	0.3	192
74	42	53	730	1.71	250.00000	0.2	128
75	41	56	1099	2.10	250.00000	0.4	237
76	8	60	1954	2.80	250.00000	0.9	562
77	7	10	922	1.92	250.00000	0.3	182
78	6	13	395	1.26	250.00000	0.1	51
79	5	16	335	1.16	250.00000	0.1	40
80	4	19	705	1.68	250.00000	0.2	122
81	3	22	1700	2.61	250.00000	0.7	456
82	2	25	3667	3.83	250.00000	2.2	1446
83	30	1	0	206.33	0.00000	0.0	0
84	8	62	41	67.59	0.00906	0.4	285
85	62	63	41	67.34	0.00906	0.4	284
86	63	64	25	69.91	0.00514	0.3	180
87	64	65	38	67.90	0.00828	0.4	266
88	65	66	37	67.40	0.00828	0.4	257
89	66	67	38	68.58	0.00828	0.4	268
90	67	68	42	71.40	0.00828	0.5	309
91	68	69	25	55.95	0.00828	0.2	144
92	69	70	20	50.30	0.00828	0.2	104
93	70	71	254	50.30	0.10047	2.0	1315
94	71	72	7726	50.30	3.05423	61.2	39998
95	73	75	9561	55.95	3.05423	84.3	55066
96	76	78	15568	71.40	3.05423	175.1	114411
97	79	81	14363	68.58	3.05423	155.2	101389
98	82	84	13874	67.40	3.05423	147.3	96253
99	85	87	14083	67.90	3.05423	150.7	98436
100	88	90	9269	69.91	1.89684	102.1	66696
101	91	93	15160	67.34	3.34358	160.9	105078
102	94	60	15275	67.59	3.34358	162.7	106274

TABLE S9.6.6 VNETPC Computer Output
South Ramp System

103	68	101	11	14.58	0.05313	0.0	17
104	101	102	223	14.58	1.05349	0.5	335
105	103	76	10080	15.47	42.13944	24.6	16048
106	102	103	0	22.29	0.00000	0.0	0
107	72	73	0	61.37	0.00000	0.0	0
108	75	76	0	61.35	0.00000	0.0	0
109	78	79	0	73.19	0.00000	0.0	0
110	81	82	0	72.14	0.00000	0.0	0
111	84	85	0	72.59	0.00000	0.0	0
112	87	88	0	74.37	0.00000	0.0	0
113	90	91	0	72.09	0.00000	0.0	0
114	93	94	0	72.31	0.00000	0.0	0
115	69	72	8001	5.66	250.00000	7.1	4659
116	68	75	0	-0.02	250.00000	0.0	0
117	67	78	-1985	-2.82	250.00000	0.9	576
118	66	81	-347	-1.18	250.00000	0.1	42
119	65	84	63	0.51	250.00000	0.0	3
120	64	87	1000	2.00	250.00000	0.3	206
121	63	90	-1648	-2.57	250.00000	0.7	436
122	62	93	16	0.25	250.00000	0.0	0
123	104	102	13956	6.82	300.00000	15.0	9798
124	103	104	13956	6.82	300.00000	15.0	9798
125	74	72	8794	5.41	300.00000	7.5	4901
126	73	74	8794	5.41	300.00000	7.5	4901
127	77	75	8798	5.42	300.00000	7.5	4904
128	76	77	8798	5.42	300.00000	7.5	4904
129	80	78	6382	4.61	300.00000	4.6	3030
130	79	80	6382	4.61	300.00000	4.6	3030
131	83	81	6749	4.74	300.00000	5.0	3295
132	82	83	6749	4.74	300.00000	5.0	3295
133	86	84	6592	4.69	300.00000	4.9	3181
134	85	86	6592	4.69	300.00000	4.9	3181
135	89	87	5971	4.46	300.00000	4.2	2742
136	88	89	5971	4.46	300.00000	4.2	2742
137	92	90	6769	4.75	300.00000	5.1	3310
138	91	92	6769	4.75	300.00000	5.1	3310
139	95	93	6690	4.72	300.00000	5.0	3252
140	94	95	6690	4.72	300.00000	5.0	3252
141	68	102	235	0.89	300.00000	0.0	21

Number of Iterations = 50

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	-50	3	-98	4	-145
5	-191	6	-236	7	-281	8	-325
9	9936	10	-1203	11	10729	12	4763

TABLE S9.6.6 VNETPC Computer Output

South Ramp System

13	-631	14	10981	15	5175	16	-526
17	10793	18	5133	19	-850	20	10043
21	4596	22	-1798	23	8435	24	3318
25	-3717	26	5547	27	915	28	-7069
29	-9397	30	0	31	-3534	40	-326
41	-345	42	-365	43	-385	44	-404
45	-413	46	-633	47	-6497	48	10807
49	2155	50	-1341	51	11457	52	5058
53	-1095	54	11469	55	5187	56	-1444
57	10834	58	4695	59	-1276	60	-2279
61	3828	62	-366	63	-407	64	-432
65	-470	66	-507	67	-545	68	-587
69	-612	70	-632	71	-886	72	-8612
73	8977	74	182	75	-587	76	17009
77	8211	78	1440	79	14204	80	7822
81	-160	82	13338	83	6589	84	-533
85	12651	86	6059	87	-1432	88	10510
89	4539	90	1241	91	14779	92	8010
93	-384	94	12996	95	6306	96	-412
97	-1137	98	27058	99	12961	101	-598
102	-821	103	27091	104	13135		

**** NETWORK EXERCISE COMPLETE ****

10. CONCLUSION AND RECOMMENDATION

10.1. Face Air Velocity

Based upon mining industry practices, and for the purpose of general arrangement, a range of face air velocities between 140-150 fpm is recommended for the ESF construction and operation. It is cautioned, however, that this recommendation will be reviewed and may be changed as needed depending on the impact of the following undetermined factors:

- Severity presence of potential toxic respirable dust such as quartz, cristobalite, and tridymite.
- Water usage limit for dust control.
- Use of large mechanical miners.

10.2. Air Quantity for ESF Construction

To support the ESF construction (Ref. A,B), and initial site characterization (worst case), four headings are advanced simultaneously at either the North or the South Ramp System.

The design air quantity of the ventilation system will include reasonable leakages to yield the recommended net air velocity at the face of about 145 fpm. For purposes of general arrangement plan, a 15% leakage factor is initially used to yield the

following air quantities:

		CFM
1.	TS Ramp or TS Drift driven by Tunnel Boring Machine	82,000
2.	TS Lateral Drift (12 ft. x 20 ft.)	40,000
	Total for TS Level	122,000
3.	CH Ramp or CH Drift driven by Tunnel Boring Machine.....	42,500
4.	CH Lateral Drift (9 ft. x 16 ft.)	24,000
	Total for CH Level	66,500

The total quantity required, including 15% leakages, is about 188,500 cfm for each construction of the north or south ramp.

10.3. Size of Vent Duct

To induce the airflow needed at the face, the following sizes of ventilation ducts are to be installed:

		DUCT DIAMETER (INCHES)
1.	Portal to TS/CH Ramp Intersection	72 or 78
2.	TS Ramp Below TS/CH Int. to Main Drift	60 or 66
3.	TS Main Drift	60 or 66
4.	TS Lateral	36 or 42
5.	CH Ramp	48 or 54
6.	CH Main Drift	48 or 54
7.	CH Lateral	30 or 36

Note that there are two diameters given in the preceding table. The smaller duct diameter is used in the computer model as the allowed physical size to occupy in the ramp or drift (Ref. A). The larger diameter is a possibility for installation to drastically reduce ventilation power requirement, that is, if the drift or ramp size constraints will allow a larger vent duct. Preliminary estimate of about 35% and 55% reduction in power requirement

will be attained, if vent duct diameters are to be increased by 6 inches increment respectively from the original duct size used in the model. The maximum feasible vent duct size will be recommended as soon as drift configurations are about to be finalized.

10.4. Power Distribution and Pressure of Fans

From the computer ventilation simulation output, the power and pressure of fans are summarized.

North Ramp System

(Approximate Performance Based on Fan Operation)

	APPROXIMATE DUCT LENGTH (FT)	TOTAL POWER BHP @ 60% MOTOR EFF.	AVE. FAN PRESSURE IN. W.G./ 1000'
Portal to TS/CH Ramp Intersection	5540	3380	11.3
TS Ramp Below TS/CH Int. to Main Drift.....	950	400	12.3
TS Main Drift (Halfway)	5320	1250	7.9
TS Lateral	2000	280	14.0

CH Ramp	4460	500	5.9
CH Main Drift (Halfway)...	6300	1070	9.8
CH Lateral	2000	160	12.8

South Ramp System

(Approximate Performance Based on Fan Operation)

	APPROXIMATE DUCT LENGTH (FT)	TOTAL POWER BHP @ 60% MOTOR EFF.	AVE. FAN PRESSURE IN. W.G./ 1000'
Portal to TS/CH Ramp Intersection	7840	4650	11.1
TS Ramp Below TS/CH Int. to Main Drift.....	1310	420	9.4
TS Main Drift (Halfway)	5330	1250	8.0
TS Lateral	2000	280	14.1
CH Ramp	7310	1000	7.1

CH Main Drift (Halfway)...	6080	1070	10.1
CH Lateral	2000	160	14.0

The lengths of ramps or drifts used are approximate for simulation model assembly only. Actual data on ramps and drift lengths, which are being checked as of this writing, vary slightly from these numbers. As soon as these lengths are finalized, a change of computer input will be made. The change is expected to be insignificant to the overall picture of the system.

Raytheon Services Nevada	DESIGN ANALYSIS Number: ST-MN-031 Rev: 1 Page 1 of 35

WBS No. 1.2.6	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	Romeo S. Jurani	[signature]	Sr. Mining Engr.	8/22/91
CHECKER:	Mark J. Esp	[signature]	Sr. Mining Engr.	8/22/91
APPROVAL - LDE:	Bruce T. Stanley	[signature]	Ld. Mining Engr.	8-22-91
APPROVAL - SCDM:	Bolek R. Chytrowski	[signature]	SCDM	8/22/91
QA CONCURRENCE:	Paul Hale	[signature]	Sr. QA Specialist	8/22/91

SUBJECT: ESF VENTILATION

TITLE: Preliminary Ventilation Analysis
ESF Operation Phase

QAG Reference: RSN-GR-013, Rev. 0

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1. PURPOSE:

a) To determine the airflow requirement during the operation phase of the Exploratory Studies Facilities (ESF), after the north and south ramps are connected; and

b) To establish the location of the main fan, its air quantity output, pressure, and motor horsepower needed during the ESF operation and site characterization activities.

Revision 1 is issued to incorporate the Management and Technical Review comments.

2. METHOD:

The general mining plan and site characterization strategy are analyzed and provided with the appropriate ventilation airflows in accordance with the general mining industry practices and project requirement documents.

2.1. The ventilation practices of the mining industry are reviewed to determine the range of airflow velocities applicable to the ESF.

2.2. The air quantities to support the ESF operation and site characterization plans are calculated based on general mining industry practices. This is after the ramps are connected at the TS and CH levels. Prior to connection, another mode of ventilation (construction phase) would have been implemented as discussed in a separate study, # ST-MN-030.

2.3. A ventilation schematic is prepared to reflect the ESF operation model and calculate air resistances for each branch.

2.4. The approximate size of the main and auxiliary fans available in the market are installed in the model to produce a general arrangement plan. The established air quantities are to be induced to the working areas by the fans.

2.5. Based on the ESF operation model, a computer simulation of the ventilation system is generated using VNETPC Version 3.0 software.

2.6. Computer output which satisfies the estimated airflow requirement is to be modeled. The corresponding leakages and fan power distribution along branches are to be tabulated and plotted. This data is the basis for the recommendation of this study.

3. DESIGN INPUT:

3.1. YMP/CC-0013 (ESFDR) Rev. 5/31/91 issued May 31, 1991.

Sec. 1.2.6.3.1/FR.1.

Provide a ventilation system to supply ventilation air to and exhaust ventilation from the subsurface workings to meet the needs of construction and operation of the underground site characterization and testing program.

Sec. 1.2.6.3.1/PC.1a.

The ventilation system shall supply and exhaust adequate quantities of air to and from underground working areas such that operator safety, health and productivity requirements are maintained.

Sec. 1.2.6.3.1/PC.1e.

The ventilation system shall minimize leakage to the extent practicable.

3.2 YMP/CC-0002 (RIB) Ver. 4, Rev. 4, issued April 8, 1991.

o Chapter 2, Section 4, Item 2, Table 1.

Ramp or drift air velocity shall not exceed 1,500 ft./min.

4. CODES AND STANDARDS:

4.1 30 CFR 57, Revised July 1, 1988 (MSHA)

4.2 DOE Order #5480.4 with Change 2, issued 5/16/89

4.3 California Code 8 CAC 4.20 and 8 CAC 4.17, issued 7/11/81

5. REFERENCE MATERIAL:

A. RSN Report, ST-MN-010, Preliminary Underground Transportation Methods Analysis, Rev. 1, issued June 14, 1991.
B. RSN Report, ST-MN-020, ESF Preliminary Excavation Plan, Rev. 1, issued June 13, 1991.
C. Mine Ventilation and Air Conditioning, 1982, Second Edition, by Hartman, Mutmansky, and Wang.
D. Joy Axivane Fan Catalog # J 610 (Fan Curves as dated).
E. VNETPC Version 3.0 Software, Ventilation Simulation Program with Gas Distribution User's Manual, July, 1988.
F. VNETPC Version 3.0 Certified Run Package, ACL -14, ESF Operation Phase issued 7/23/91.
G. RSN Report, ST-MN-030, Preliminary Ventilation Analysis - ESF Construction Phase, Rev. 0, issued July 24, 1991.
H. Drawing No. YMP-025-2-MING-MI01, Rev. A.
I. Drawing No. YMP-025-2-MING-MI13, Rev. A.
J. Drawing No. YMP-025-2-MING-MI51, Rev. A.
K. Drawing No. YMP-025-1-MING-MI01, Rev. C.
L. FSN Report, FSN-AS-430, Rev. 2, Alternative Study Option # B7, Scenario 2)
M. Drawing No. YMP-025-2-MING-MI52, Rev. A.

6. ASSUMPTIONS:

6.1. It is assumed that all input will be included in the approved Basis For Design (BFD)

6.2. For the purpose of general arrangement concept, the assumptions used are common mining engineering practices and are not subject to verification. The ESF operation ventilation may be used to support initial repository construction until this function can be assumed by repository facilities.

6.3. The report deals mostly with airflow distribution issues. Other related subjects such as heat loads and heat stress, fan noise, dust control, and environmental monitoring are to be addressed in a separate report.

7. COMPUTER PROGRAMS:

VNETPC Version 3.0, Ventilation Simulation Program with Gas Distribution Software. The following documentation are referred:

- ESF Operation Phase - ACL Number: ACL-14
- Program Name: VNETPC Version 3.0
- Computer Type: Dell 325
- Software Design Description Waiver: SDDW-02, Rev. 00

- Software Validation Waiver: SVW-02, Rev. 00
- Hardware Certification Form Number: HCR-01-00
- Software Certification Form Number: SCF-02-00
- Refer to ACL 14 for Input/Output certification run
- Basis for Application: VNETPC Version 3.0 was developed to simulate underground mine ventilation. Refer software documentation SVVR - 02, Rev. 00, Test 3, for applicability.

8. UNITS USED: - English Standard (British if noted)

9. ANALYSIS:

9.1. Determining Drift Air Velocity in ESF Work Place by Industry Practices

9.1.1. Survey of Air Velocity Used by Mining Operations

From the survey of operating mines as discussed in RSN Report ST-MN-030 (Ref. G and C), the commom face air velocity practice as responded by mining operators has been established to be in the range of 100 to 150 fpm.

9.1.3. Face Air Velocity Recommendation and Precaution

For the purpose of general arrangement, a range of face air velocities between 140-150 fpm is recommended for the ESF operation. It is cautioned however, that this recommendation will be reviewed and may be changed as needed depending on the impact of the following undetermined factors:

- Severity of the presence of potential toxic respirable dust such as quartz, cristobalite, and tridymite.
- Water usage limit for dust control.
- Use of large mechanical miners.

9.2. Determination of Air Quantity for ESF Operation

9.2.1. Airflow Requirement

The design air quantity of the ventilation system will include reasonable leakages to yield the recommended air velocity range at the work face of about 140 to 150 fpm. At 15% leakage factor, a net velocity range of (140/0.85 and 150/0.85) 165 to 176 fpm is used for the design calculation.

To support the underground plans (Ref. K) of the ESF operation and site characterization, all major test drifts and shops are presumed to be operating simultaneously (worst case) and

allocated with the following air quantities:

Topopah Spring Level

	cfm
o TS Imbricate Drift.....	40,000
o TS West Drift	40,000
o TS East Drift	40,000
o TS Main Test Area[1].....	130,000
o TS Mechanics Shop[1].....	35,000
Total for TS Level..	285,000 cfm

Calico Hills Level

	cfm
o CH Imbricate	25,000
o CH West Ghost Dance...	25,000
o CH East Ghost Dance...	25,000
o CH Solitario	25,000
o CH Mechanics Shop (TBD)..	15,000
Total for CH Level...	115,000 cfm

Table 9.2 shows the calculated data for the bases of these air quantities including the 15% leakage factor. Projected air velocities when leakages are increased to 20% and 25% are also shown in the table.

[1]Detailed air distribution for the TS Main Test Area and the TS Mechanics Shop is shown in Drawing No. YMP-025-2-MING-MI52[Rev 1].

TABLE 9.2 Air Quantity For ESF Operation

VENTILATION DATA

AIR QUANTITY DISTRIBUTION & PROJECTED DRIFT
AIR VELOCITY DURING OPERATION PHASE

TOTAL AIR SUPPLY = 400,000 cfm.

R.S. Jurani 7/17/91

TOPOPAH SPRING LEVEL	Volume in cfm	Cross Area* (Est. only) Ft^2	Projected Max Drift Air Velocity (fpm)	Projected Air Velocity @ Face Less 15% Leakage (fpm)	Projected Air Velocity @ Face Less 20% Leakage (fpm)	Projected Air Velocity @ Face Less 25% Leakage (fpm)
TS Imbricate Drift	40,000	12'x20'	167	142	133	125
TS West Drift	40,000	12'x20'	167	142	133	125
TS East Drift	40,000	12'x20'	167	142	133	125
TS Core Area (MTL)	130,000	Lump	Package	Package	Package	Package
TS Mechanics Shop	35,000	Lump	Package	Package	Package	Package

TS Total= 285,000 cfm

CALICO HILLS LEVEL	Volume in cfm	Cross Area* (Est. only) Ft^2	Projected Max Drift Air Velocity (fpm)	Projected Air Velocity @ Face Less 15% Leakage (fpm)	Projected Air Velocity @ Face Less 20% Leakage (fpm)	Projected Air Velocity @ Face Less 25% Leakage (fpm)
CH Imbricate Drift	25,000	16'x9'	174	148	139	130
CH West Ghost Dance	25,000	16'x9'	174	148	139	130
CH East Ghost Dance	25,000	16'x9'	174	148	139	130
CH Solitario Drift	25,000	16'x9'	174	148	139	130
CH Mechanics Shop	15,000	Lump	Package	Package	Package	Package

CH Total= 115,000 cfm

MAIN AIRWAYS	Volume in cfm	Cross Area* (Est. only)	Projected Max Drift Air Velocity (fpm)
TS Ramp Airflow	400,000	25' dia	815 **
TS Main Dr Airflow	285,000	25' dia	580
CH Ramp Airflow	115,000	18' dia	452
CH Main Dr Airflow	115,000	18' dia	452

* Calculation of drift cross section in rectangular shape is not final and will be changed to realistic dimension once the cutter head configuration of the mechanical miner is finalized.

** Air velocities at the TS North (intake) & TS South (exhaust) Ramps above 600 fpm are relatively high, picking up dust from roadways and conveyor belts. Proper dust control precaution must be exercised.

The total air quantity required for the ESF operation and site characterization is about 400,000 cfm . The details of airflow distribution are found in Drawing No. YMP-025-2-MING-MI51.

9.2.2. Ramp Air Velocity Constraint

Table 9.2 indicates the air velocity along the TS ramps is about 815 fpm. Air velocity greater than 600 fpm (Ref. C, p. 394) will tend to pick up settled dust from conveyor belts and roadways. Extra precaution must be exercised to control dust along these areas.

9.2.3. Diesel Ventilation

It is estimated that the air quantity in each drift will support a limited number of diesel equipment (100 cfm/BHP) to service the testing activities and personnel.

The ESF will be developed mostly by mechanical miners with conveyor haulage system (Ref. A). Diesel ventilation therefore will not be the driving criterion in determining drift air quantity requirement.

9.2.4. Ventilation Flexibility

The relatively high air velocity in the ramp with a conveyor haulage system has possibly limited the flexibility of the ESF ventilation system to expand for more air capacity. Unless some other ways are found, the flexibility to ventilate ESF expansion activities will be through controlled recycling of air, a common mining industry practice.

9.3 Determining Primary Fresh and Return Airway

There are two ESF ramp entries planned; one is the intake and the other is the exhaust ramp. Since the alternative studies (Ref. L) were completed, there are enough reasons to justify the north ramp as the intake airway. Some of these reasons may have changed but the general idea of having the intake in the north ramp is premised by the following:

- The general topography and surface landscape of the north ramp portal is more favorable to installation of buildings and support facilities, therefore, the north ramp is in close proximity to provide access for men and material services. This favors an intake north ramp.

- Conveyor haulage operations (Ref. B) will be concentrated in the south ramp after the ramps are connected. The dust potential hazards of the

conveyor haulage favor the exhaust air in the south ramp.

- More testing activities are to be conducted in the TS north ramp and therefore the TS north ramp has more need for the fresh air intake.

- Repository interface documents, RIB Version 4, Rev. 4, issued 04/08/91, Chapter 2.4.2, Table 2 shows the waste ramp (north ramp) as intake.

There may be some other reasons to justify or not justify the north intake ramp, but for preliminary general arrangement purposes, the north ramp will be the intake airway.

9.4 Determining Location of Primary Fan

The main fan will be located in the surface to satisfy California Code 8 CAC 4.17.7099.b issued 7/11/81. This will either be in the north or south portal.

The justification for installing an exhaust fan near the south portal is based on the following:

- There are less support facilities present at the south portal. The inherent fan noise, despite installation of silencers, will impact fewer numbers of support personnel at the south portal.

- The lesser volume of traffic through the south portal is an advantage. Minimizing disturbances of the portal airlocks also minimizes short circuiting

of air from the portal to the main fan.

- The surface real estate occupied by the main and backup fans, and the fan control building will impact fewer personnel. It will also impact less non-expendable landscape in the south portal area.

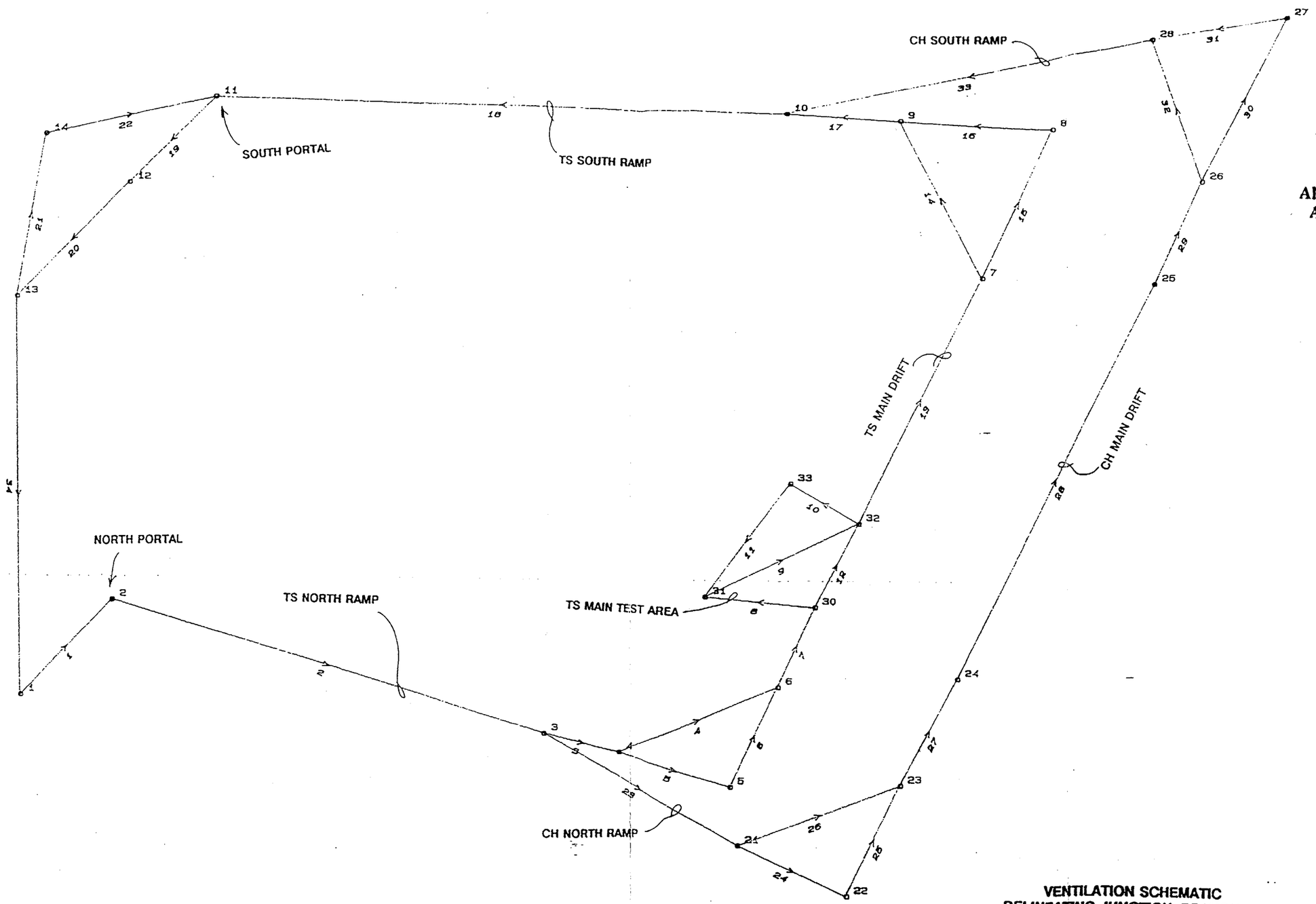
- The installation of the main fan at the south portal will allow the exhaust air to be discharged in a vertical stack and diverted away from ground personnel.

9.5. Ventilation Schematic

A ventilation schematic representing the ESF operation phase is shown in Figure 9.5. The schematic establishes the junction numbers delineating ventilation branches.

To simplify the model, the auxiliary ventilation of lateral drifts is not included. The effect of not including the auxiliary system is insignificant because each lateral's air supply is taken from an intersection of a main air stream and returned to the same intersection. The determination of vent duct sizes and fan horsepower requirements for major lateral drifts is discussed in Section 9.9.

Figure 9.5 Ventilation Schematic
ESF Operation



SI APERTURE CARD

Also Available On Aperture Card

VENTILATION SCHEMATIC DELINEATING JUNCTION, BRANCH AND AIRFLOW DIRECTION

9112020061-//

9.6. Estimation of Airway Resistances

Each branch airway is identified and supplied with the following ventilation data:

- Frictional coefficient factor x 10^{-10}, (K)
- Cross section area (A), ft^2
- Perimeter (P), ft
- Equivalent length (L), ft

The resistance of the airway (R) as VNETPC Software input (in PU units) is calculated as:

$$R = K \times P \times L / (52 \times A^3)$$

The data and calculations of the airway resistances are tabulated in Table 9.6, Resistance Calculation - Operation Phase.

Based upon good engineering judgement, the K factor used is 75 for the ramps or drifts and 15 for the ventilation ducts. Ventilation control resistance (PU units) equivalent is 10 for the surface fan leakages and 2 for the TS Main Test Area fan leakages.

The lengths and cross section areas of ramps or drifts used are approximate for the simulation model. Actual data, which are being checked as of this writing, vary slightly from these numbers. As soon as these are

TABLE 9.6 Resistance Calculation
Operation Phase

FLOW-THROUGH SYSTEM -OPERATION VENTILATION DATA R.S. Jurani 7/17/91

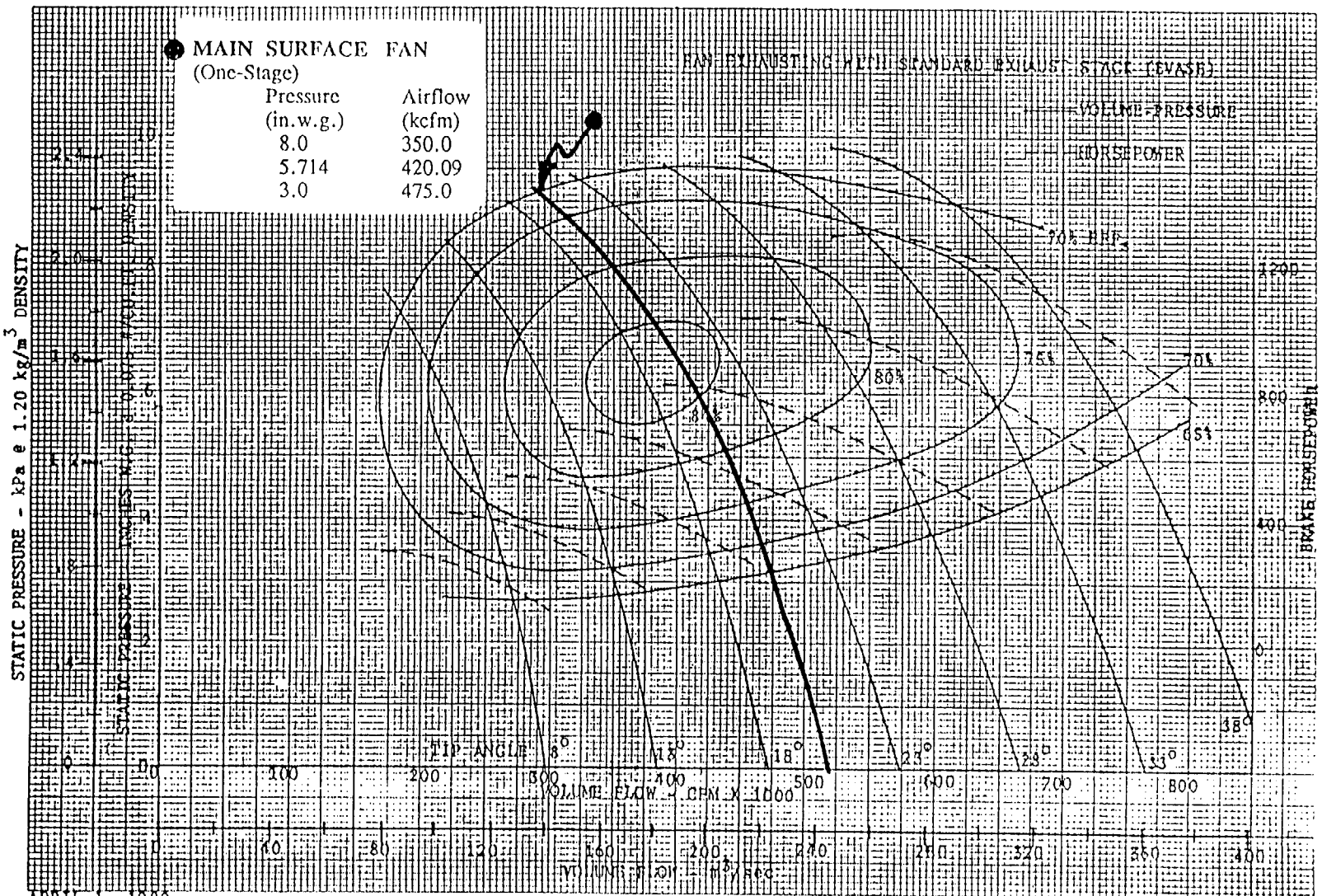
Line No.	BRANCH From	BRANCH To	RESISTANCE in PU R	FRICTION FACTOR K	CROSS AREA A ft^2	PERIMETER P (Ft)	ACTUAL LENGTH L' (Ft)	EQUIV. LENGTH L=L'+10% (Ft)	NOTES FOR BRANCH DESCRIPTION	LINE NO.
1	1	2	0.00053	75	490.8750	78.5400	500	550	TS North Ramp Intake (portal loses)	1
2	2	3	0.00583	75	490.8750	78.5400	5533	6086	TS North Ramp to TS/CH Intersection	2
3	3	4	0.00010	75	490.8750	78.5400	95	105	TS/CH Intersection to TS N curve	3
4	4	6	0.00090	75	490.8750	78.5400	850	935	TS North Curve	4
5	4	5	0.09916	75	64.0000	32.0000	512	563	TS North Conveyor Bypass (1)	5
6	5	6	0.09916	75	64.0000	32.0000	512	563	TS North Conveyor Bypass (2)	6
7	6	30	0.00135	75	490.8750	78.5400	1283	1411	TS Main Drift to Imbricate Inters.	7
8	30	31	0.01983	75	240.0000	64.0000	2700	2970	Rep. for Main Test Area & Imbricate	8
9	31	32	Aux. Fan	75	0.0000	0.0000	0	0	Aux. Fan	9
10	32	33	Fan Leak R=1	75	0.0000	0.0000	0	0	Aux. Fan Leak R=1	10
11	33	31	Fan Leak R=1	75	0.0000	0.0000	0	0	Aux. Fan Leak R=1	11
12	30	32	0.00052	75	490.8750	78.5400	490	539	Imbricate Inters. to Core Return	12
13	32	7	0.00935	75	490.8750	78.5400	8872	9759	TS Main Drift (Cont)	13
14	7	9	0.00127	75	490.8750	78.5400	1206	1327	TS South Curve	14
15	7	8	0.18244	75	64.0000	32.0000	942	1036	TS South Conveyor Bypass (1)	15
16	8	9	0.18244	75	64.0000	32.0000	942	1036	TS South Conveyor Bypass (2)	16
17	9	10	Regulator R	75	490.8750	78.5400	100	110	TS South Curve to TS/CH Inters.	17
18	10	11	0.00826	75	490.8750	78.5400	7836	8620	TS South Ramp	18
19	11	12	0.00952	75	100.0000	40.0000	150	165	TS South Portal Vent Tunnel	19
20	12	13	Main Fan	75	100.0000	40.0000	150	165	Main Fan (TS South Portal)	20
21	13	14	5.00000	75	0.0000	0.0000	0	0	Fan and Portal Leakages (1)	21
22	14	11	5.00000	75	0.0000	0.0000	0	0	Fan and Portal Leakages (2)	22
23	3	21	0.01056	75	254.4696	56.5488	1939	2133	CH North Ramp Upper Part	23
24	21	22	0.00257	75	254.4696	56.5488	472	519	CH North Ramp Curve (1)	24
25	22	23	0.00257	75	254.4696	56.5488	472	519	CH North Ramp Curve (2)	25
26	21	23	0.11640	75	64.0000	32.0000	601	661	CH North Conveyor Bypass	26
27	23	24	0.01389	75	254.4696	56.5488	2551	2806	CH North Ramp Lower Part	27
28	24	25	0.05790	75	254.4696	56.5488	10635	11699	CH Main Drift	28
29	25	26	0.02069	75	254.4696	56.5488	3800	4180	CH South Ramp Lower Part	29
30	26	27	0.00257	75	254.4696	56.5488	472	519	CH South Ramp Curve (1)	30
31	27	28	0.00257	75	254.4696	56.5488	472	519	CH South Ramp Curve (2)	31
32	26	28	0.11640	75	64.0000	32.0000	601	661	CH South Conveyor Bypass	32
33	28	10	0.01812	75	254.4696	56.5488	3328	3661	CH South Ramp Upper Part	33
34	13	1	0.00000	75	0.0000	0.0000	0	0	Surface Dummy Connection	34

finalized, change of computer input will be made. The change is expected to be insignificant to the overall picture of the system.

9.7. Computer Simulation of ESF Ventilation (Operation Phase) by VNETPC Software

9.7.1. Vane axial fan catalogs are referred, and the fan units expected to provide the airflow requirement are selected. Two sizes are analyzed and each of their performance characteristics and curve data are shown on Figures 9.7.1A and 9.7.1B.

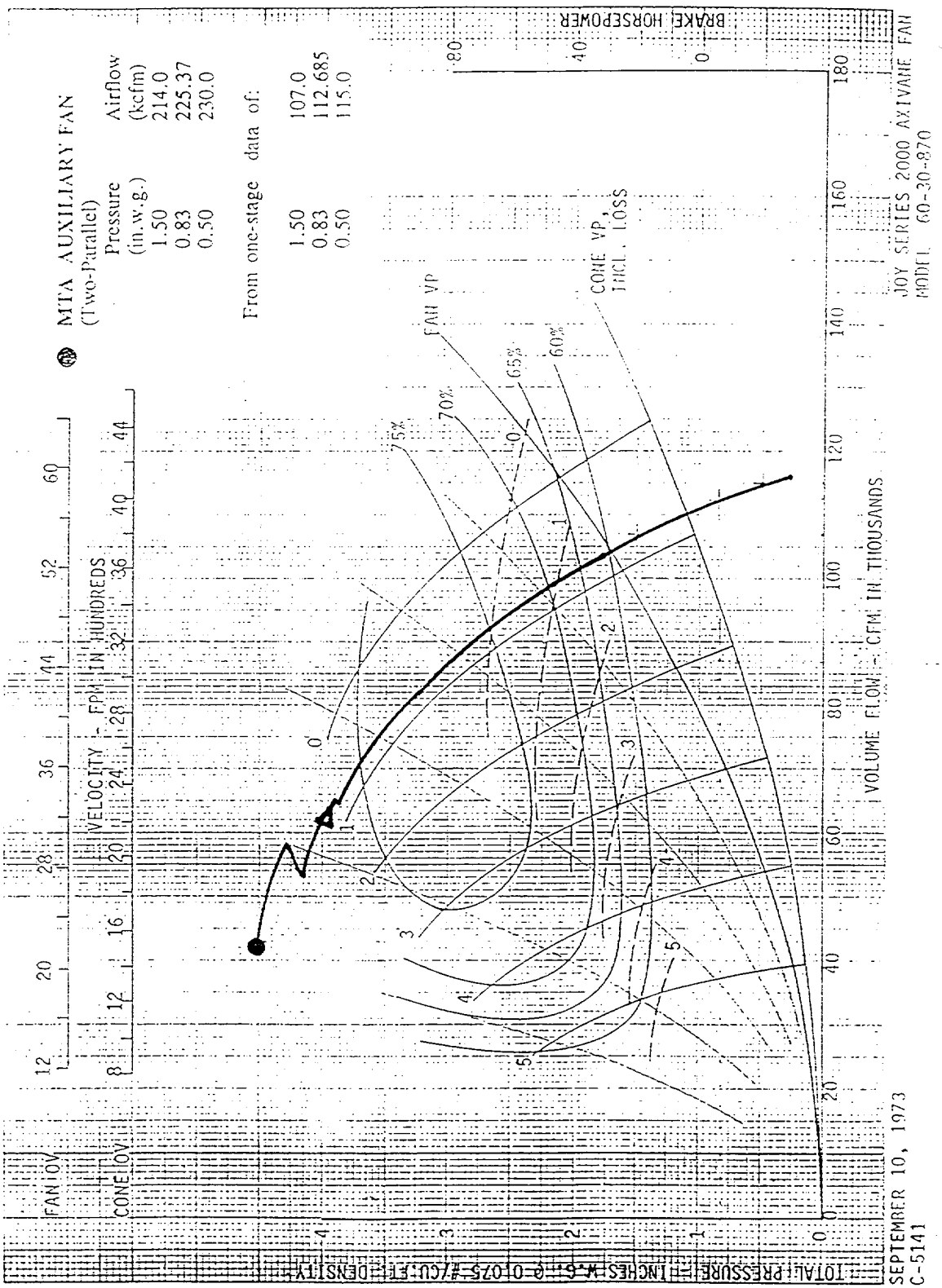
FIGURE 9.7.1A Main Surface Fan



APRIL 1, 1982
C-8230

JOY AXIVANE MINE FAN
FAN MODEL M120-65-710

FIGURE 9.7.1B
Main Test Area Auxiliary Fan



9.7.2. The ventilation schematic, resistance data and the fan sizes discussed in Sections 9.5, 9.6 and 9.7.1 are used as a basis to provide input to the VNETPC Software Codes (Ref. E).

All computer input is printed to check and compare the raw data in the computer to the original data gathered. These printouts are shown in Table 9.7.2.

TABLE 9.7.2 VNETPC Computer Input
ESF Operation

VNETPC (Version 3.0)
07-23-1991
11:42:51

* DESCRIPTIVE DATA *

File Name: CAL031
Network Title: ESF TITLE 1
Mine Name: RAYTHEON SERVICES NEVADA
Company Name: YMP
Comments: SUPPORT CALC 031 OPERATION
British Units
Surface Reference Junction Number 1

* FAN DATA *

Average Efficiency of Fans is 60 %, Power Costs are 6.0 cents/KWh

Fan Ref No.	From	To	Operating Pressure (in.w.g)	No. of Char. Pts.
14	12	13	5.000	3
13	31	32	1.000	3

* FAN CHARACTERISTICS *

Fan 1	Pressure (in.w.g)	Airflow (kcfm)
	8.000	350.00
	5.714	420.09
	3.000	475.00

Fan 2	Pressure (in.w.g)	Airflow (kcfm)
	1.500	214.00
	0.830	225.37
	0.500	230.00

* BRANCH DATA *

```
*****************************************************************************
* BR Units: p- m.in.w.g  Q-kcfm R-   P.U.    k-lbf m^2/f^4 L-    ft          *
*****************************************************************************
```

No.	From	To	Resist.	Airflow	Press. drop	K	Length	Equiv. length	Area	Per
1	1	2	0.00053							

TABLE 9.7.2 VNETPC Computer Input

ESF Operation

2	2	3	0.00583
3	3	4	0.00010
4	4	6	0.00090
5	4	5	0.09916
6	5	6	0.09916
7	6	30	0.00135
8	30	31	0.01983
9	31	32	0.00000
10	32	33	1.00000
11	33	31	1.00000
12	30	32	0.00052
13	32	7	0.00935
14	7	9	0.00127
15	7	8	0.18244
16	8	9	0.18244
17	9	10	0.00811
18	10	11	0.00826
19	11	12	0.00952
20	12	13	0.00000
21	13	14	5.00000
22	14	11	5.00000
23	3	21	0.01056
24	21	22	0.00257
25	22	23	0.00257
26	21	23	0.11640
27	23	24	0.01389
28	24	25	0.05790
29	25	26	0.02069
30	26	27	0.00257
31	27	28	0.00257
32	26	28	0.11640
33	28	10	0.01812
34	13	1	0.00000

9.7.3. Ventilation controls such as doors, regulators, stoppings, dampers, etc. are assigned with an approximate branch line resistance to control the airflow in a specific branch.

9.7.4. The ventilation simulation program is run in accordance with the software instruction manual (Ref. E).

9.7.5. The airflow output is compared with the predetermined airflow requirement (design goal) of the system. Initially, if the run is not satisfactory, the preceding steps are repeated by trying another set of fan curves and ventilation control resistances until the design goals are satisfied.

9.7.6. A satisfactory computer run with airflow quantity plotted is shown in Figure 9.7.6. The computer simulation has detailed output shown in Table 9.7.6. The table shows the branch airflow, pressure, resistance and air horsepower needed.

The computer output has the following airflow summary:

	Air Volume (cfm)
a) TS North Ramp Intake.....	400,000
b) TS Level Main Drift.....	285,000

c) CH Level Ramps and
CH Main Drift..... 115,000

d) TS South Ramp Exhaust.... 400,000

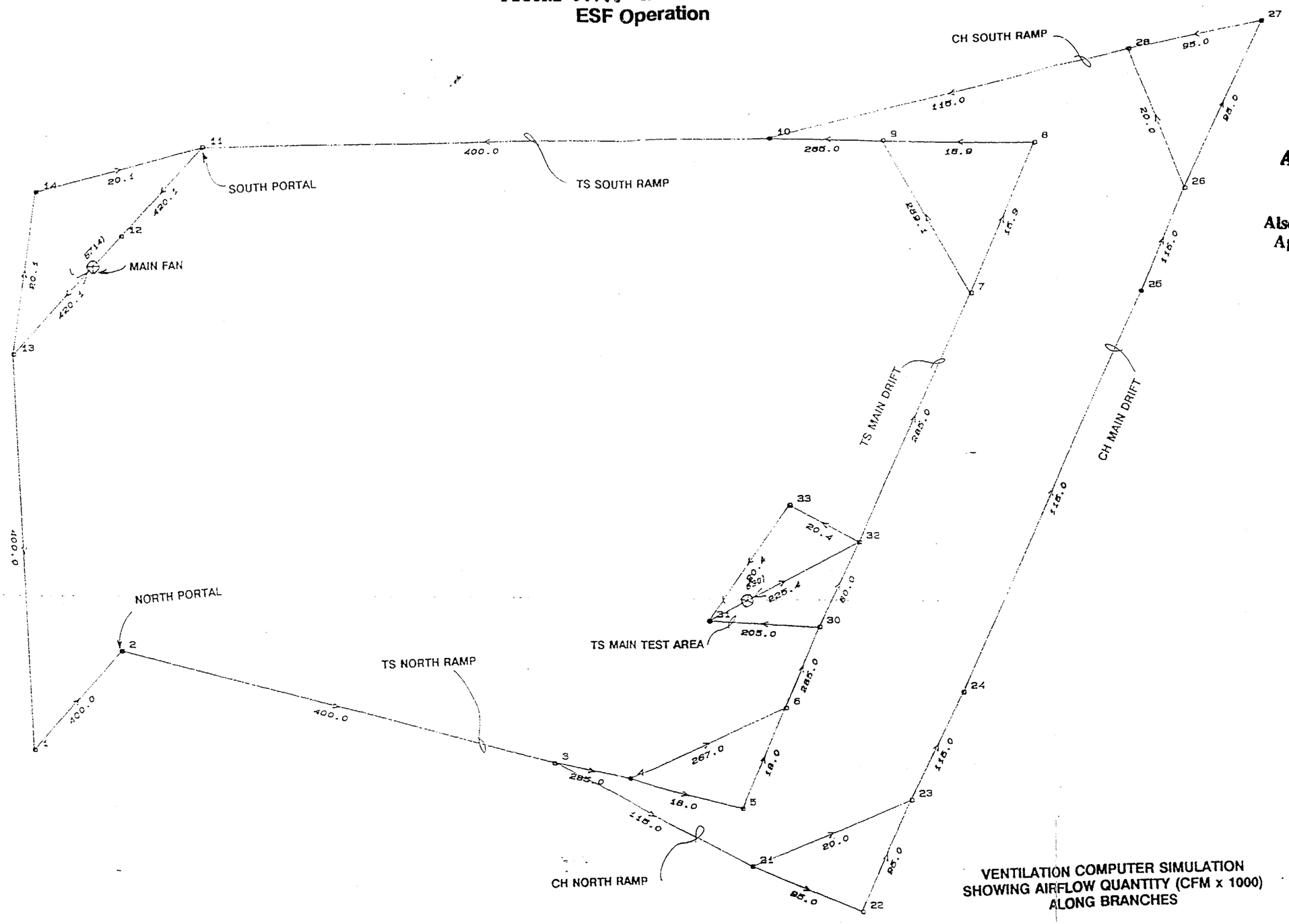
A satisfactory computer run is gaged mainly on the combined potential ventilating air that could be made available at the TS and CH levels. Regulating actual airflow to direct specific air quantity to a particular level will be left to field tune-up.

9.8. Main Fan Features

From the computer output, the surface main fan unit will require a duty air horsepower of 378 when delivering an air quantity of 420,000 cfm at static pressure of 5.7 inches water gage (wg). About 20,000 cfm of this volume is included to represent leakages around the TS South Ramp airlocks and main fan structures. At 60% total motor efficiency, the main fan will require about 630 BHP. For the purpose of general arrangement, the main fan (Ref. J) to be installed features the following maximum performance:

Air Quantity	420,000 cfm
Motor	700 BHP
Static Pressure	7.0 inches wg

FIGURE 9.7.6 AIRFLOW OUTPUT
ESF Operation



SI APERTURE CARD

Also Available On Aperture Card

VENTILATION COMPUTER SIMULATION
SHOWING AIRFLOW QUANTITY (CFM x 1000)
ALONG BRANCHES

TABLE 9.7.6 AIRFLOW OUTPUT
ESF Operation

VNETPC (Version 3.0)
11:41:11
07-23-1991

Output File Name: OUTPUT.TMP
Network File Name: CAL031
Network Title: ESF TITLE 1
Mine Name: RAYTHEON SERVICES NEVADA
Company: YMP
Comments: SUPPORT CALC 031 OPERATION

**** OUTPUT DATA ****

Annual costs are based on electricity charges of 6.0 cents per kWh and fan efficiencies of 60.0%
Cost given for an NVP represents money saved by natural ventilation

*** Fan Operating Points ***

Fan No.	Ref	From	To	Pressure in.w.g.	Quantity kcfm	Air Power hp	Op.Cost $/year
1	14	12	13	5.714	420.09	378.24	247080
2	13	31	32	0.830	225.36	29.47	19254

*** Branch Data ***

Branch	From	To	Press.Dp m.in.wg.	Airflow kcfm	Resist. P.U.	AP Loss hp	Op.Cost $/year
1	1	2	84	400.00	0.00053	5.3	3459
2	2	3	932	400.00	0.00583	58.7	38374
3	3	4	8	284.99	0.00010	0.4	235
4	4	6	64	267.01	0.00090	2.7	1759
5	4	5	32	17.99	0.09916	0.1	59
6	5	6	32	17.99	0.09916	0.1	59
7	6	30	109	284.99	0.00135	4.9	3198
8	30	31	833	204.99	0.01983	26.9	17576
9	31	32	0	225.36	0.00000	0.0	0
10	32	33	415	20.38	1.00000	1.3	870
11	33	31	415	20.38	1.00000	1.3	870
12	30	32	3	80.01	0.00052	0.0	25
13	32	7	759	284.99	0.00935	34.1	22266
14	7	9	91	269.12	0.00127	3.9	2521
15	7	8	45	15.88	0.18244	0.1	74
16	8	9	45	15.88	0.18244	0.1	74
17	9	10	658	284.99	0.00811	29.6	19303
18	10	11	1321	400.00	0.00826	83.3	54390
19	11	12	1680	420.09	0.00952	111.2	72645

TABLE 9.7.6 VNETPC Computer Output
ESF Operation

20	12	13	0	420.09	0.00000	0.0	0
21	13	14	2017	20.09	5.00000	6.4	4170
22	14	11	2017	20.09	5.00000	6.4	4170
23	3	21	139	115.01	0.01056	2.5	1645
24	21	22	23	95.04	0.00257	0.3	225
25	22	23	23	95.04	0.00257	0.3	225
26	21	23	46	19.97	0.11640	0.1	95
27	23	24	183	115.01	0.01389	3.3	2166
28	24	25	765	115.01	0.05790	13.9	9056
29	25	26	273	115.01	0.02069	4.9	3232
30	26	27	23	95.04	0.00257	0.3	225
31	27	28	23	95.04	0.00257	0.3	225
32	26	28	46	19.97	0.11640	0.1	95
33	28	10	239	115.01	0.01812	4.3	2829
34	13	1	0	400.00	0.00000	0.0	0

Number of Iterations = 9

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	-84	3	-1016	4	-1024
5	-1056	6	-1088	7	-1959	8	-2004
9	-2050	10	-2708	11	-4029	12	-5709
13	5	14	-2012	21	-1155	22	-1178
23	-1201	24	-1384	25	-2149	26	-2422
27	-2445	28	-2468	30	-1197	31	-2030
32	-1200	33	-1615				

**** NETWORK EXERCISE COMPLETE ****

There is an apparent need to vary the air quantity in the ESF caused by phased development, testing, and other operational activities after the main fan is in operation. The main fan will be flexible to varying underground air quantity (also the ramp air velocity), as needed, by having a controllable pitch. The pitch will be mechanically adjustable, which minimizes any interruption or stoppage of the ventilation system.

Control packages of the main fan have to be in a dedicated building to shelter the hydraulics and fan operational monitors.

9.9. Lateral Drift Ventilation

The local ventilation of lateral drifts will route the fresh air from the main air stream to the face, and the return air through vent ducts back to the general area (downstream) where the fresh air came from, with the very minimum recirculation as practicable. Vane axial fans in the vent duct move the air.

There are seven major lateral drifts, three in the TS level, and four in the CH level. The ventilation of these drifts is not included in the ventilation schematic as mentioned in Section 9.5.

The size of ventilation ducts and fan power distribution are analyzed. The calculations of fan horsepower and pressure for various duct sizes that may fit into the drift are shown in Table 9.9.

From the vent duct size allowed in the drift (Ref. A, H and I), the following data is summarized:

	Drift Length (ft)	Vent Duct Diameter (inch)	Total BHP @60% Motor Efficiency
TS Level			
TS Imbricate.....	2,250	36	320
TS East.....	3,220	36	460
TS West.....	3,800	36	540
CH Level			
CH Imbricate.....	2,160	30	190
CH East Ghost Dance..	1,520	30	130
CH West Ghost Dance..	1,075	30	90
CH Solitario.....	2,200	30	190

It should be noted that the existing ventilation ducts and fans used during the construction of these lateral drifts may be used for the operation mode. These construction fans and ducts will be in place and do not have to be moved. The transition from construction to operation mode will have minimum disturbance to the ventilation system.

Table 9.9 Lateral Drift Ventilation Calculation

ESF Ventilation Operation for Dead End Lateral Drifts, Page 1 of 2

TS LEVEL DRIFT LENGTH (Reference Drawing # YMP-025-2-MING-MI01, Rev. A)
CH LEVEL DRIFT LENGTH (Reference Drawing # YMP-025-2-MING-MI13, Rev. A)

Calculation of Fan Horsepower & Pressure — R. S. Jurani 7/22/91

	Duct Size (inches diameter) at K factor = 15, 60% fan eff.				
	54	48	42	36	30
	R54	R48	R42	R36	R30
Resistance/100' >>	1.01369	1.8267	3.56144	7.69763	19.15429
TS LEVEL					
TS IMBRICATE DRIFT (2250 Ft.)					
Q=40,000 cfm 40000					
Equiv. L=L'x1.10= 2475					
Total BHP for 2475'	42	76	148	320	797
BHP for 1000'	17	31	60	129	322
Total S. Pres. (In WG)	4	7	14	30	76
Total S. Pres./1000'	1.6	2.9	5.7	12.3	30.6
TS EAST DRIFT (3220 Ft.)					
Q=40,000 cfm 40000					
Equiv. L=L'x1.10= 3542					
Total BHP for 3542'	60	109	212	458	1141
BHP for 1000'	17	31	60	129	322
Total S. Pres. (In WG)	6	10	20	44	109
Total S. Pres./1000'	1.6	2.9	5.7	12.3	30.6
TS WEST DRIFT (3800 Ft.)					
Q=40,000 cfm 40000					
Equiv. L=L'x1.10= 4180					
Total BHP for 4180'	71	128	250	541	1346
BHP for 1000'	17	31	60	129	322
Total S. Pres. (In WG)	7	12	24	51	128
Total S. Pres./1000'	1.6	2.9	5.7	12.3	30.6

Table 9.9 Lateral Drift Ventilation Calculation

ESF Ventilation Operation for Dead End Lateral Drifts, Page 2 of 2

Calculation of Fan Horsepower & Pressure — R. S. Jurani 7/22/91

	Duct Size (inches diameter) at K factor = 15, 60% fan eff.				
	54	48	42	36	30
	R54	R48	R42	R36	R30
Resistance/100' >>	1.01369	1.8267	3.56144	7.69768	19.15429
CH LEVEL					
CH IMBRICATE DRIFT (2160 Ft.)					
Q=25,000 cfm 25000					
Equiv. L=L'x1.10= 2376					
Total BHP for 2376'	10	18	35	75	187
BHP for 1000'	4	7	15	32	79
Total S. Pres. (In WG)	1.5	2.7	5.3	11.4	28.4
Total S. Pres./1000'	0.6	1.1	2.2	4.8	12.0
CH EAST GHOST DANCE DRIFT (1520 Ft.)					
Q=25,000 cfm 25000					
Equiv. L=L'x1.10= 1672					
Total BHP for 1672'	7	13	24	53	131
BHP for 1000'	4.2	7.5	14.6	31.6	78.6
Total S. Pres. (In WG)	1.1	1.9	3.7	8.0	20.0
Total S. Pres./1000'	0.6	1.1	2.2	4.8	12.0
CH WEST GHOST DANCE DRIFT (1075 Ft.)					
Q=25,000 cfm 25000					
Equiv. L=L'x1.10= 1183					
Total BHP for 1183'	5	9	17	37	93
BHP for 1000'	4.2	7.5	14.6	31.6	78.6
Total S. Pres. (In WG)	0.7	1.4	2.6	5.7	14.2
Total S. Pres./1000'	0.6	1.1	2.2	4.8	12.0
CH SOLITARIO DRIFT (2200 Ft.)					
Q=25,000 cfm 25000					
Equiv. L=L'x1.10= 2420					
Total BHP for 2420'	10	18	35	76	190
BHP for 1000'	4.2	7.5	14.6	31.6	78.6
Total S. Pres. (In WG)	1.5	2.8	5.4	11.6	29.0
Total S. Pres./1000'	0.6	1.1	2.2	4.8	12.0

10. CONCLUSION AND RECOMMENDATION

10.1. Face Air Velocity

Based upon mining industry practices, a range of drift air velocities between 140-150 fpm is recommended for the ESF drift operation and maintenance.

10.2. Air Quantity for ESF Operation

The ESF will need an air quantity of about 400,000 cfm to support all the test drifts and shops simultaneouly in operation. About 285,000 and 115,000 cfm will be distributed to the Topopah Spring and Calico Hills levels respectively. The design air quantity includes about 15% leakage allowances.

10.3. Ramp Air Velocity Constraint

The air velocity in the TS ramps is about 820 fpm. This is relatively high velocity in a conveyor haulage system. Velocities greater than 600 fpm will tend to pick up settled dust from the conveyor belts and roadways. Extra precaution for dust control must be exercised in the TS ramp areas.

10.4. Diesel Ventilation

A limited number of diesel equipment (100 cfm/BHP) can be used in any ESF drift to service the testing activities and personnel. The ESF will be mostly developed by mechanical miners with conveyor haulage system. Diesel ventilation will not be the driving criterion in determining drift air quantity.

10.5. Ventilation Flexibility

The relatively high air velocity in the TS ramps with a conveyor haulage system has possibly limited the flexibility of the ESF ventilation system to expand for more air capacity. Unless some other ways are found, the flexibility to ventilate ESF expansion activities will be through controlled recycling of air, a common mining industry practice.

10.6 Establishing Primary Airways and Location of Main Fan

There are enough reasons to justify the north ramp as the intake airway and the south ramp as the exhaust airway. The current testing and operational strategy support the location of the main fan and airlock structure in the surface at the south portal.

10.7. Main Fan Feature

The surface main fan unit will require a duty air horsepower of 378 when delivering an air quantity of 420,000 cfm at static pressure of 5.7 inches water gage (wg). About 20,000 cfm of this volume is included to represent leakages around the TS South Ramp airlocks and main fan structures. At 60% total motor efficiency, the main fan will require about 630 BHP. The main fan to be installed features the following maximum performance:

Air Quantity ..... 420,000 cfm
Motor ..... 700 BHP
Static Pressure .... 7.0 inches wg

The main fan will be flexible to varying the underground air quantity (also the ramp air velocity), as needed, by having a controllable pitch, mechanically adjustable to minimize any interruption or stoppage of the ventilation system.

10.8. Lateral Drift Ventilation

The local ventilation of lateral drifts will route the fresh air from the main air stream to the face, and the return air through vent ducts back to the general area (downstream) where the fresh air came from, with the very minimum recirculation as practicable. Vane axial fans in the vent duct moves the air.

The vent duct size allowed in the configuration of the lateral drift and their respective fan power distribution are summarized in the following table:

	Drift Length (ft)	Vent Duct Diameter (inch)	Total BHP @60% Motor Efficiency
TS Level			
TS Imbricate.....	2,250	36	320
TS East.....	3,220	36	460
TS West.....	3,800	36	540
CH Level			
CH Imbricate.....	2,160	30	190
CH East Ghost Dance..	1,520	30	130
CH West Ghost Dance..	1,075	30	90
CH Solitario.....	2,200	30	190

Raytheon Services Nevada

DESIGN ANALYSIS

Number: ST-MN-035 Rev: 1

WBS No.	PRINT NAME	SIGNATURE	TITLE	DATE
ORIGINATOR:	Saeed Bonabian	Saeed Bonabian	Eng Tech Analyst/Spec	8-21-91
CHECKER:	Edward Fitch	Edward F Fitch	Sr Mining Eng/Spec	8-21-91
APPROVAL - LDE:	Bruce Stanley	Bruce T. Stanley	Ld. Mining Eng.	8-21-91
APPROVAL - SCDM:	Bolek Chytrowski	B. R. Chytrowski	SCDM	2-21-91
QA CONCURRENCE:	Paul Hale	Paul B Hale	Sr QA Specialist	8-21-91

SUBJECT: ESF Ground Support Systems

TITLE: Preliminary Opening Stability Analyses

QAG Reference: RSN-GR-013, Rev. 0

1.0 PURPOSE: Please refer to Section 2.0 of the report Page 7 of 80. This revision incorporates the management and technical review comment resolutions.

2.0 METHOD: The preliminary approach for the design of the ground support systems is presented in Section 3.0 of the report page 8 of 80. Both empirical and analytical methods are used to perform the analyses.

3.0 Design Inputs:

Reference Information Base (RIB) Version 4, Revision 4, is used for all the technical input data (Chap.1, Sec. 2, Item 5, page 4 of 4, Table 2; Chap. 1, Sec. 2, Item 10, Page 4 of 5, Table 2; and Chap. 1, Sec. 1, Item 1, Page 3 of 6, Figure 1).

The preliminary numerical modeling results is provided from computer analyses ACL-2, ACL-3, ACL-4, ACL-5, ACL-6, ACL-7, ACL-8, ACL-9, ACL-10, ACL-11.

YMP/CC-0013 (ESFDR) Rev. 5/31/91 issued May 31, 1991
- o Section 1.2.6.4: PC.2h and PC.2j
- o Section 1.2.6.5: PC.2h and PC.2j
- o Section 1.2.6.6: PC.2i and PC.2k

4.0 CODES AND STANDARDS:

No codes or standards were identified which specifically apply to preliminary analyses.

5.0 ASSUMPTIONS:

It is assumed that all input will be included in the approved Basis For Design (BFD).

For computer modeling, the low and the high horizontal to vertical stress ratios of 0.3 and 1.0 is assumed.

6.0 REFERENCE MATERIAL:

Please refer to Section 9.0 of the report, Pages 78-80.

7.0 COMPUTER PROGRAMS:

Fast Lagrangian Analysis of Continua (FLAC), Version 2.27TC
Software Configuration Management Log Number: SCML-01-00
Software Certification Number: SCF-01-00
Software Design Description Waiver Number: SDDW-01 Rev. 00
Software Validation Waiver Number: SVW-01 Rev. 00
Computer Hardware: DELL 325
Hardware Certification Form Number: HCR-01-00
Hardware Configuration Management Log Number: SCCML-01-00
Certified Runs Used: ACL-2, ACL-3, ACL-4, ACL-5, ACL-6, ACL-7, ACL-8, ACL-9, ACL-10, ACL-11

Software Verification and Validation Report SVVR-01 Rev. 00 Test Application #4 (Elasto-Plastic Model) provides support for the applications performed in the analyses in this report.

Refer to Respective ACL's for input and output.

8.0 UNITS: Metric units are used in the analyses.

9.0 CALCULATIONS:

Please refer to Pages 3 to 80.

10.0 CONCLUSIONS:

Please refer to Section 8.0 of report, Pages 76 of 80.

PRELIMINARY OPENING

STABILITY ANALYSES

ST-MN-035
Rev. 0

July 24, 1991

RAYTHEON SERVICES NEVADA

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1.0 INTRODUCTION

The Exploratory Studies Facilities (ESF) is to be designed and constructed as a major part of the overall efforts carried out under the auspices of the U.S. Department of Energy generally referred to as Yucca Mountain Project (YMP). The task of rock mechanics in the overall ESF design and future construction efforts is to assist in the development of safe underground openings. Excavation of underground openings in rock creates a disturbance of virgin stress fields existing within the rock mass. The in situ stress field, rock strength properties, existing discontinuities, geometry and size of the opening, and the method of excavation are the major factors among many contributing to the problem of opening stability.

Underground openings for the ESF will be excavated through rock of varying quality. This report presents a preliminary approach for designing ESF underground openings and for selecting appropriate ground support for various conditions. The reports presented by Nolting and Schmidt, September 1990, and Langkopf and Gnirk, February 1986 have been used as the main references in the development of the design approach.

Design of underground openings is a complex task due to the variable nature of the rock mass. Therefore, implementation of a single method (analytical or empirical) is not sufficient to produce accurate ground support recommendations. The design effort must include both analytical and empirical methods, coupled with assessment of plausible failure modes and visual inspection during construction. The use of observation and monitoring during and after construction is essential to verify rock properties and opening performance, and

to implement ground support modifications if required.

Design of the ESF access ramps, optional shaft and Main Test Area (MTA) require comprehensive design input data including site and engineering data. Site data include topographic, geologic, geomechanical, thermomechanical and seismic data. Design data include conceptual layouts, opening configurations, and results of analyses incorporating effects of geostatic, thermal and seismic loads. However, design input data change and evolve as the design analyses proceeds as new site specific data is available. The new data are entered into the design data bases, e.g. Reference Information Base (RIB), and are incorporated in the updated design analyses. Moreover, part of the data cannot be completely determined before the opening is excavated which necessitates presence of qualified observers during construction to instruct and implement required procedures.

1.1 ROCK SUPPORT

Engineering means by which the safety of the opening and its functionality are provided, depend on proper design of ground support system. Generally, rock support needs are determined using several available methods. These methods include both analytical and empirical approaches, which are supported by historical experience with underground construction. These analyses include considerations of in situ stress, stress induced by excavation and thermal loading, and response to seismic events. Results of these analyses serve as a basis for development of flexible rock reinforcement systems capable of accommodating various rock conditions to be encountered underground.

Ground support requirements for each segment of an underground opening may vary over relatively short distances depending on the local geologic conditions. Based on the visual inspection performed locally by qualified professionals, local ground conditions are classified in terms of rock mass categories. In turn, each rock mass category is assigned a specific rock support system, which includes the procedures for its proper implementation and the necessary hardware.

Depending on the rock mass class the rock support system may include typical hardware items such as rock bolts, wire mesh, shotcrete, or the combination of these as specified for each system.

2.0 PURPOSE AND SCOPE

The main purposes of this study are: (1) to prepare a preliminary approach for the design of effective and versatile ground support systems for the Exploratory Studies Facility (ESF) at the Yucca Mountain, and (2) to perform preliminary stability analyses. A description of the methods that will be used for the design of underground openings are presented in this report which include both analytical and empirical approaches. Some preliminary analyses are also included which simulate the state of in situ and excavation induced stresses. Fast Lagrangian Analysis of Continua (FLAC) computer code is used to perform the preliminary analyses. FLAC has been verified under a project approved Software Quality Assurance Plan (SQAP) and the analyses are performed in compliance with RSN SQAP procedures.

The ground support for the potential shaft is not considered in this report and will be addressed in the future reports if required.

3.0 APPROACH

The design approach addressed in this report incorporates both analytical and empirical methods as well as observation and monitoring during construction. A detailed description of both analytical and empirical methods and their limitations are presented later in this report. The design approach presented here is, for the most part, based on empirical rock mass classification and support selection guides. The analytical method (use of numerical codes) provides a check on empirical results and assists in providing information where empirical methods fall short. This information includes, in particular, predicted stresses and stress states around openings induced by the excavation and stress changes resulting from thermal loads and seismic effects. Furthermore, empirical methods do not provide a prediction or assessment of expected or plausible failure modes. Development of plausible failure modes of underground openings will be aided by the use of numerical codes to supplement empirical methods.

Empirical methods also do not incorporate the effect of excavation techniques. The selection and design of ground support components are not complete without consideration of the excavation and installation process. For the method to be developed for the ESF design an adjustment will be made to consider the effect of excavation methods.

In summary, the ground support design process is a complex one that must integrate empirical methods of ground support selection, analytical modeling, evaluation of fundamental rock behavior, practical considerations of constructability and durability, observation during construction, and

considerations of long term maintainability. In this process, analytical activities are not separate from the empirical and more fundamental considerations; neither the analytical modeling nor the empirical support selection should be done independently (Nolting & Schmidt, 1990). A proposed preliminary approach, as shown in Figure 1, breaks up the design approach into 7 categories or steps. Each step consists of several components. It should be noted that development of some of these categories are concurrent and sometimes iterative. Therefore the steps are not necessarily required to be completed in the order presented. The end product of the design approach is a set of construction documents including drawings, specifications, and procedures.

It should be mentioned that the approach presented here is preliminary and it will be evolved as the design process proceeds. This approach ultimately uses the classification and ground support method coupled with observation during construction of the underground facilities. As construction proceeds, the exposed rock is classified and ground support modified as required to suit local variations in rock mass properties as determined by rock mass classification.

The following sections of this report mainly address the first three steps of the process presented in Figure 1. The following steps will be developed and addressed in future design reports. As mentioned earlier, the methodology suggested by Nolting and Schmidt (1990), and rock mass classification of Yucca Mountain by Langkopf and Gnirk (1986) have been used as primary references in development of the approach presented in this report.

FIGURE 1. Preliminary Ground Support Design Approach

1. ESTABLISH DESIGN INPUTS
   - Site Specific Rock Properties
   - Thermal Stress Data
   - Seismic Data
   - Q & RMR Rating Data

2. ANALYTICAL METHODS
   - Stress Analysis
   - Opening Shape Assesment

3. CLASSIFY ROCK MASS & MAKE PRELIMINARY SUPPORT RECOMMENDATIONS
   - CSIR (RMR Ratings & Recommendations)
   - NGI (Q Ratings & Recommendations)

4. ADJUST RECOMMENDATIONS TO INCORPORATE
   - Plausible Failure Modes
   - Excavation Methods
   - Thermal Effects
   - Seismic Effects
   - Constructability Issues

5. SELECT DETAILED SUPPORT COMPONENTS
   - Corrosion Considerations
   - Temperature Compatability
   - Inspection and Maintenance

6. ESTABLISH GROUND SUPPORT CLASSES
   - Rock Classes
   - Opening Classes

7. DEVELOP CONSTRUCTION DOCUMENTS
   - Drawings
   - Specifications
   - Procedures

4.0 DESIGN INPUT DATA (STEP 1)

The design of effective ground support systems requires comprehensive design input data. The first step in the design approach is to identify and assemble the required site specific and engineering data. Because of the importance of the Yucca Mountain Project, the design input data is subject to a strictly controlled quality assurance processes. Both site specific and engineering data must be qualified, approved and baselined before use in the design of the ESF. The collection of design data is an evolving process and its documentation must be controlled. For the ESF design, the Reference Information Base (RIB) is the controlling document that provides summary data and information to the project. With the exception of standard handbooks, use of the RIB is required for all technical data used in the design and analysis activities that may be used for the future licencing activities. The RIB is periodically updated to incorporate the latest available site specific and engineering data in accordance with project configuration management procedures.

As the design proceeds, the designers are required to request the incorporation of the needed information into the RIB. For the purposes of computer analysis, as a part of ESF underground opening design, a representative subsurface geologic and thermal/mechanical model of the proposed site is a prerequisite. At the present time an effort is underway to evaluate the best available geologic data and incorporate it into the RIB (Ref. 19). As a part of this effort, a series of thermal/mechanical cross sections representative of the proposed site will be included into the RIB. Cross sections along the proposed access ramp alignments will also be included in this package. With an

underground thermal/mechanical model provided, the state of in situ stresses will be calculated using computer models. The calculated stresses will in turn provide initial and boundary conditions for more detailed and local stress analysis to determine the excavation induced stresses and assess the opening shapes. The results of these analysis which represent part of the engineering data are then incorporated into the RIB.

The site specific data are periodically updated as more information is provided from new drillholes or trenches. These data are also required to be incorporated into the RIB and made available to the designers. The changes to any data are controlled in compliance with the project configuration management procedures. The site specific data are described in more detail in Section 4.2.

Engineering design data determined mainly by engineering decisions will also affect the specific rock support choice. For example, in the design of the configuration of the MTA the requirements of the testing community are of the highest priority. For instance, if certain in situ rock is required to be observed for a period of time then the use of shotcrete will not be recommended for that area. Also specific geometry of some drifts in MTA such as size, orientation, shape and spacing are required by the testers. Therefore, functional requirements introduce a series of input data that have to be considered in the design of the underground support systems. Other engineering design data will include ventilation and temperature characteristics in addition to some lifetime requirements that must be considered in the design.

Thermal and seismic data will also be considered in the design of the ground support systems. Various near field, far field and sensitivity analysis have been performed up to date to determine the thermally induced stresses and

temperature ranges due to potential waste emplacement. St. John (1987), St. John and Mitchell (1987) and Asgian (1988) conducted studies to determine the thermal stresses for the ESF (the previously configured ESF with two shafts) design. St. John assumed that all waste is emplaced at one time and that the heat output is uniform in the area of the waste emplacement. Asgian performed a thorough analysis of the ESF with incorporation of variation in panel elevations and a waste emplacement schedule into the model. Asgian's results provide estimates for thermally induced stresses at the locations of the shafts (ES1 and ES2), test drifts, and long exploratory drifts. The maximum induced temperature was estimated to be about 76°C at 100 years after waste implacement with stress changes of +10.4 MPa (compression) horizontally and -2.1 MPa vertically (Asgian, 1988). A similar analysis has to be performed to determine the temperature ranges and thermally induced stresses incorporating the latest ESF configuration. It is necessary to mention that, analyses incorporating thermal stress should be conducted for a range of conservatively estimated thermal stress state because of the uncertainty of the rate of potential waste emplacement. The working group report, Exploratory Shaft Seismic Design Basis (SNL, 1990) recommended seismic input parameters both for natural earthquakes, which may possibly occur at or near the site, and for underground nuclear explosions (UNE) at the Nevada Test Site. This study was also performed for the previously configured ESF and must be updated to incorporate the latest ESF configuration. A detailed study will be performed by RSN prior to the start of Title II design to identify, collect or produce specific thermal and seismic parameters that are required for the design of the underground support systems.

4.1 GEOLOGY

The major stratigraphic units to be encountered at the site are the tuffaceous beds of the Calico Hills and the Paintbrush Tuff. The Paintbrush Tuff is composed of four members namely: the Tiva Canyon, Yucca Mountain, Pah Canyon and Topopah Spring in descending order. Each of the four members is separated from the underlying unit by 3 to 10 m (10 to 40 ft) of bedded and/or ash-fall tuffs (Spengler, 1984).

The Tiva Canyon and Topopah Spring Members are composed primarily of moderately to densely welded ash-flow tuff, while the much thinner Yucca Mountain and Pah Canyon Members are generally nonwelded. The Topopah Spring is an ash-flow tuff in a multiple flow cooling unit.

The Topopah Spring Member, a thick densely welded unit, is being considered as the possible host rock for nuclear waste emplacement. This member is characterized by four distinct zones from top to bottom: a nonwelded to densely welded, generally vitric tuff; a moderately to densely devitrified tuff that accounts for most of the total thickness of the member; a basal vitrophyre; and a vitric tuff that grades downward from welded to nonwelded. Laboratory tests performed to date on small samples indicate that the uniaxial compressive strength of the matrix in Topopah Spring Member is strong (100 MPa or more). The unit is probably highly fractured with vertical joint spacings of three or more per meter (Blejwas, 1989). The Exploratory Study Facilities (ESF) Main Test Area (MTA) is to be designed and constructed at the target horizon (Topopah Spring Member) for detailed study of the host rock.

The tuffaceous beds of Calico Hills consists of a sequence of tuffs occupying the stratigraphic intervals between the Paintbrush Tuff and the underlying Crater Flat Tuff. The Calico Hills is composed primarily of massive, nonwelded ash-flow tuff.

The Crater Flat Tuff consists of three members: the Prow Pass Member at the top, the Bullfrog Member in the middle, and the Tram Member at the base. This unit generally consists of moderately to densely welded ash flows and bedded, reworked tuffs.

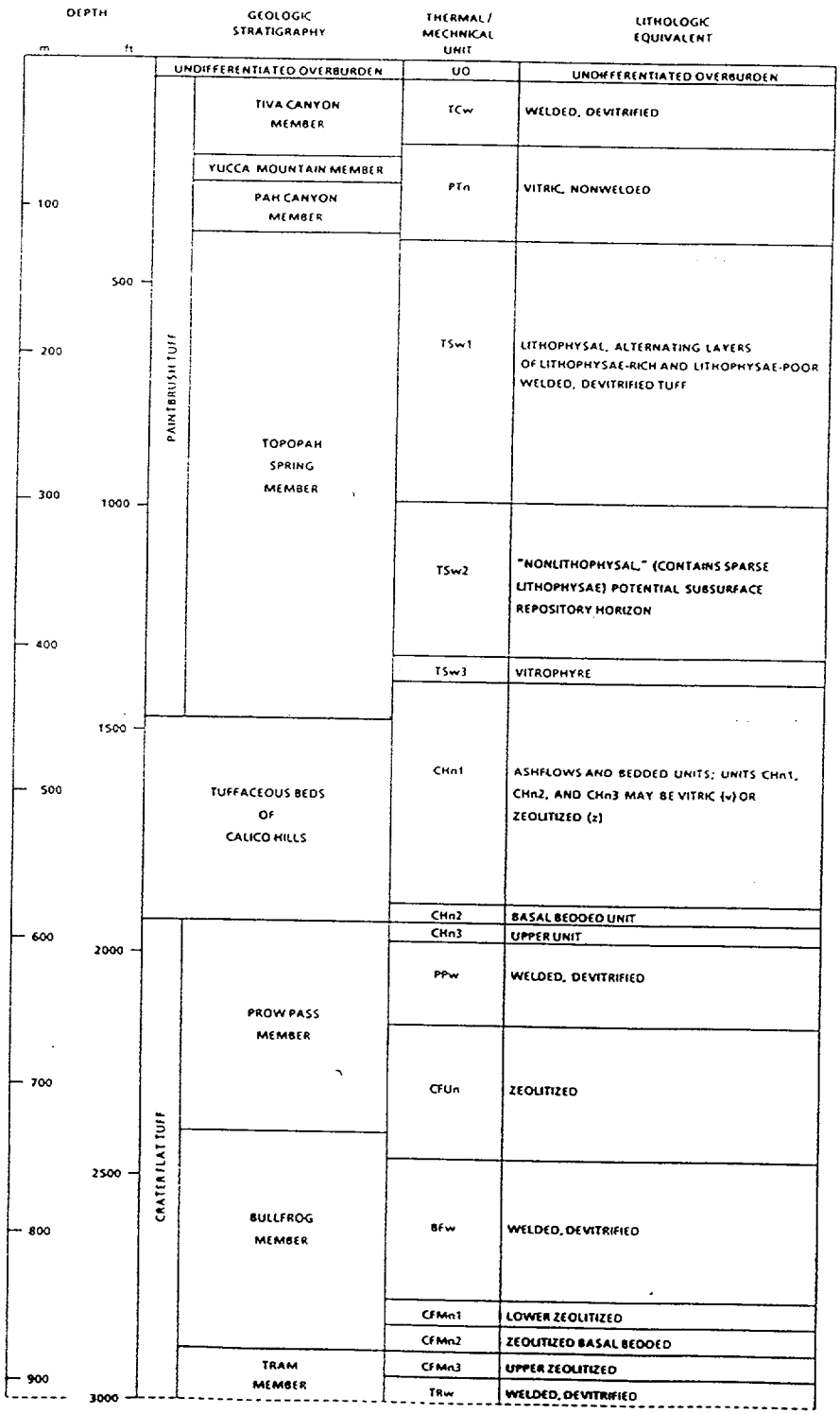
As mentioned earlier, an effort is underway to develop a geologic model of the proposed site. Thermal/mechanical cross sections including known fault traces in the Yucca Mountain will be represented in this model. This information will be incorporated into the RIB and will be used for the design of the ground support systems.

4.2 SITE SPECIFIC MATERIAL PROPERTIES

The formal geological stratigraphy and the thermal/mechanical stratigraphy for the units, which is typical of the region's geology at the site, are given in Figure 2 (Reference RIB Ver.4, Rev.4). Data in this report are grouped according to thermal/mechanical units rather than by formal stratigraphic divisions. Thermal/mechanical units have been defined such that each unit has bulk, thermal and mechanical units that may differ from those of adjacent units.

The Topopah Spring member as a formal stratigraphic unit contains all or portion of five thermal/mechanical units namely: PTn, TSw1, TSw2, TSw3, and CHn1. The intact rock mechanics properties that are used in this report are presented

FIGURE 2. Comparison Between the Thermal/Mechanical Stratigraphy and the Geologic Stratigraphy Typical of Regions Geology



Source: RIB Ver. 4, Rev. 4, Chap. 1, Sec. 1, Item 1, Page 3 of 6

in Table 1 (Reference RIB Ver.4, Rev.4). Wherever a range of values was given in the RIB for a certain property of a unit, the average value of that range was used in the analysis presented in this report. Data presented in Table 1, represent both the range and the average values used in the analyses for applicable properties.

The site specific geologic data and the understanding of the rock properties will evolve as more data is available from the site. In order to incorporate the most recent and best available data for these preliminary analyses, majority of the data are extracted from the RIB. A series of drillholes is recommended along the proposed access ramps in order to collect additional site specific data which is necessary for the proper design of the support systems for access ramps.

The rock mass is considered a composite of joints and intact rock. For a particular analyses certain properties are used depending on the model being used. In the analysis presented in this report only elastic and elasto-plastic models are considered. The rock mass properties that are used in elastic models do not explicitly account for the presence of joints. In future reports, intact rock and joint properties will be used in models that directly account for jointing. The data presented in Table 1 only contain properties which will be used for the linearly elastic and elasto-plastic models.

The site specific data for the application of empirical methods (CSIR and NGI) are addressed in Section 6.

Finally, numerous amount of data have been either collected on site or produced by engineering means during the life time of this project. Because of the differences in the interpretations or variability of the methods

TABLE 1. Material Properties (Reference: RIB Ver.4, Rev.4)**

Thermal/ Mechanical Unit	In Situ Density (Kg/m3)	Young's Modulus (GPa)	Poisson's Ratio	Cohesion (MPa)	Angle of Internal Friction (Deg.)	*Cohesion (MPa)	*Angle of Internal Friction (Deg.)
TCw	2200	20	0.1	34.2 ± 19.4	33.8 ± 15	34	34
PTn	1642	1.9	0.19	6.7 ± 3.1 4.9 ± 2.7	7.5 ± 3.4 5.4 ± 3	6	6.5
TSw1	2146	7.8	0.16	26.1 ± 10.6 31 ± 15.7 22.3 ± 8.2	27 ± 9.5 31.2 ± 12.9 23.6 ± 7.8	26	27
TSw2	2297	16.4	0.26	18.3 ± 5.2 37.8 ± 12.4	19.7 ± 5.2 36.5 ± 9	28	28
TSw3	2297	16.4	0.26	No Data	No Data	28	28
CHnlv	1972	7.9	0.17	11.5 ± 4.6 35.8 ± 9.3	12.6 ± 4.9 35 + 7	24	24

*Indicates values used in the analysis
**Chapter 1, Section 2, Item 5, Version 4, Rev.1, Page 4 of 4, Table 2, and
Chapter 1, Section 2, Item 10, Version 4, Rev. 1, Page 4 of 5, Table 2

used, discrepancies have been created in the representation of some of the parameters. This is not unusual considering the nature of the work which relies heavily on the personal interpretation and judgment. Moreover, the degree in which certain data have been subjected to quality assurance processes has varied through the years. Therefore, all existing data must be subjected to some sort of screening process. This task has already been accomplished for certain parameters but still many parameters remain to be scrutinized. For this purpose, RSN is in the process of developing a data base which first, will identify all the parameters that will be used for the design of the ground support systems during Title II. Then it will be determined what type of data is available for each parameter (i.e. site data, engineering design data, thermal and thermal stress data, seismic data, etc.). The methods and processes will be developed or recommended in order to produce values for the parameters which do not have any data available. The information in this data base will be requested to be entered into the RIB as they become available. This data base provides the means by which the activities of the Step 1 in the design process are monitored.

5.0 ANALYTICAL METHODS (STEP 2)

Analytical methods utilize the analyses of stresses and deformations around openings using numerical modeling techniques, such as the finite element and finite difference schemes. These methods are very useful in strata control because they enable comparisons of various underground excavation systems and serve as a relative design procedure. They are also useful in forecasting of the possible performance of the underground openings over extended periods of

time, where such aspects as the influence of temperature and/or time-dependent properties of rock (e.g. creep) are to be assessed.

However, analytical methods alone are not sufficient for the design of underground opening support systems. The output of numerical analyses are typically in the form of stresses, strains and definitions of yield zones. These results are usually difficult to interpret for real opening behavior. Nevertheless, the results of numerical analysis can be used effectively to adjust opening shape and layout of multiple openings and to assess ground behavior modes. The results are also used to aid in setting displacement criteria for monitoring actual performance, and more importantly, to provide input to empirical methods of rock support design and selection. Assessing the performance of the underground openings over extended period of time is an essential part of the ESF design which will be accomodated by implementation of numerical techniques.

5.1 STRESS ANALYSIS

In this report, FLAC (Fast Lograngian Analysis of Continua) computer software is used to perform the preliminary analyses to determine the theoretical stresses around the opening of a particular shape. FLAC is an explicit finite difference code which simulates the behavior of structures built of soil, rock, or other materials which may undergo plastic flow when their yield limit is reached.

For the ESF design, the shape and size of the access ramps are predetermined (Ref. 16) in which circular opening of 7.62 meter (25 foot)

diameter is produced by means of a Tunnel Boring Machine (TBM). The MTA drift opening sizes and shapes are determined for most part by considering combined functions of the drifts which is dictated by the testers. Beyond that, the openings will be shaped and oriented to minimize stress concentrations at critical locations and to reduce the possibility of structurally controlled failure.

For the preliminary analyses, three different opening configurations, Figure 3, have been analyzed to determine the theoretical stresses around the opening and in order to assess the suitability of the shape. Figures 4a, 4b, 5a, 5b, 6a and 6b show the grid used for each opening shape. The results of the analyses are presented in Figures 7a through 11b. The analyses simulate excavation of the opening in the gravity stressed rock medium using elastic and elasto-plastic stress-strain models. The zones where stress exceeds strength are determined by comparison of the rock mass strength and stress at points in the rock surrounding the opening. These zones introduce a yield that represents the point of departure from elastic behavior. In other words, with elasto-plastic modeling it is possible to predict inelastic deformation. The results of these analyses will be used as a guide for opening design and will provide additional information to complement empirical methods.

For the initial stresses, the vertical stress σ_v at a point is given by

$$\sigma_v = - \rho g h \ , \qquad (1)$$

where h is the depth of the point relative to surface and ρ is the average density of the rock mass. Assuming that lateral displacements are prevented,

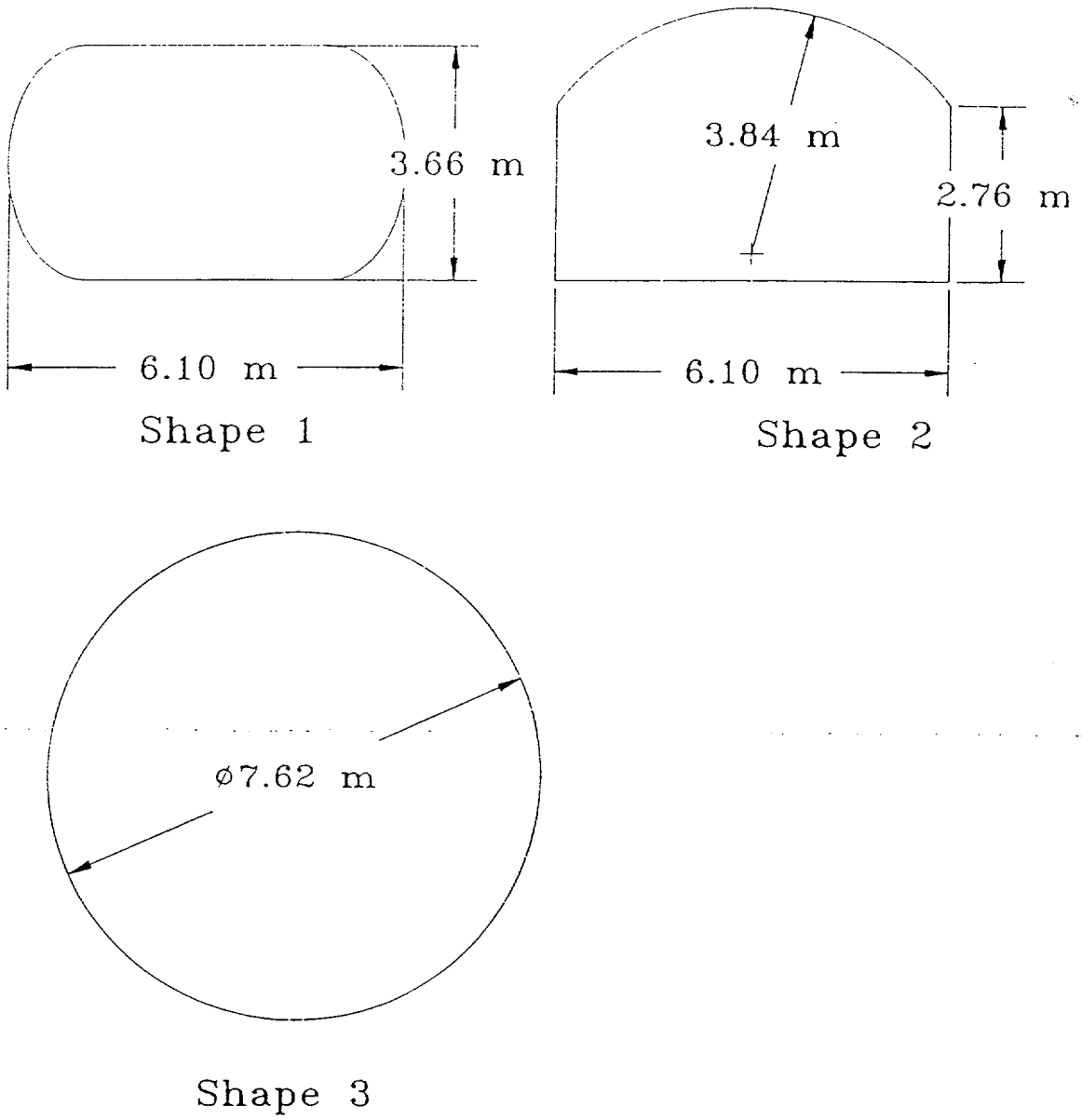


Fig. 3 Opening configurations considered in the analysis

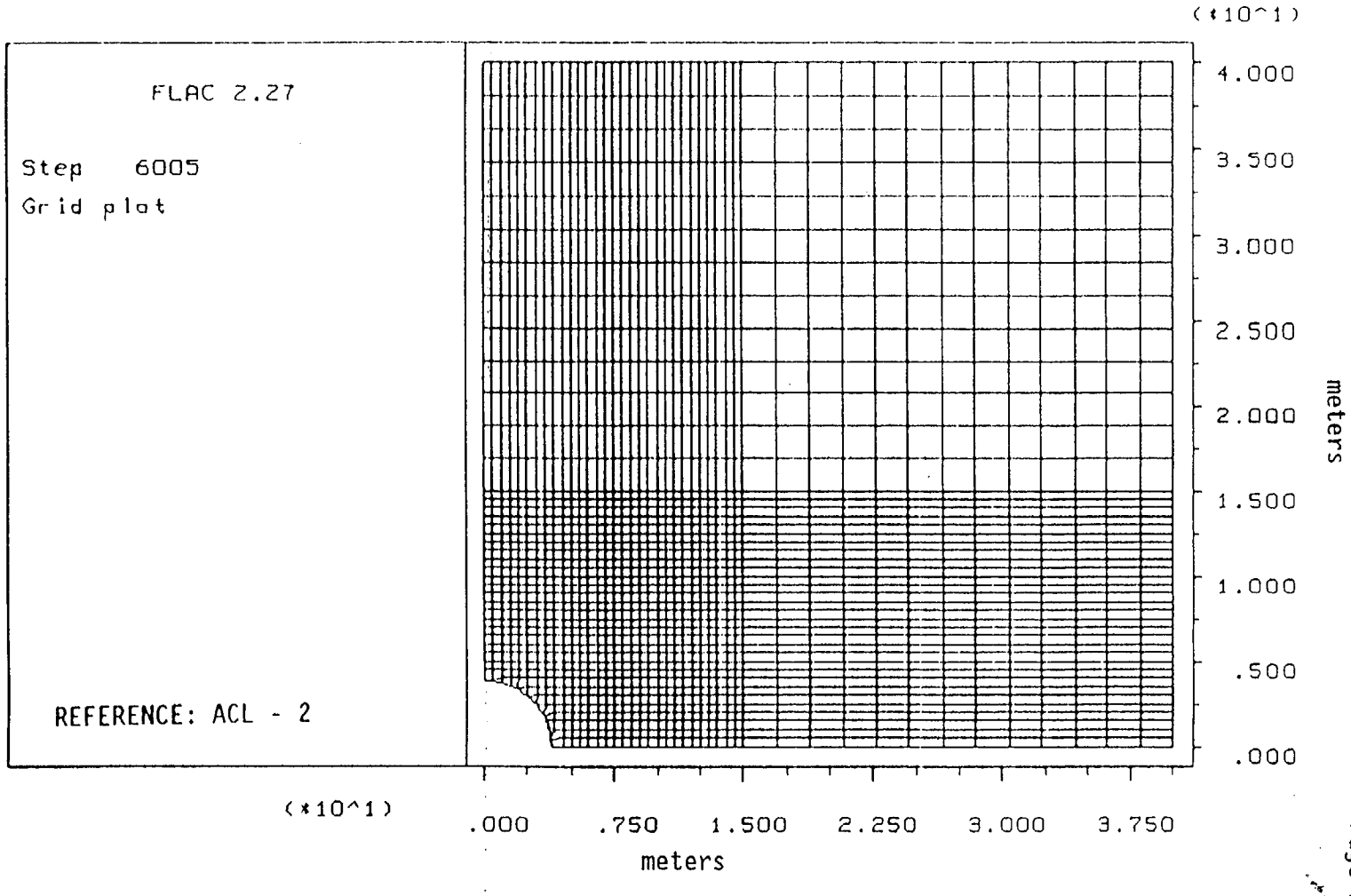


FIGURE 4a. Grid Used for Circular Opening

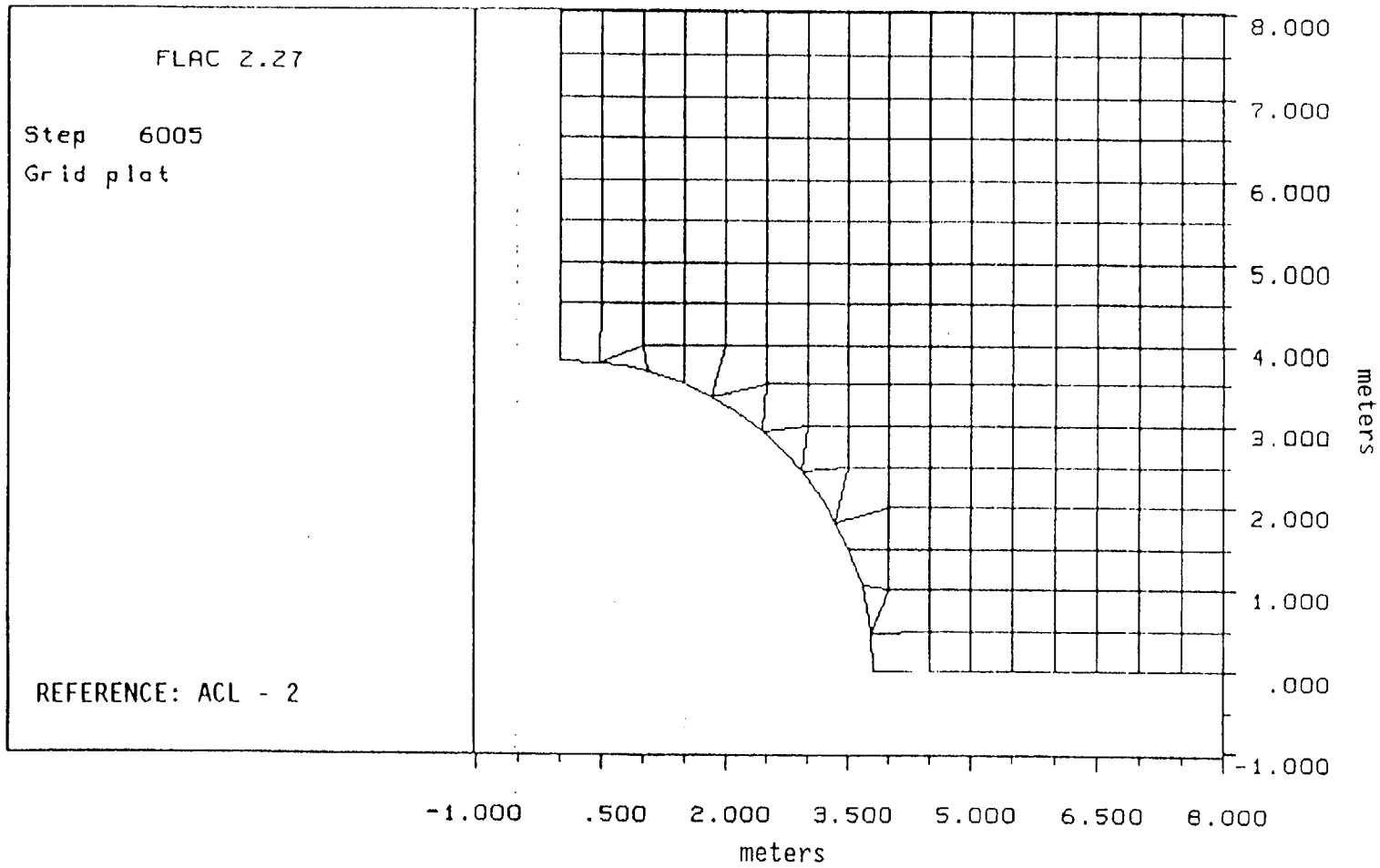


FIGURE 4b. Close-up View of Circular Opening Discretization

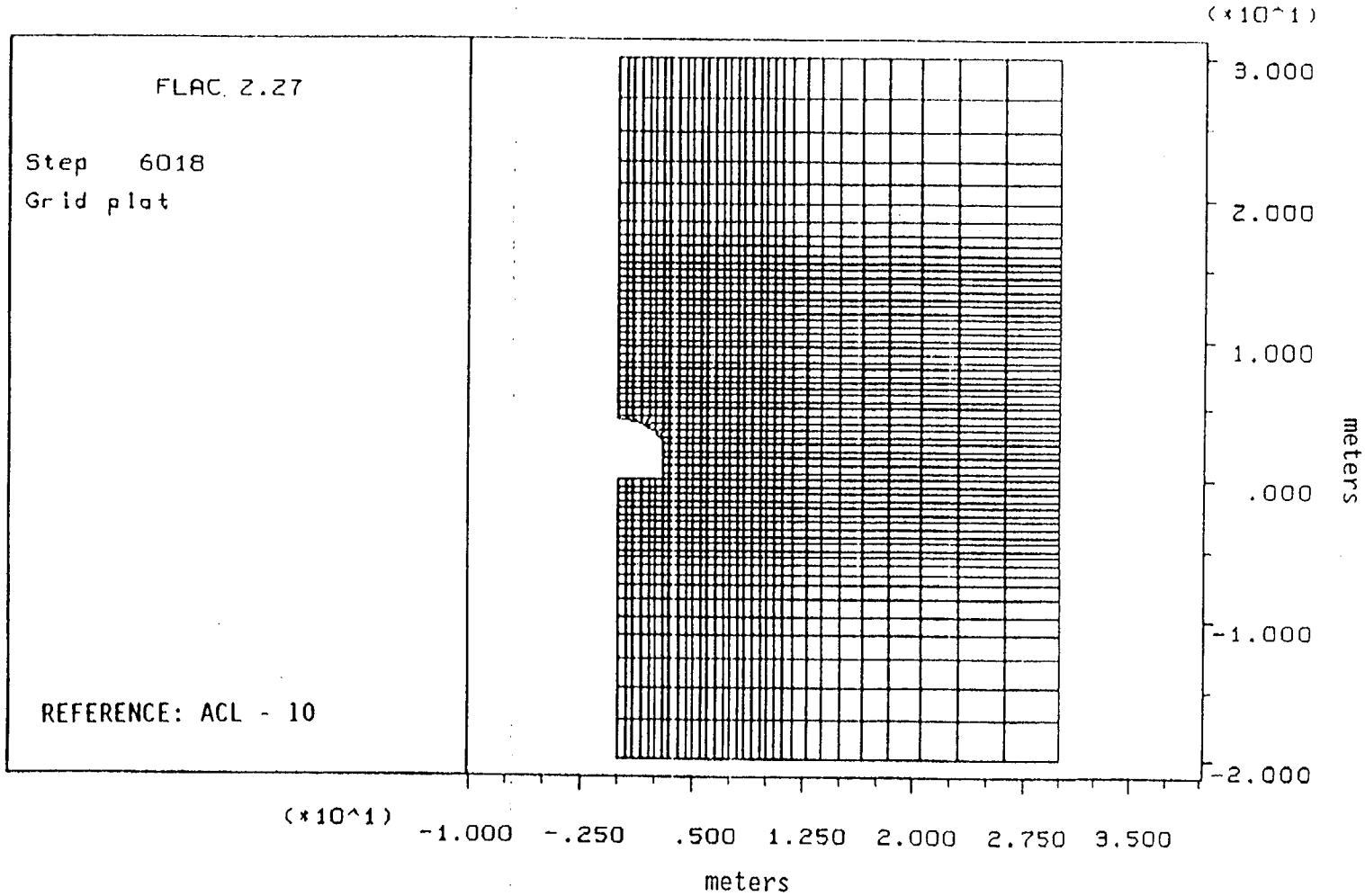


FIGURE 5a. Grid Used for Horseshoe Shape Opening

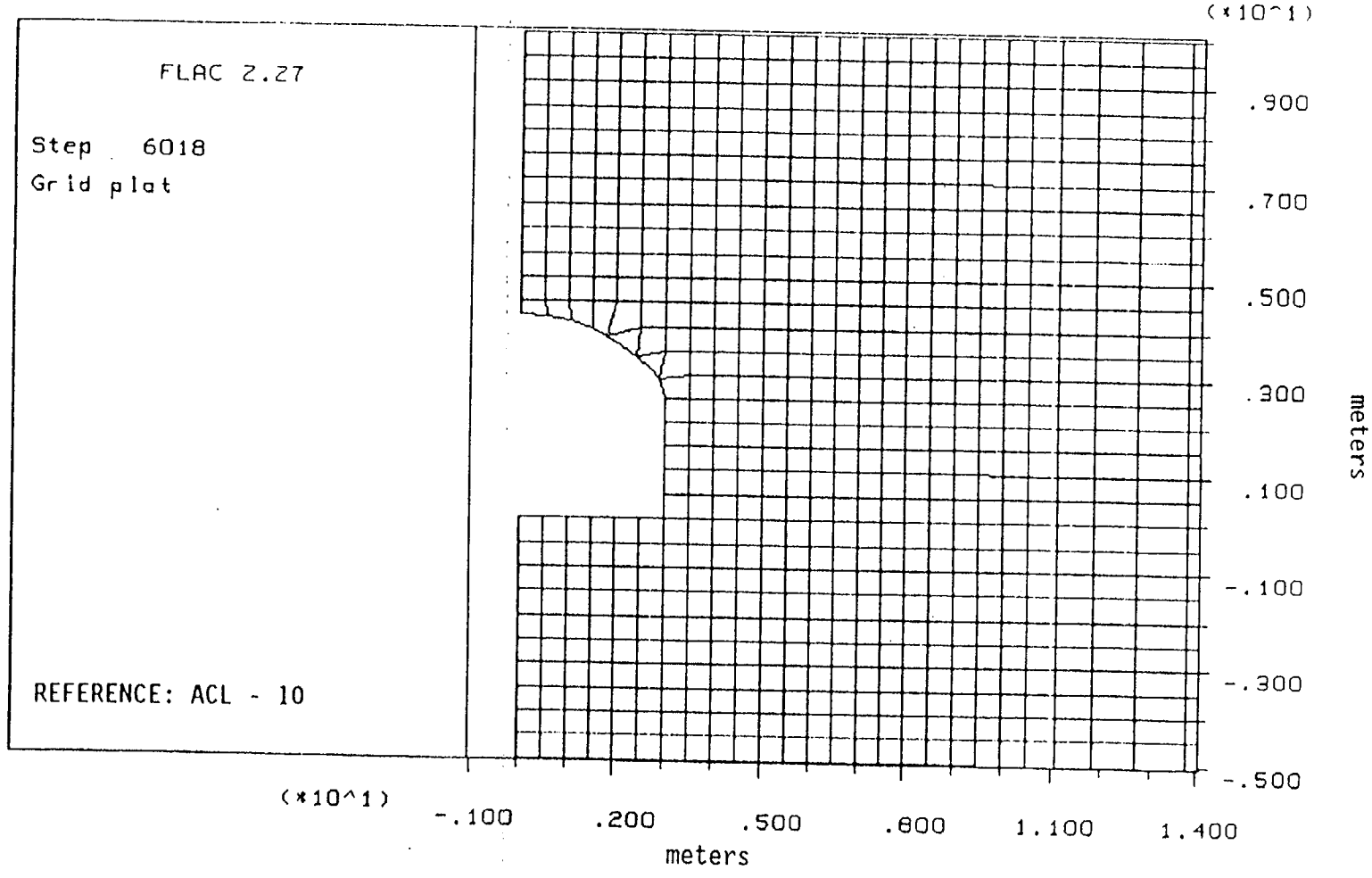


FIGURE 5b. Close-up View of Horseshoe Opening Discretization

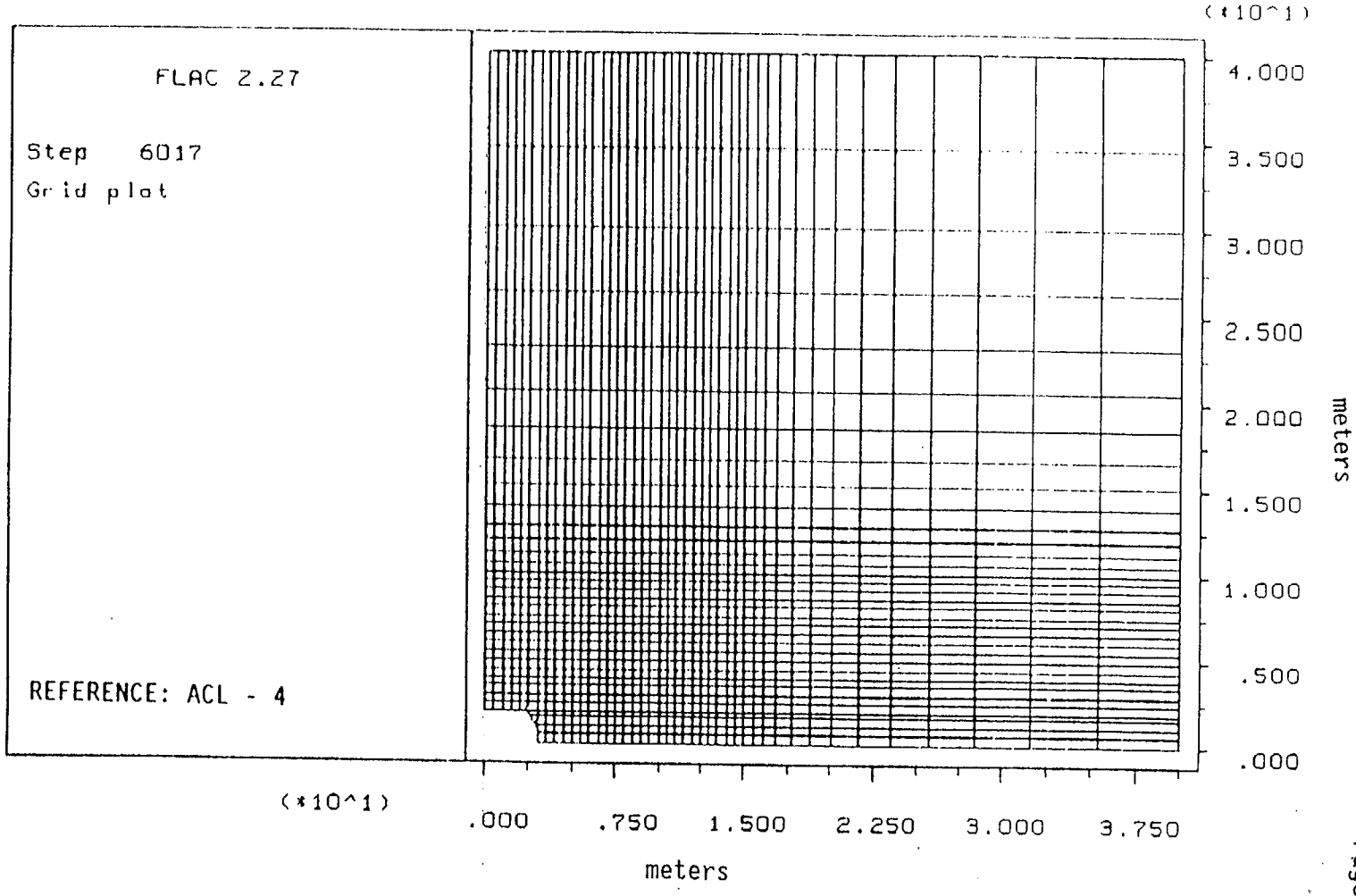


FIGURE 6a. Grid Used for Rectangular (with Concave Ribs) Shape Opening

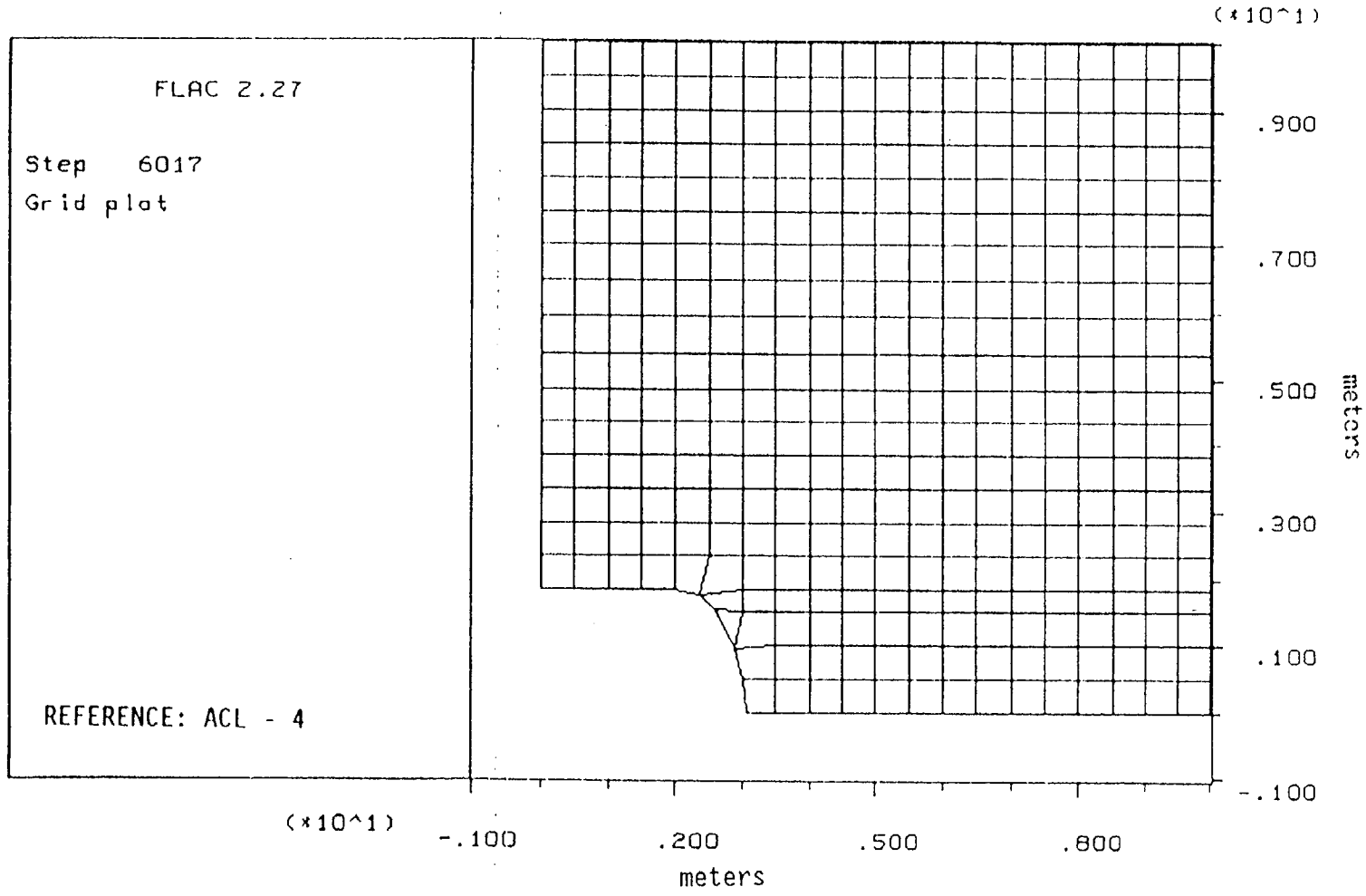


FIGURE 6b. Close-up View of Rectangular (with Concave Ribs) Opening Discretization

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

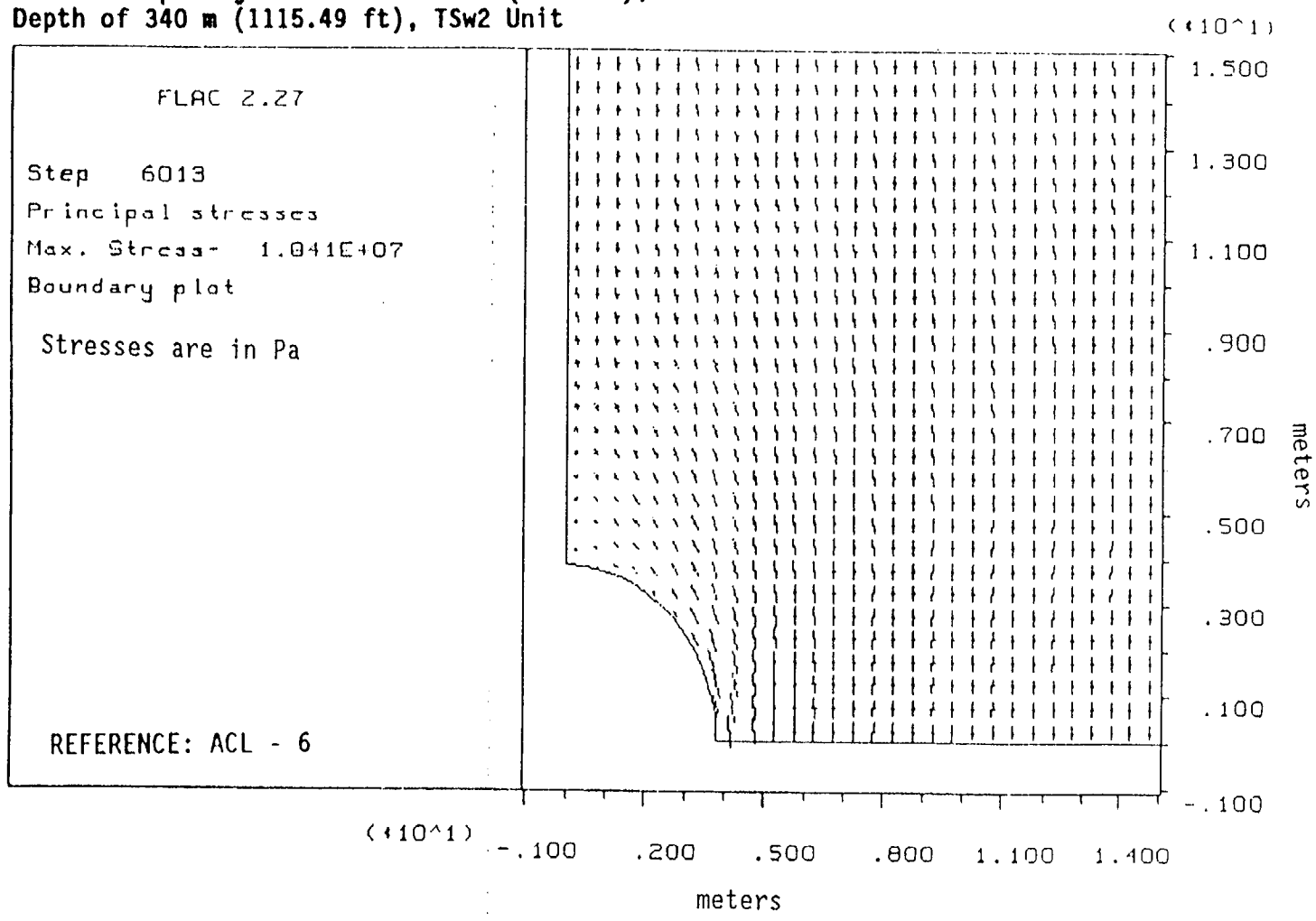


FIGURE 7a. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

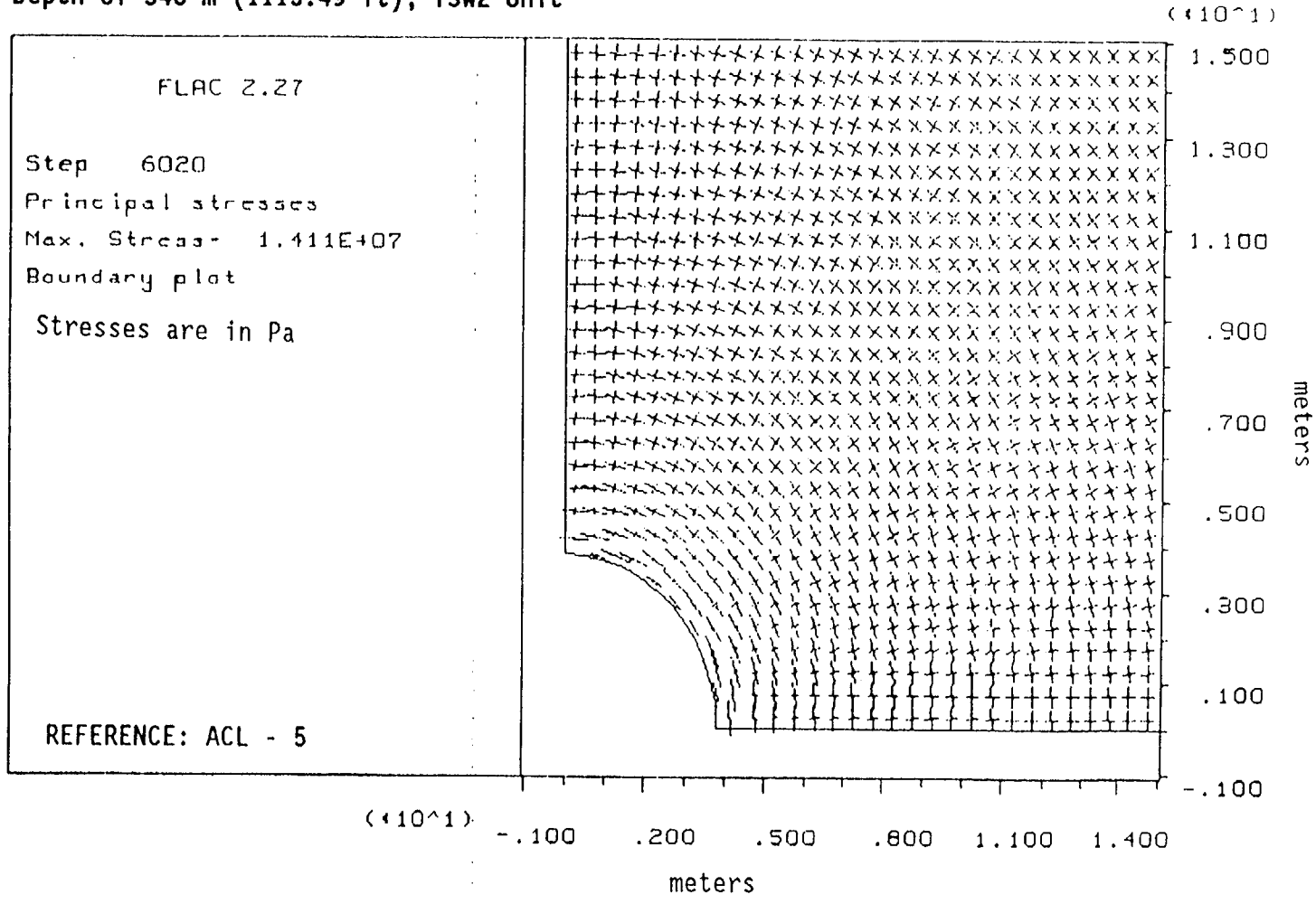


FIGURE 7b. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

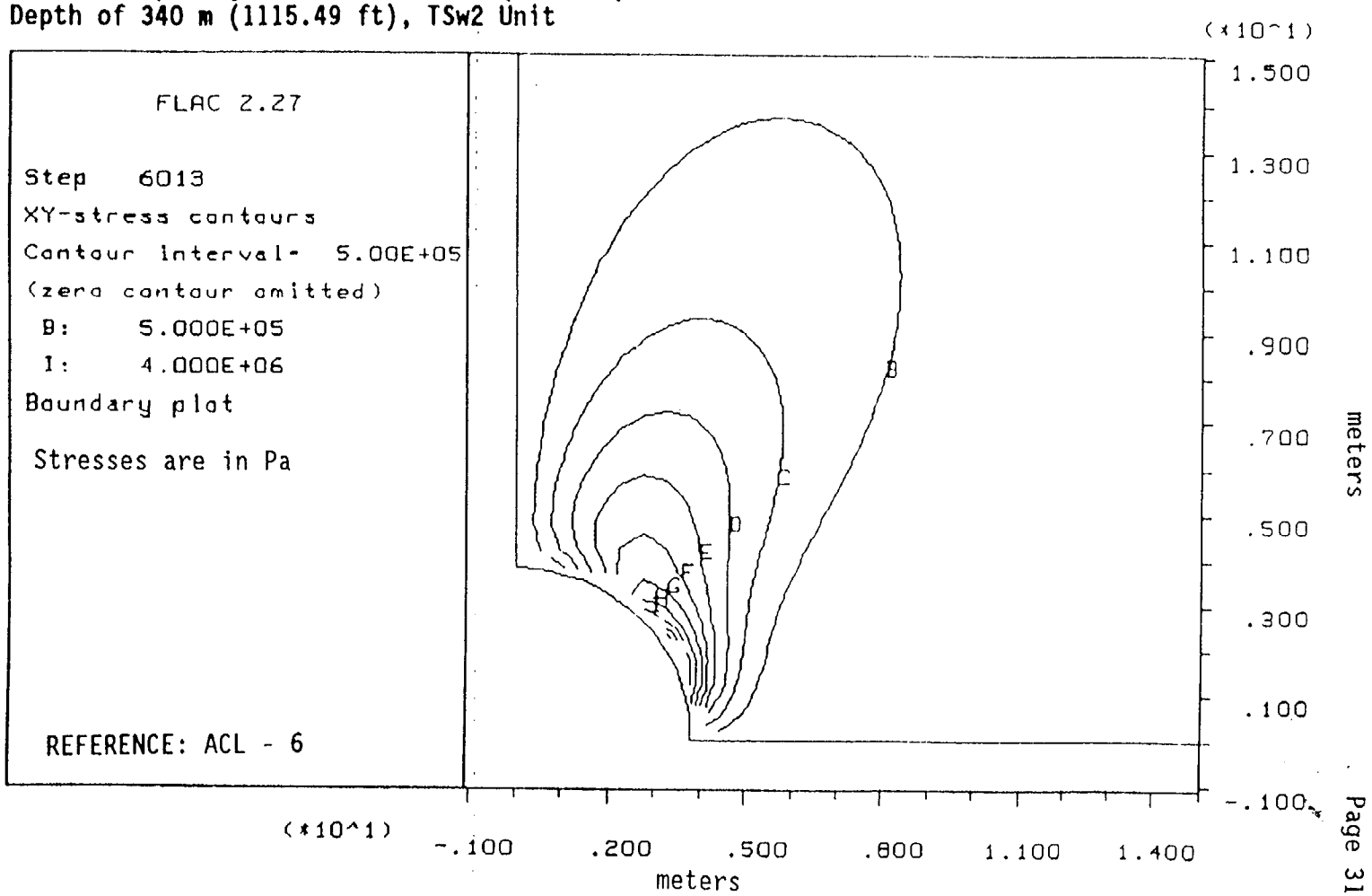


FIGURE 7c. Shear Stress Contours for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

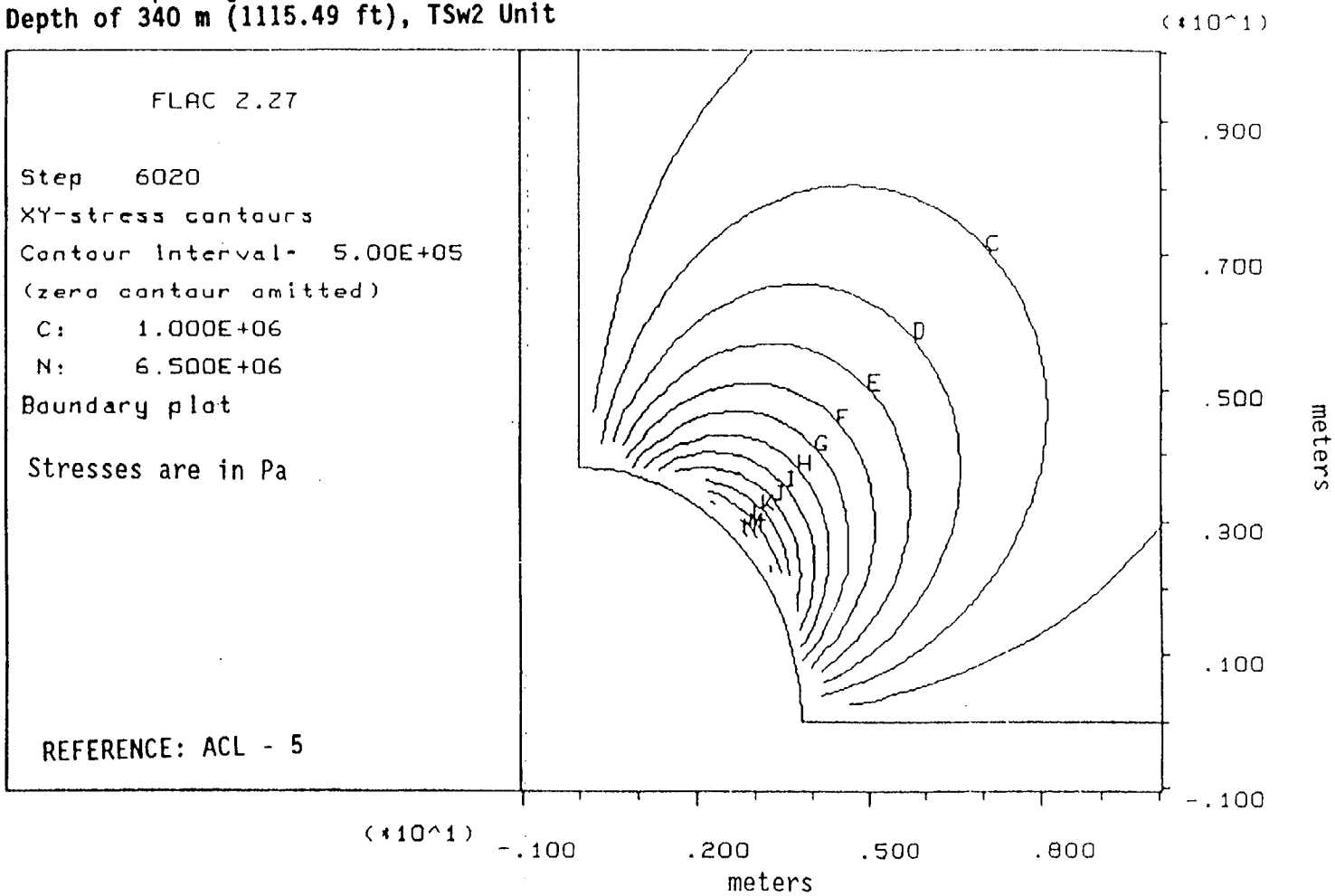


FIGURE 7d. Shear Stress Contours for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

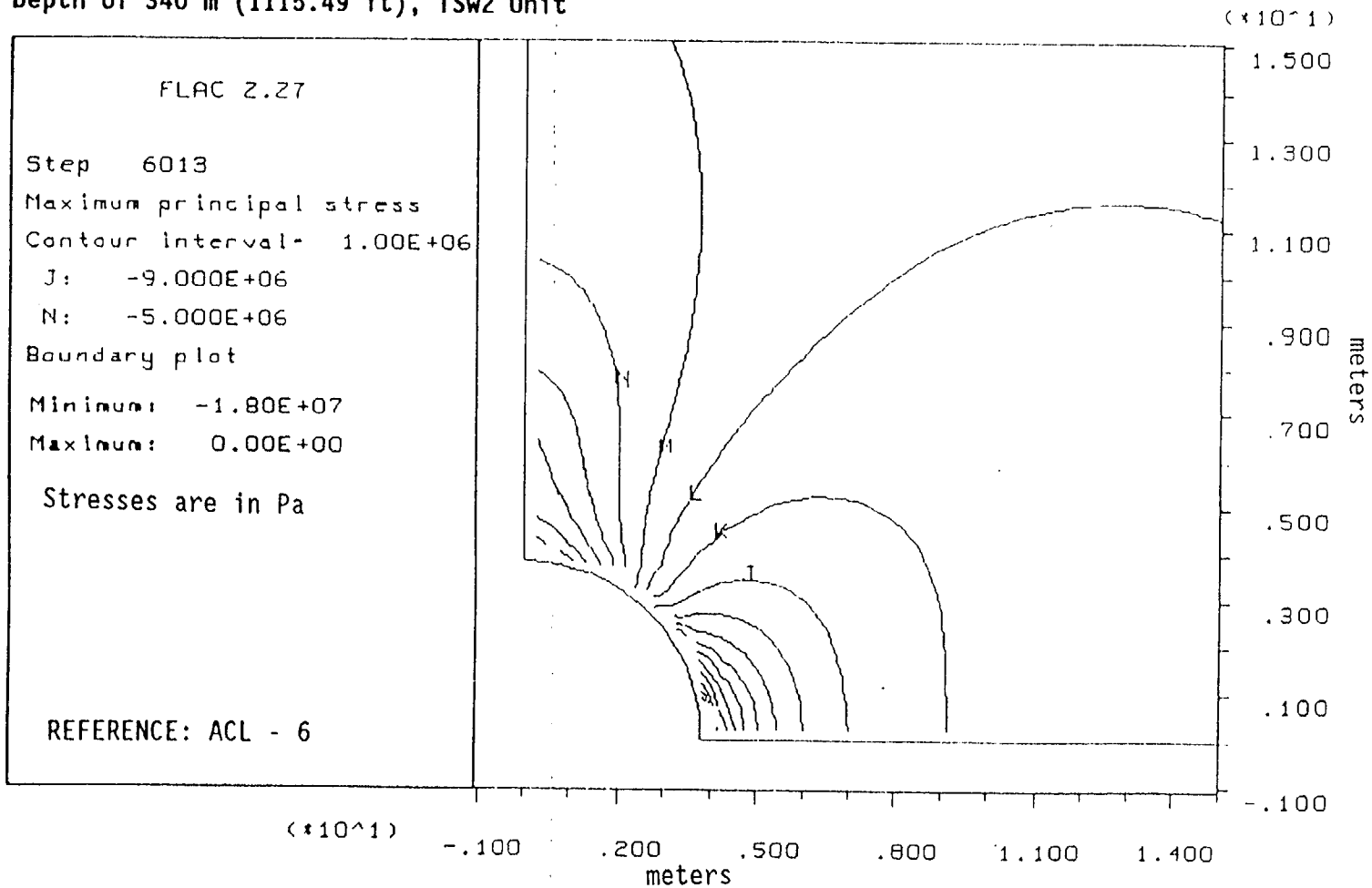


FIGURE 7e. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

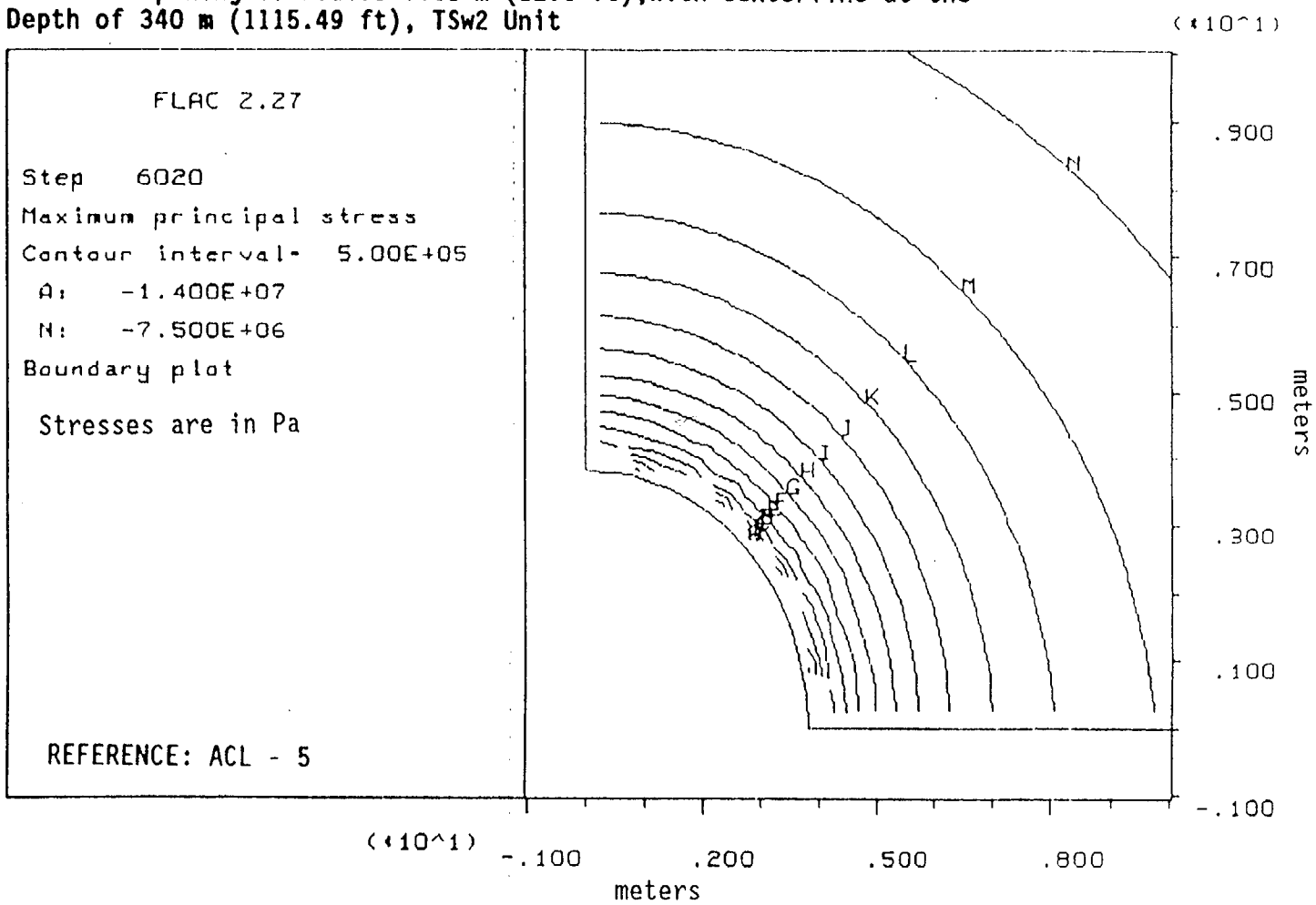


FIGURE 7f. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

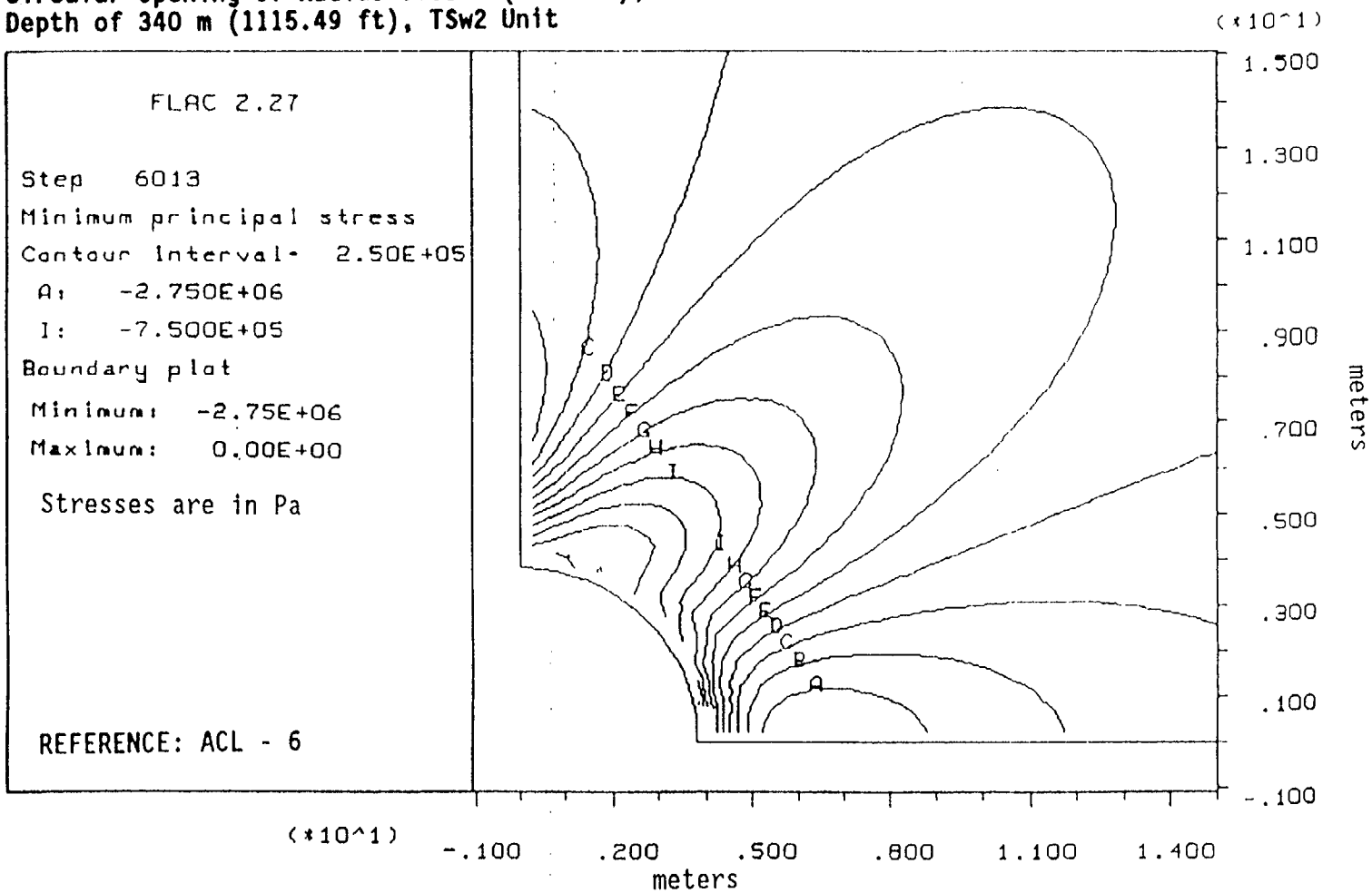


FIGURE 7g. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 340 m (1115.49 ft), TSw2 Unit

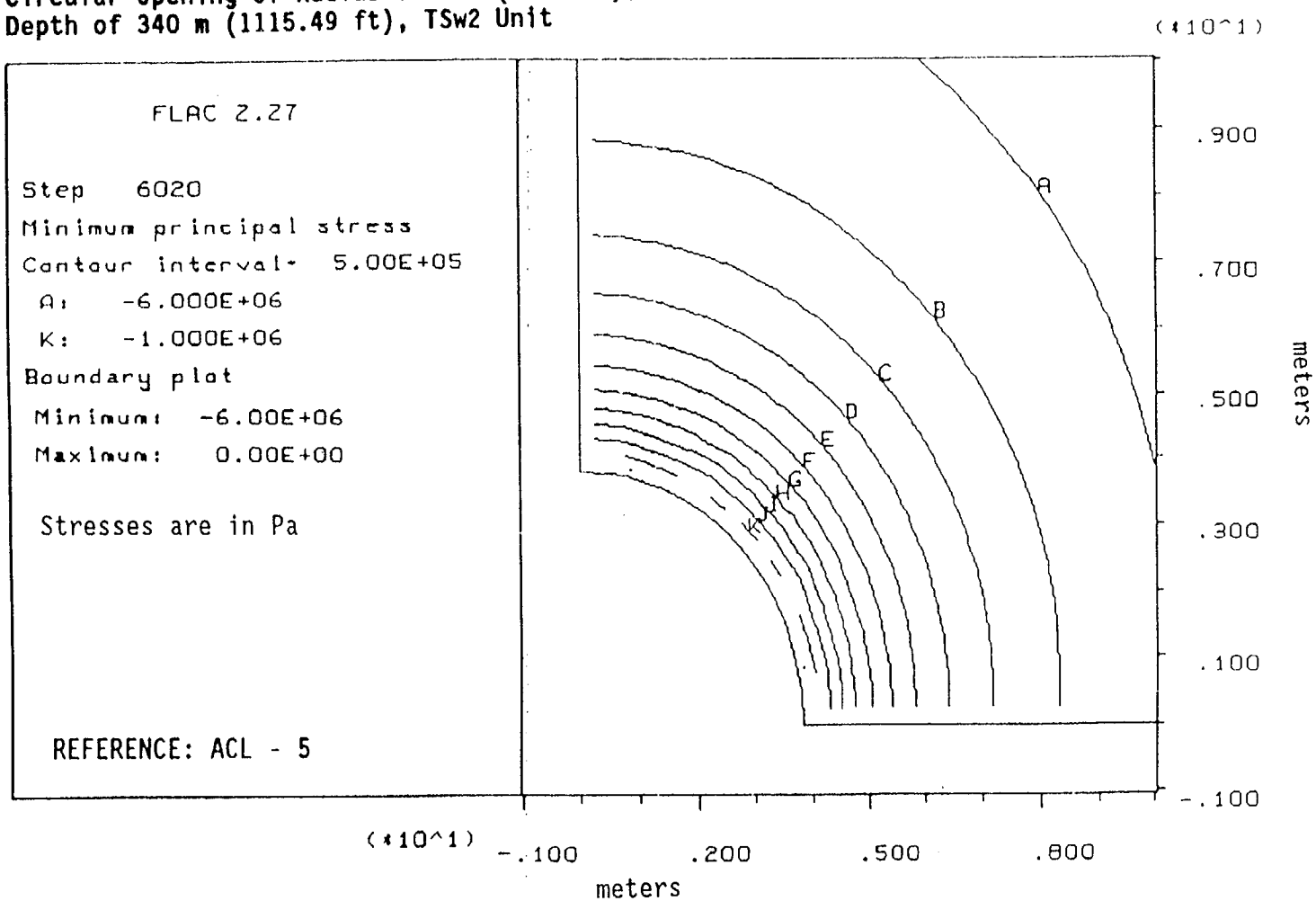


FIGURE 7h. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

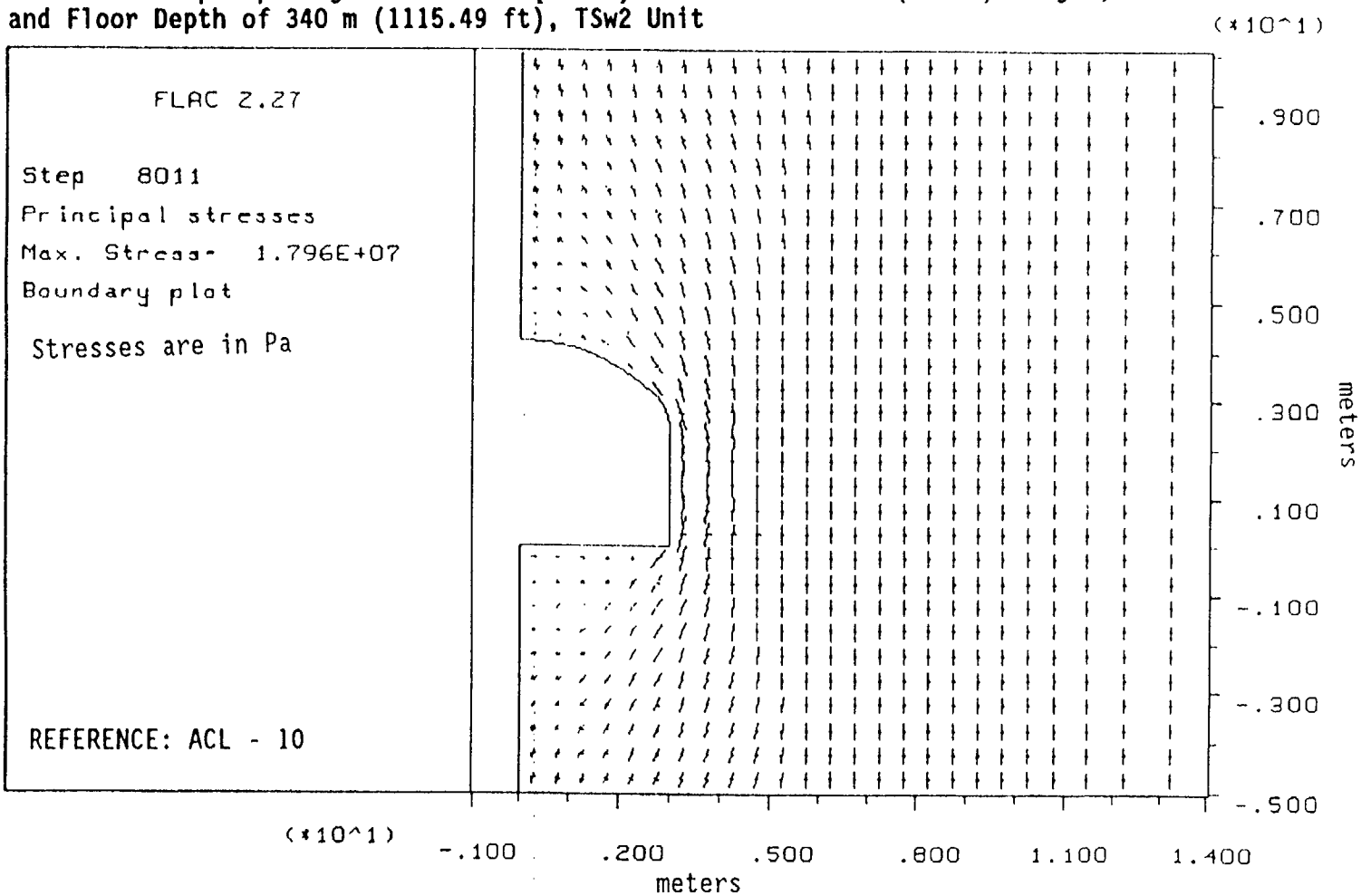


FIGURE 8a. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

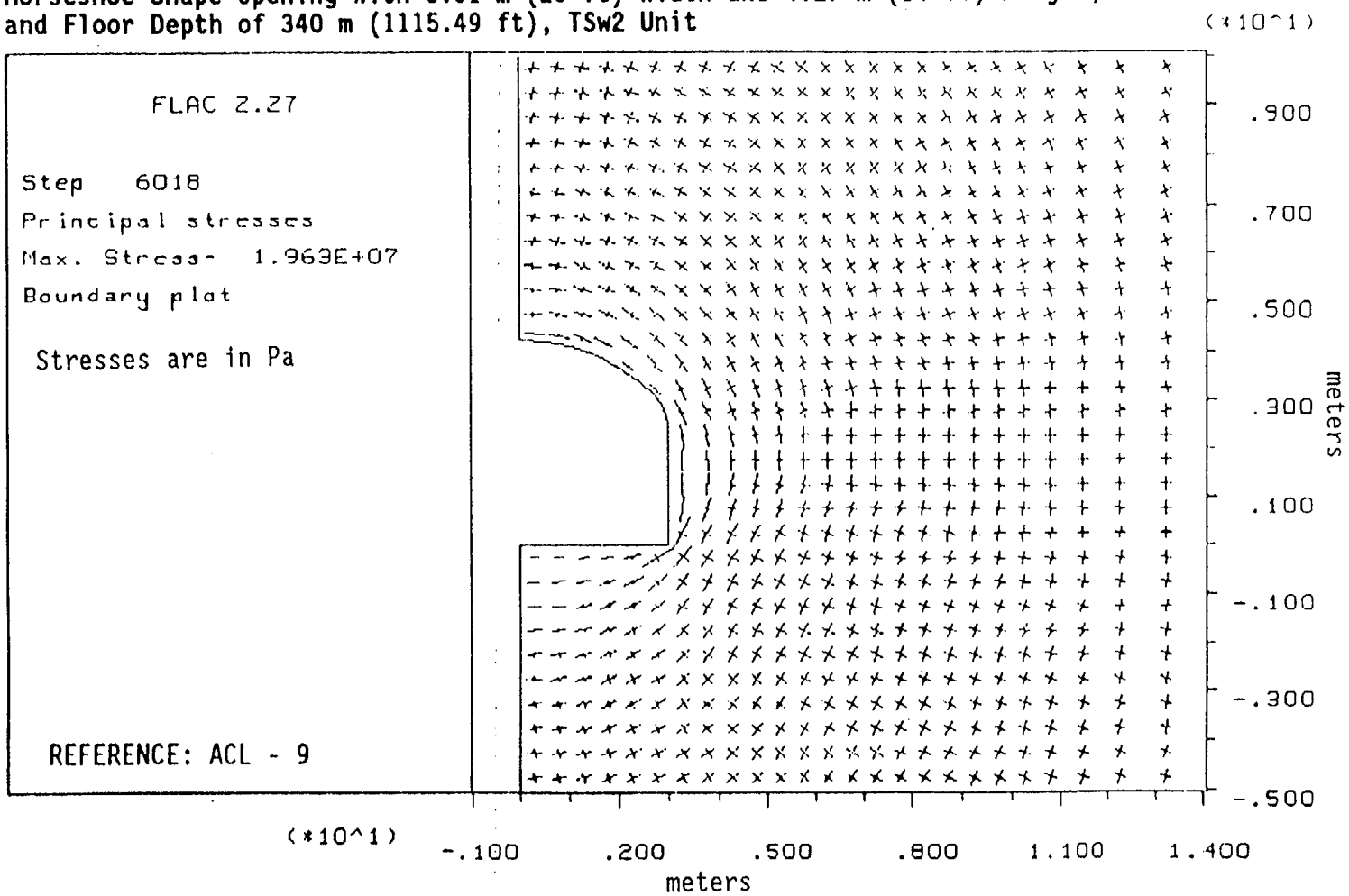


FIGURE 8b. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

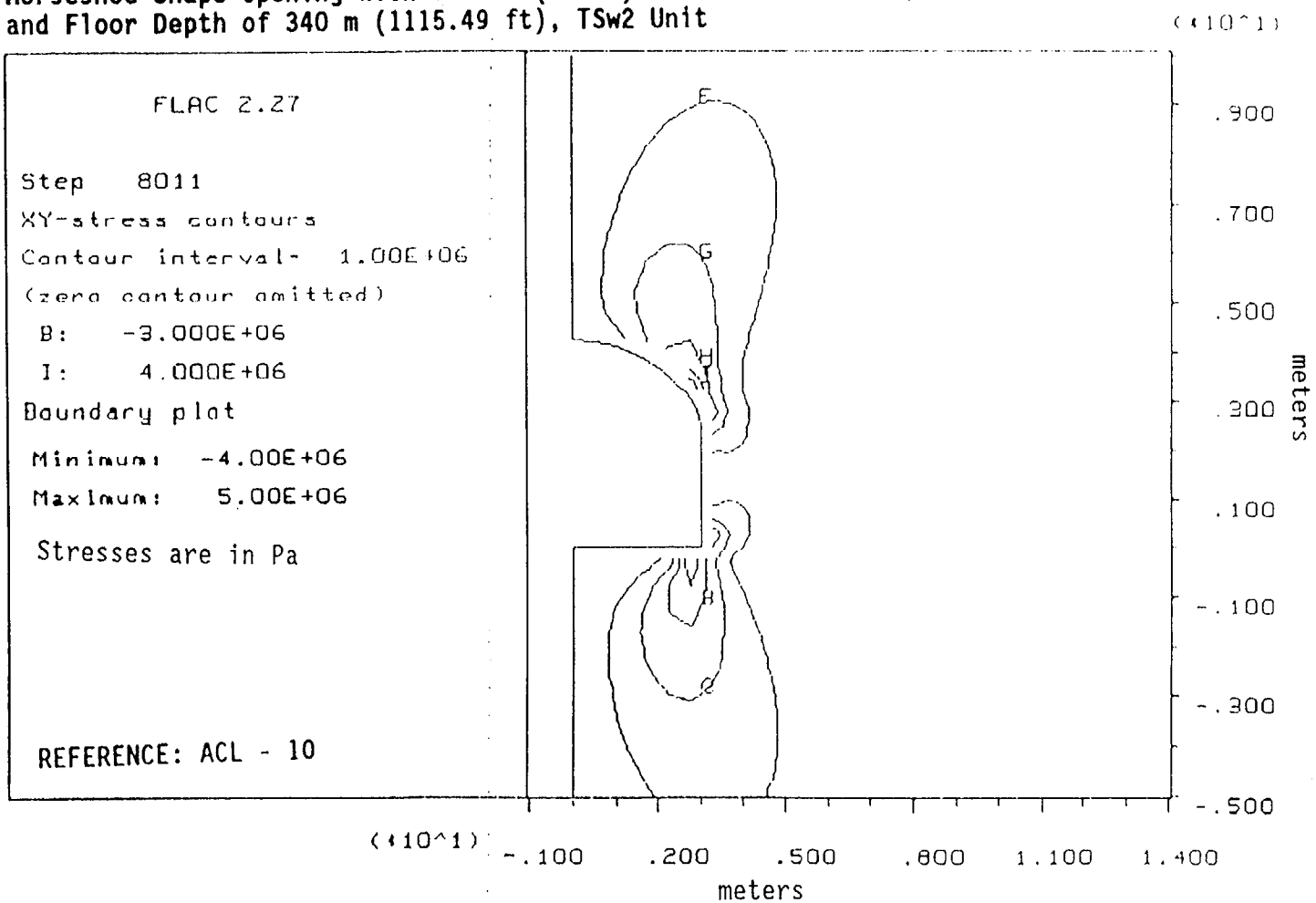


FIGURE 8c. Shear Stress Contours for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

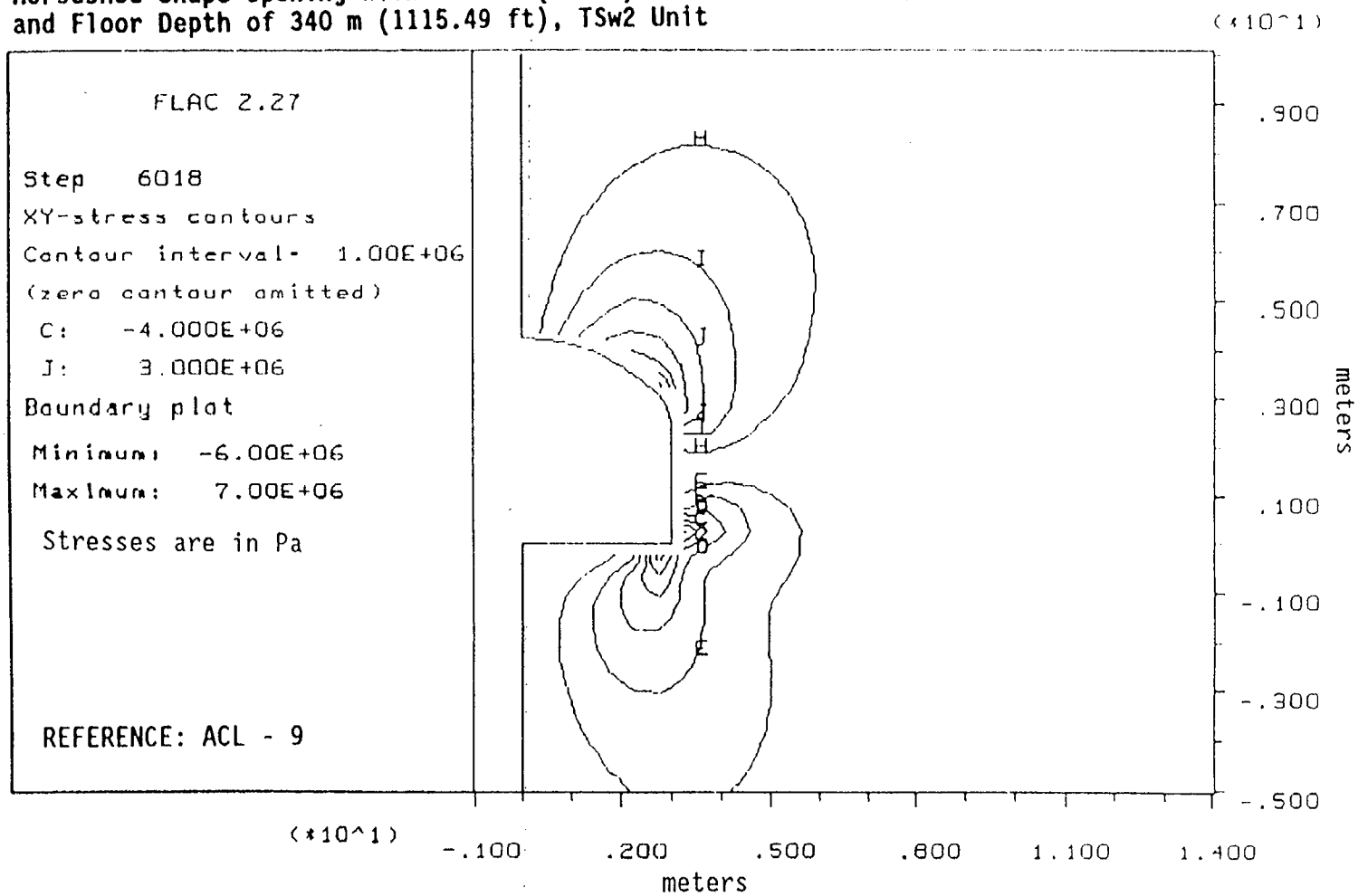


FIGURE 8d. Shear Stress Contours for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

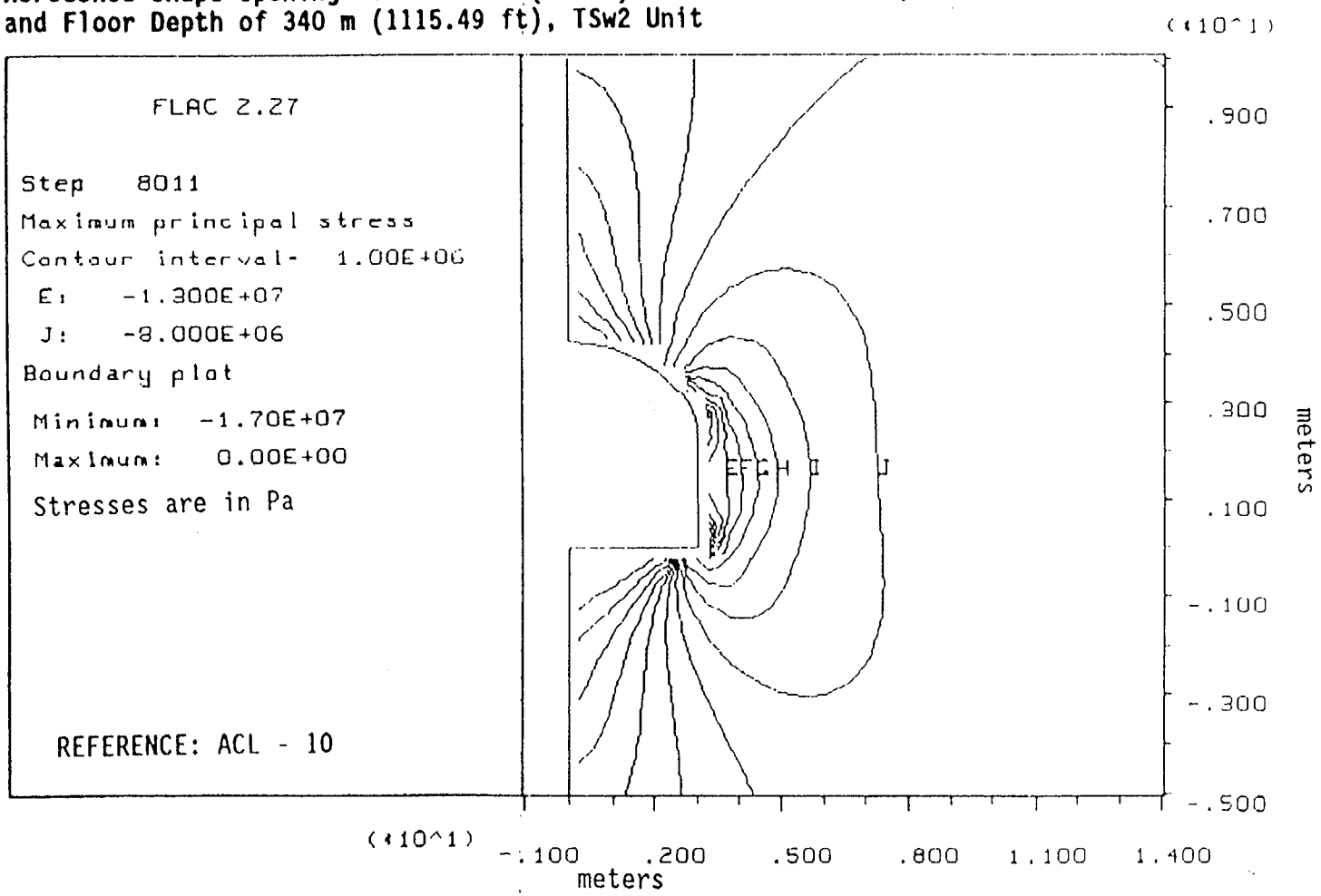


FIGURE 8e. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

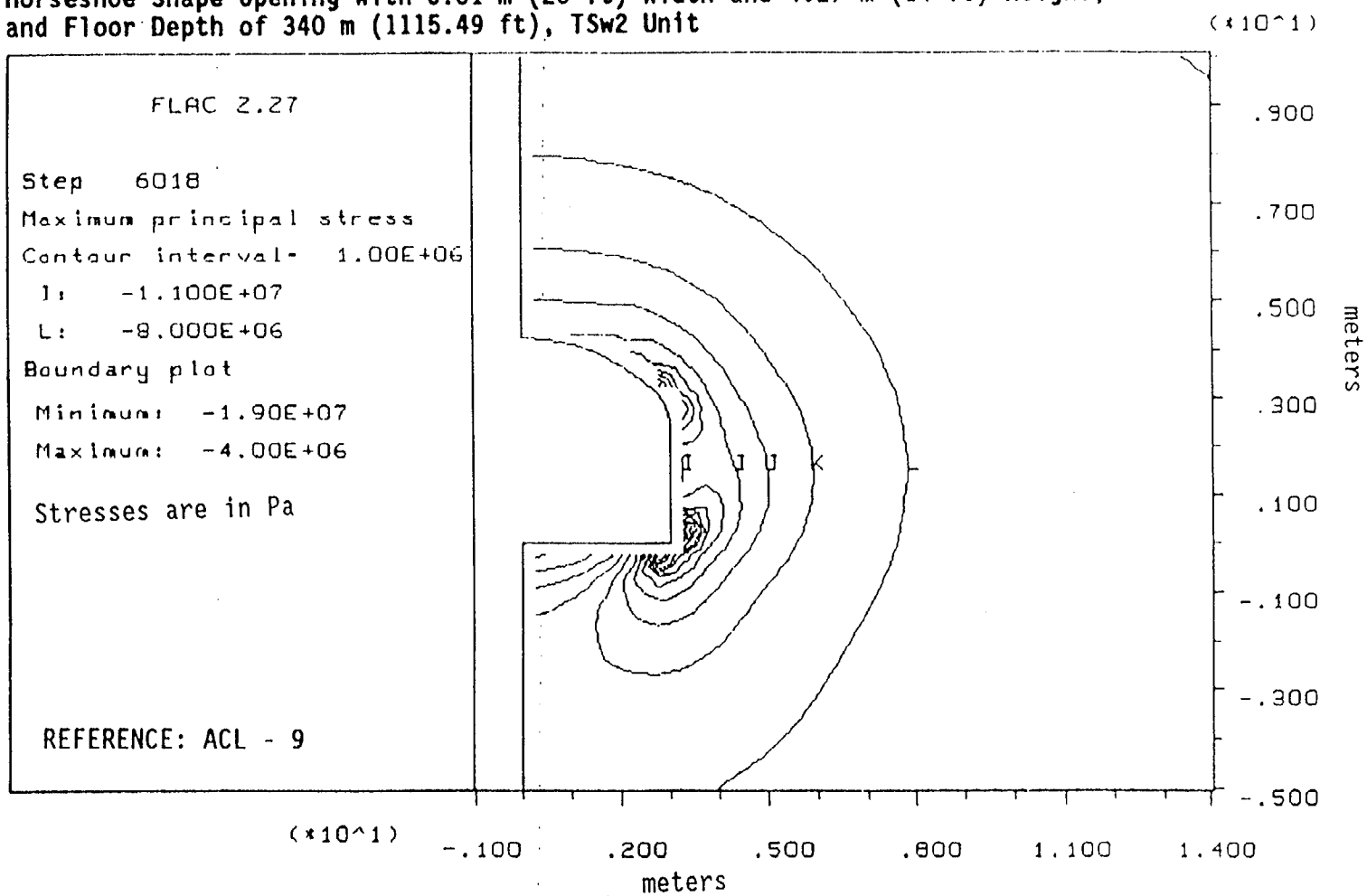


FIGURE 8f. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

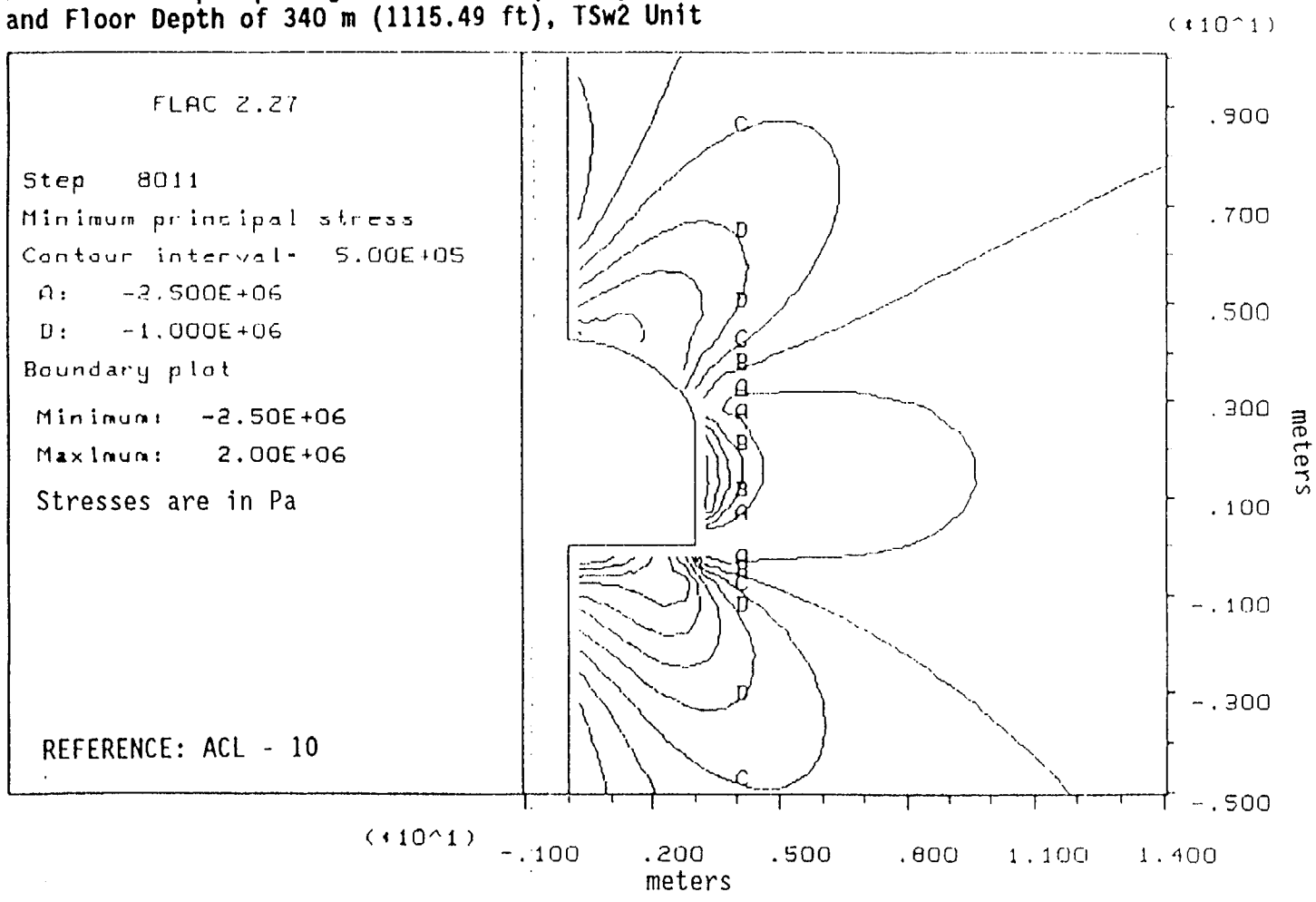


FIGURE 8g. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Horseshoe Shape Opening with 6.01 m (20 ft) Width and 4.27 m (14 ft) Height, and Floor Depth of 340 m (1115.49 ft), TSw2 Unit

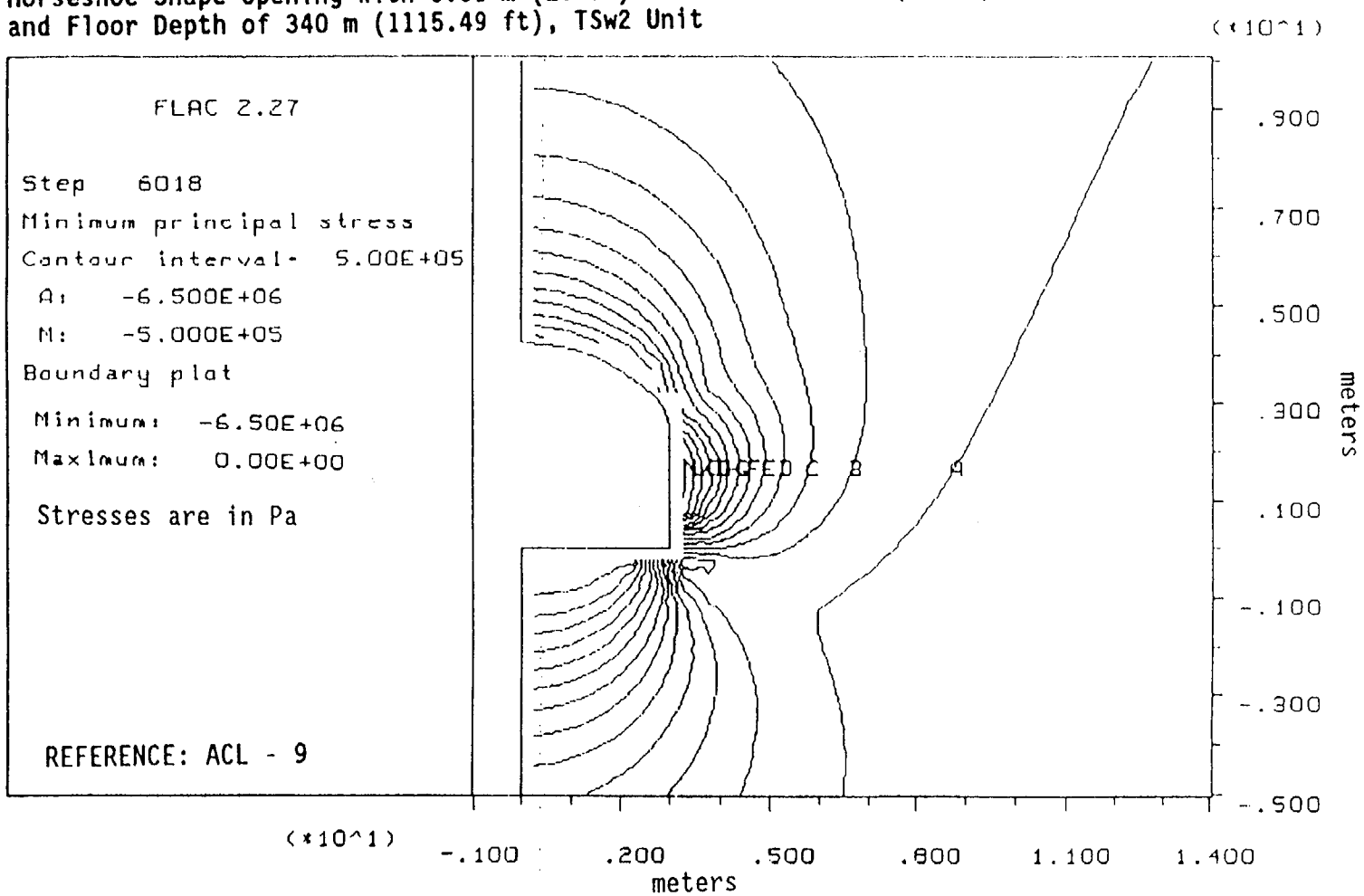


FIGURE 8h. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

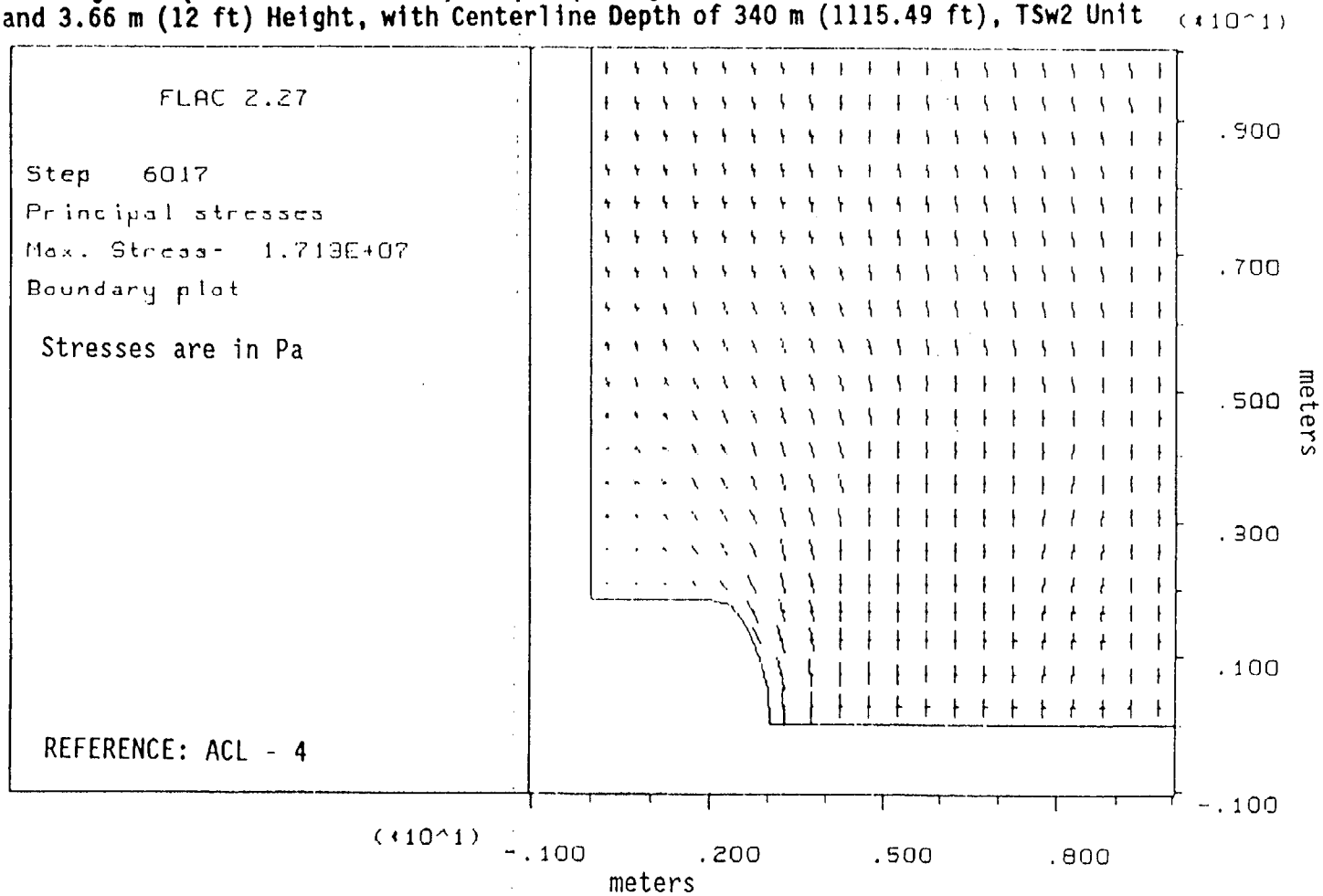


FIGURE 9a. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

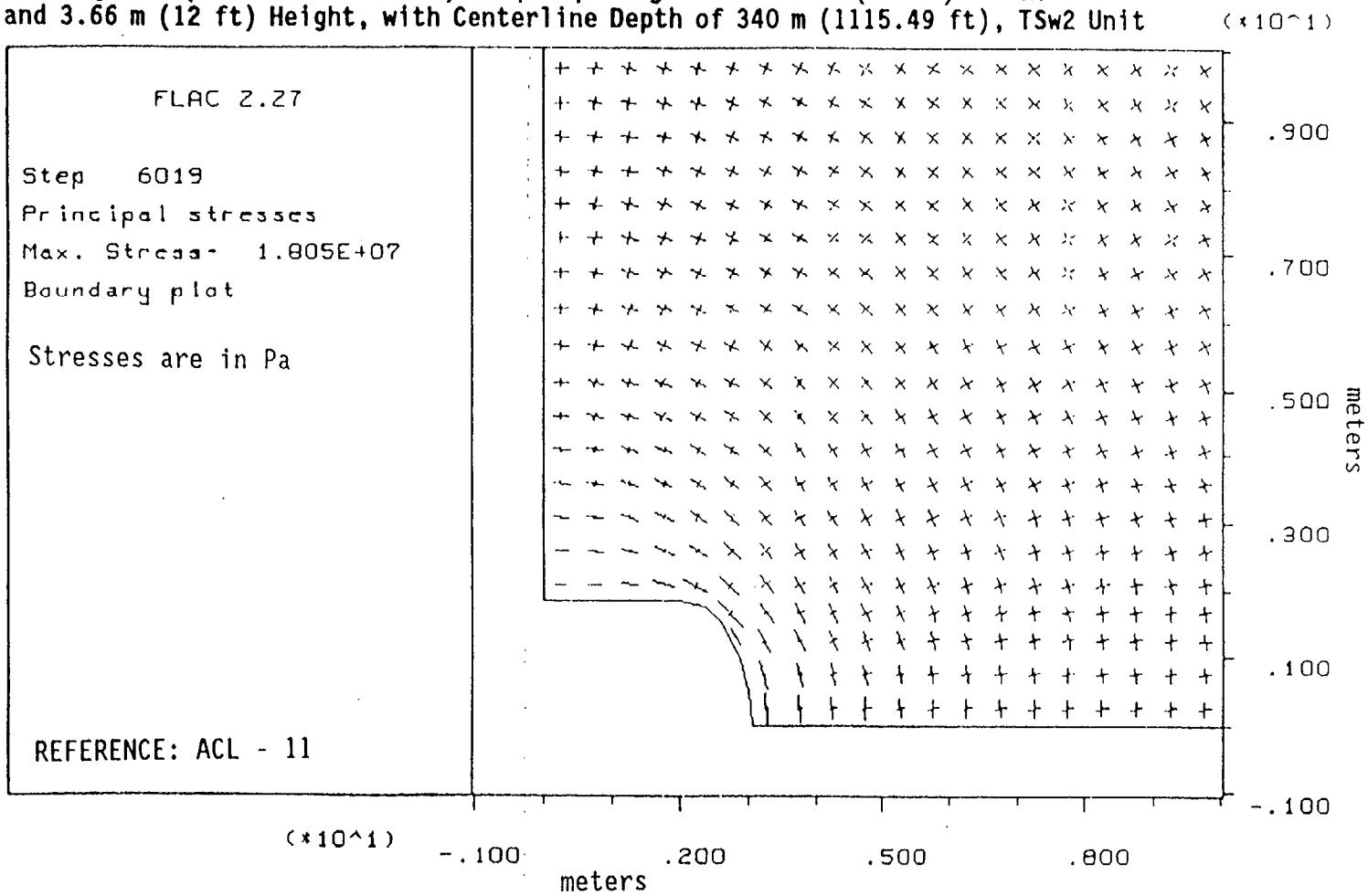


FIGURE 9b. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

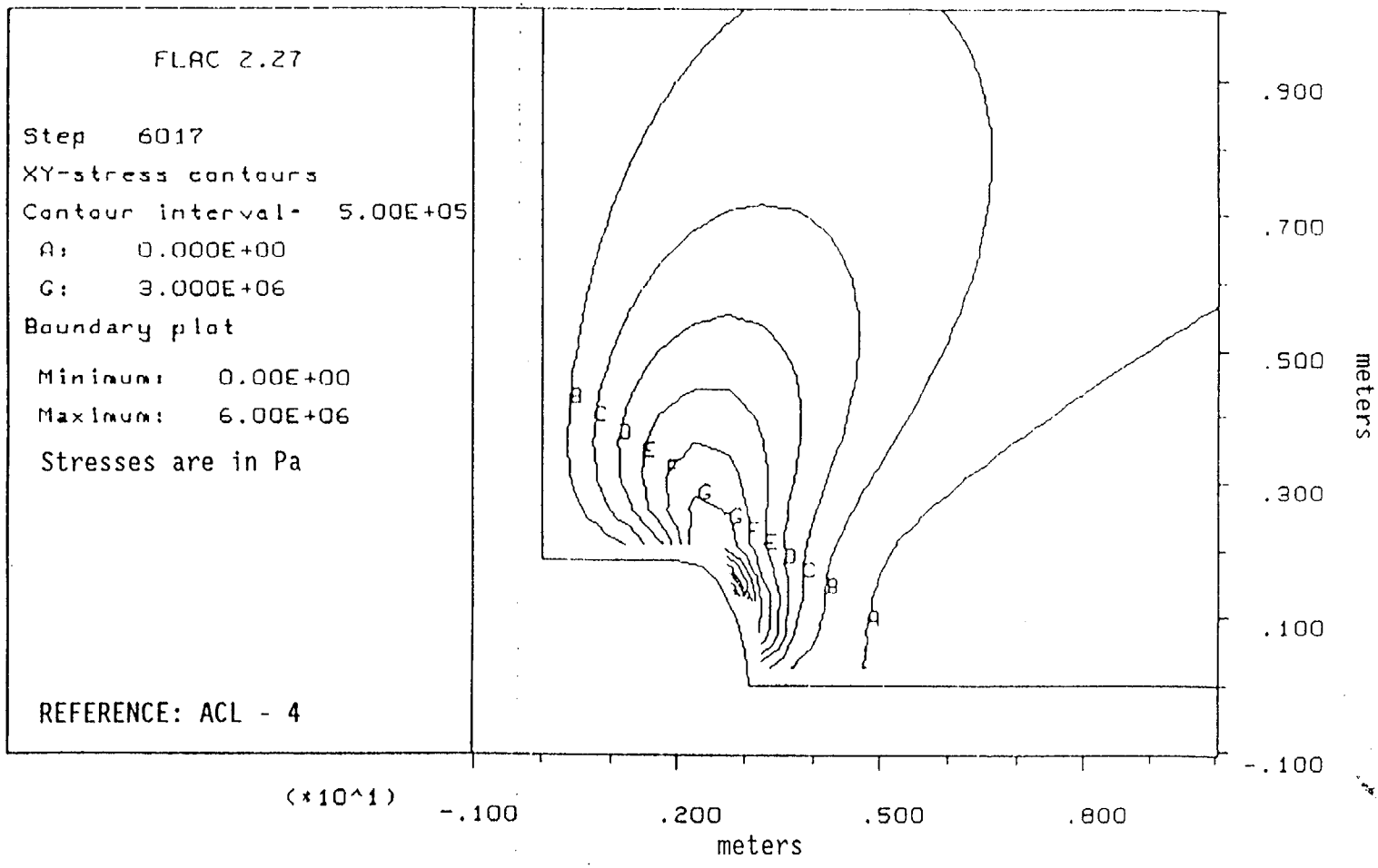


FIGURE 9c. Shear Stress Contours for Elasto-Plastic Model, Case 1 (σ_x/σ_y = 0.3), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

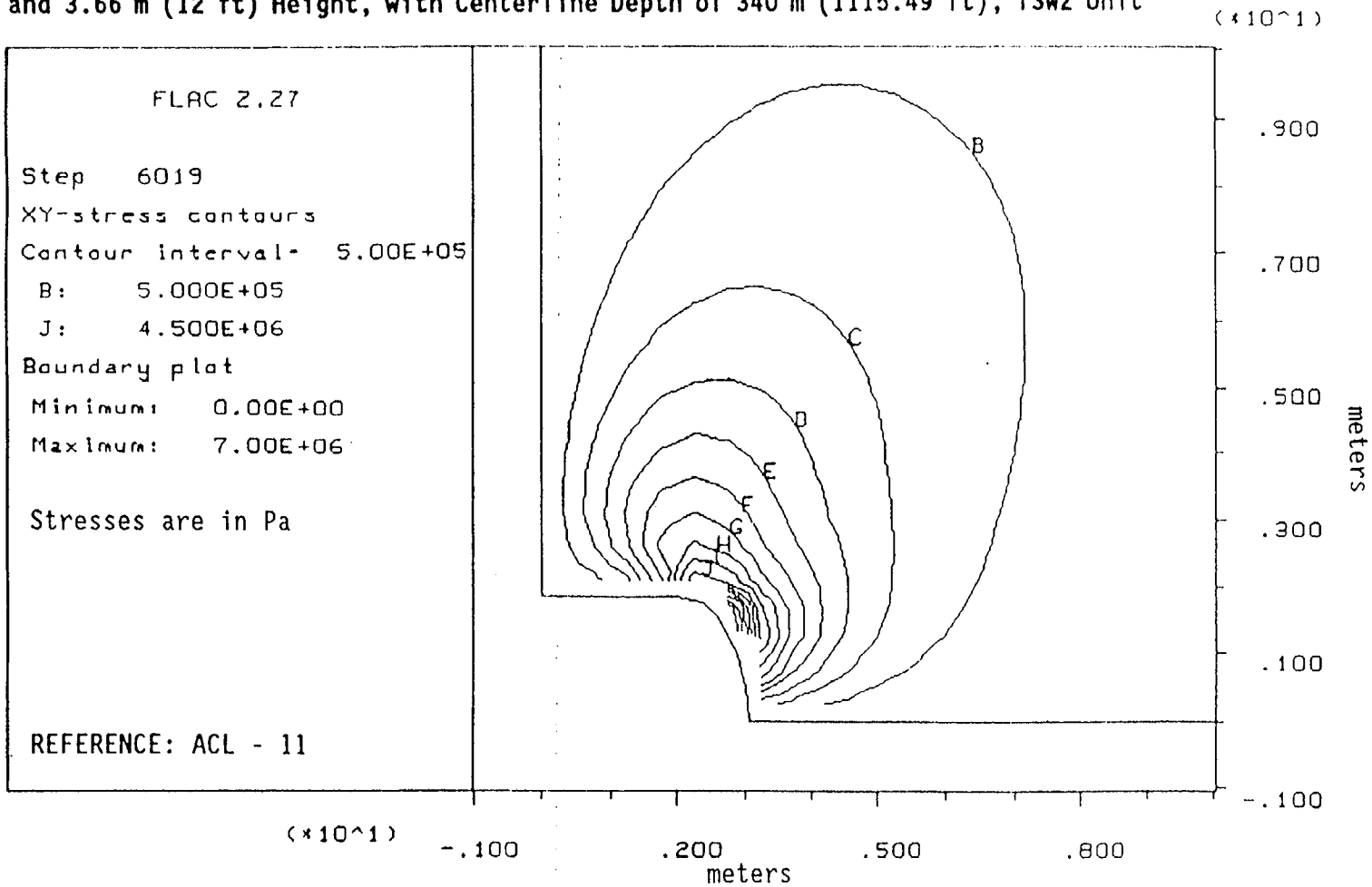


FIGURE 9d. Shear Stress Contours for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

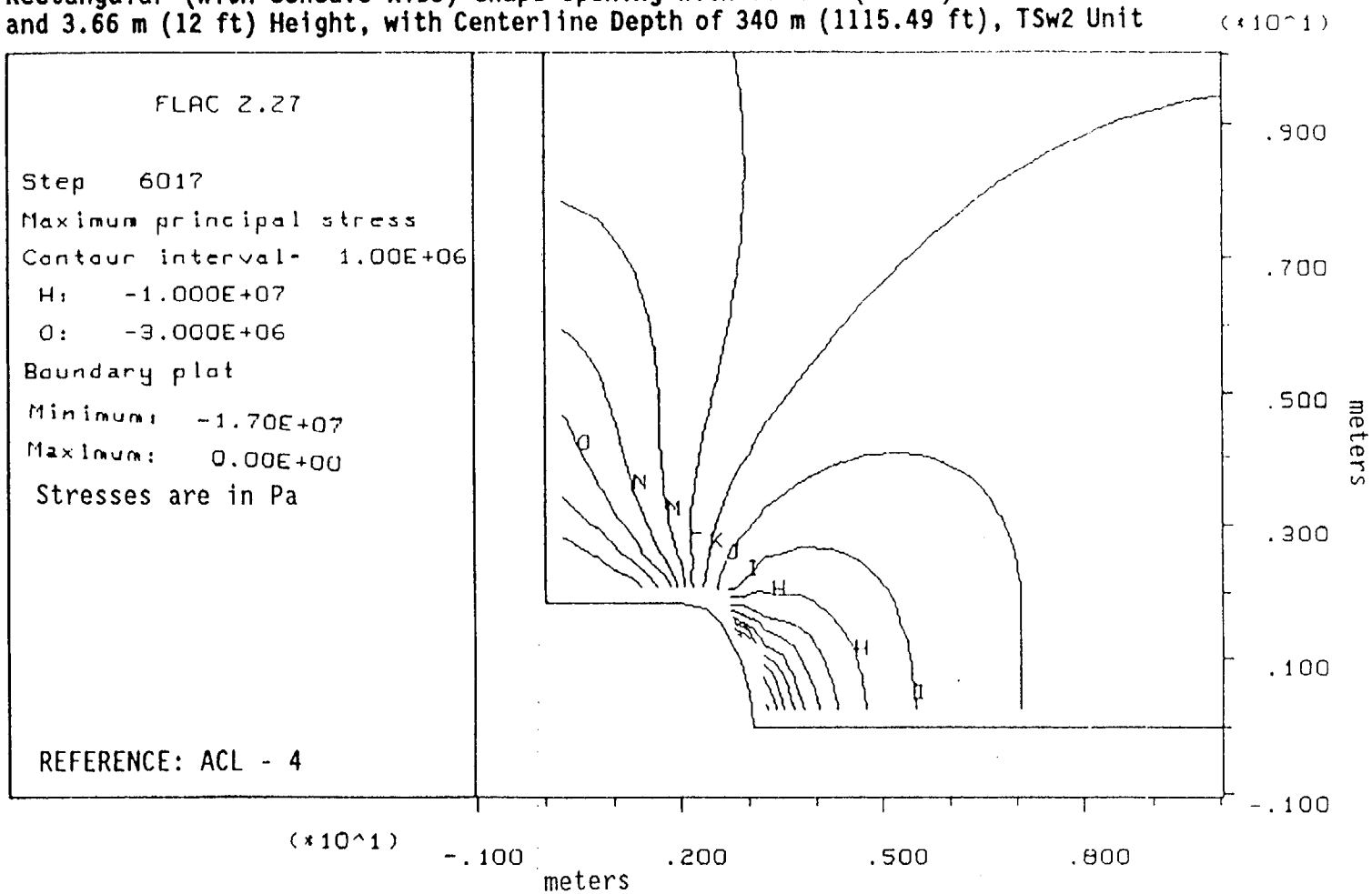


FIGURE 9e. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

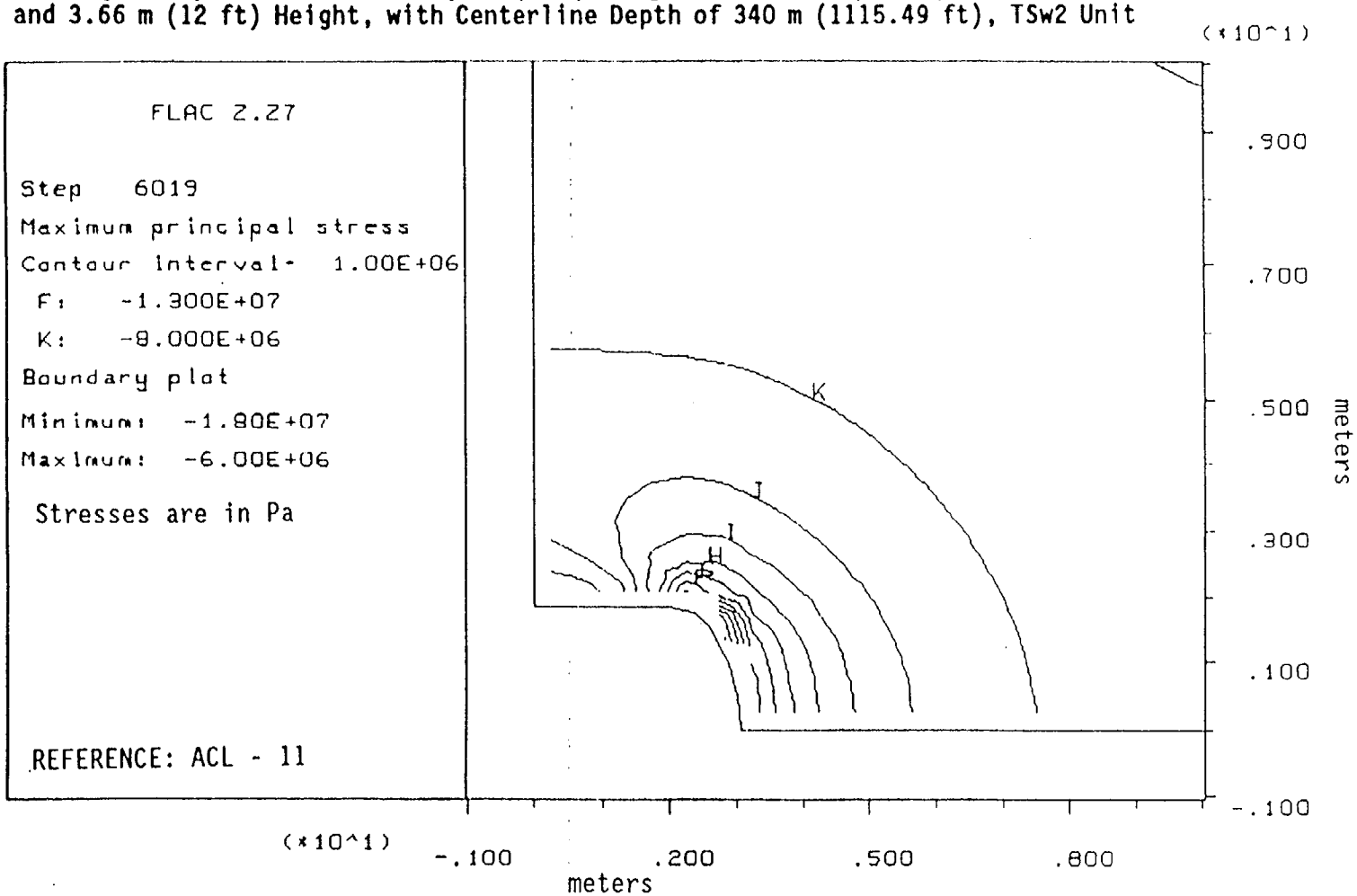


FIGURE 9f. Maximum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

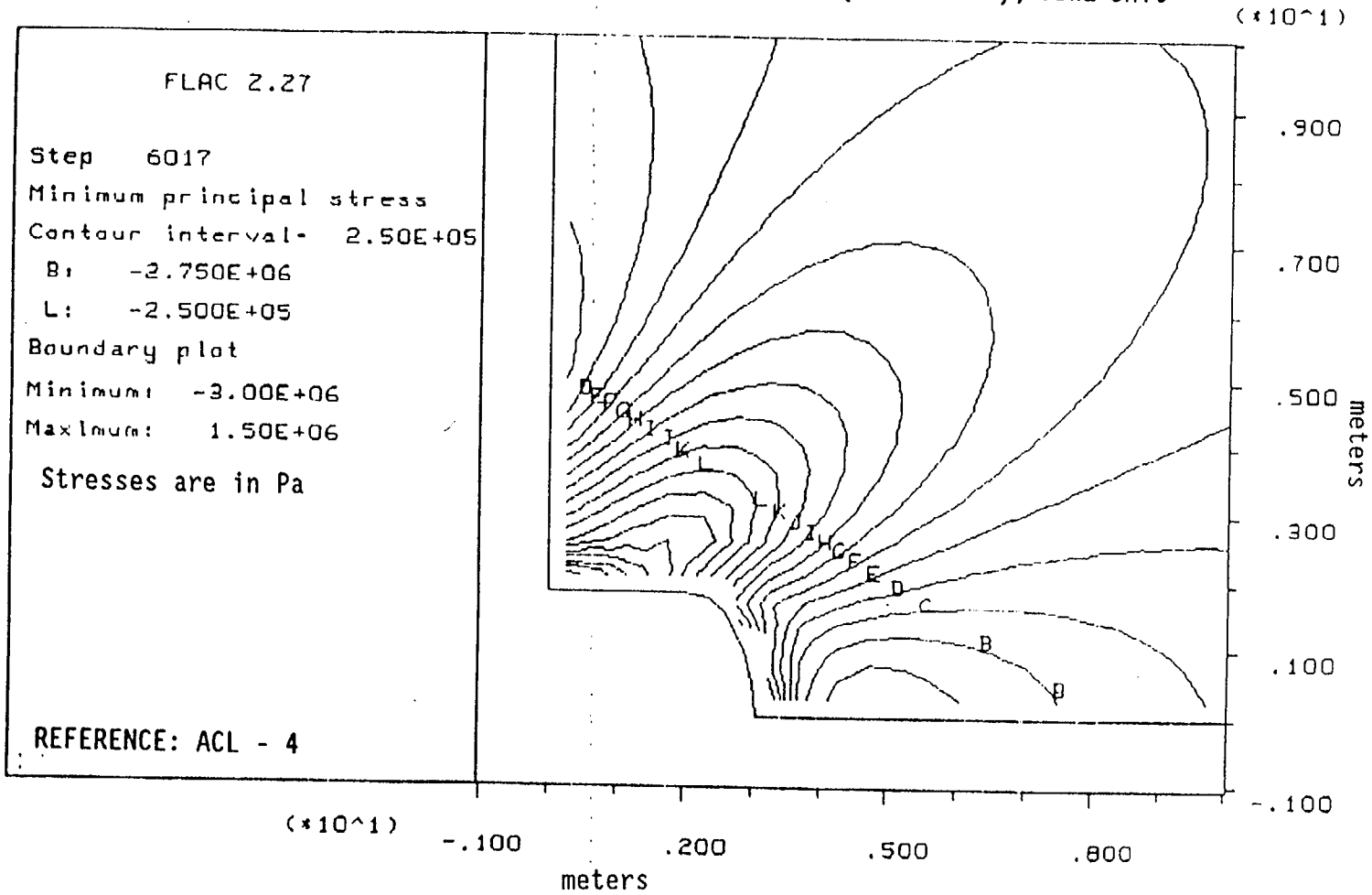


FIGURE 9g. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Rectangular (with Concave Ribs) Shape Opening with 6.01 m (20 ft) Width and 3.66 m (12 ft) Height, with Centerline Depth of 340 m (1115.49 ft), TSw2 Unit

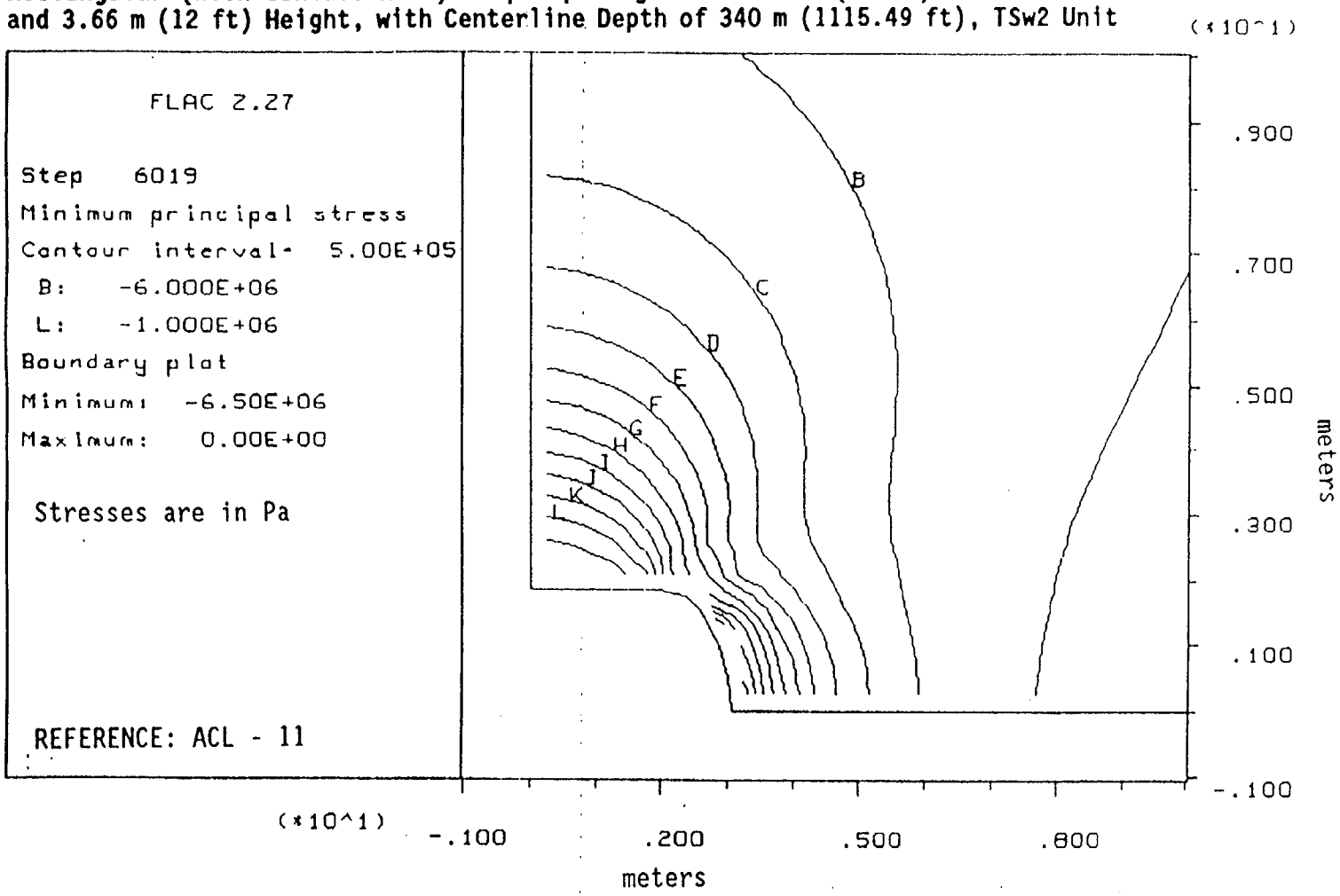


FIGURE 9h. Minimum Principal Stress Contours Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 106 m (347.77 ft), PTn Unit

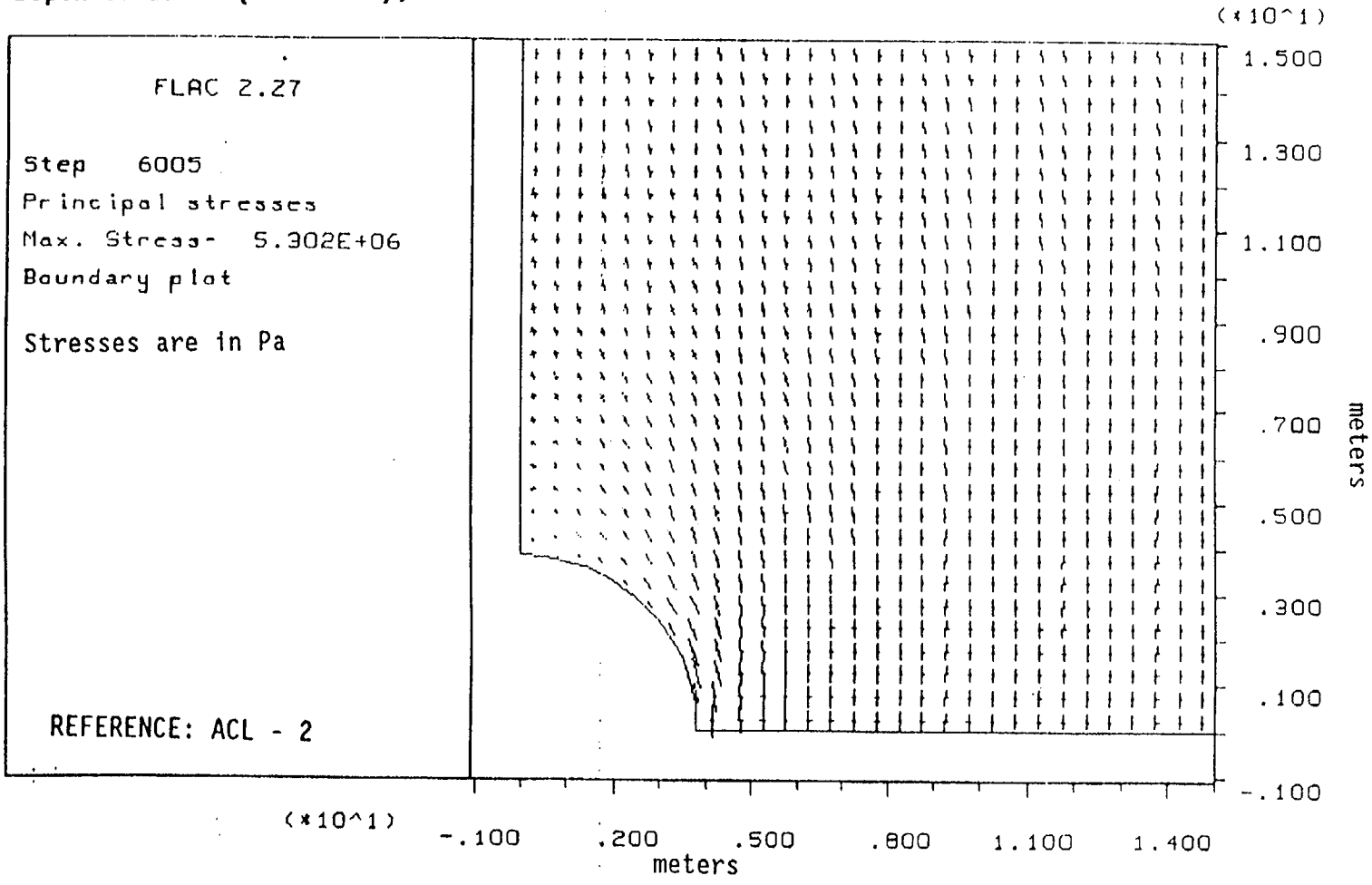


FIGURE 10a. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 106 m (347.77 ft), PTn Unit

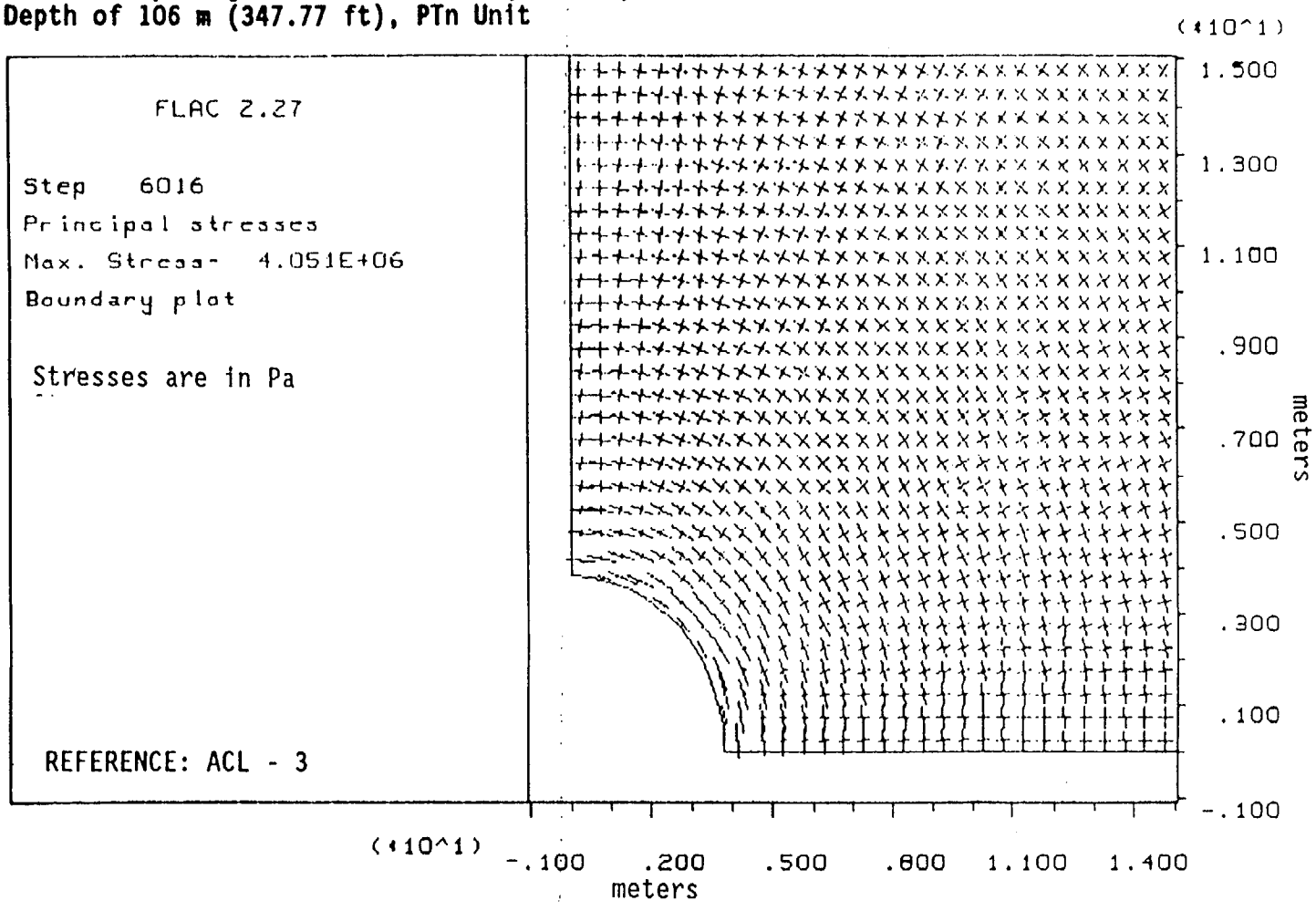


FIGURE 10b. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 200 m (656.17 ft), TSw1 Unit

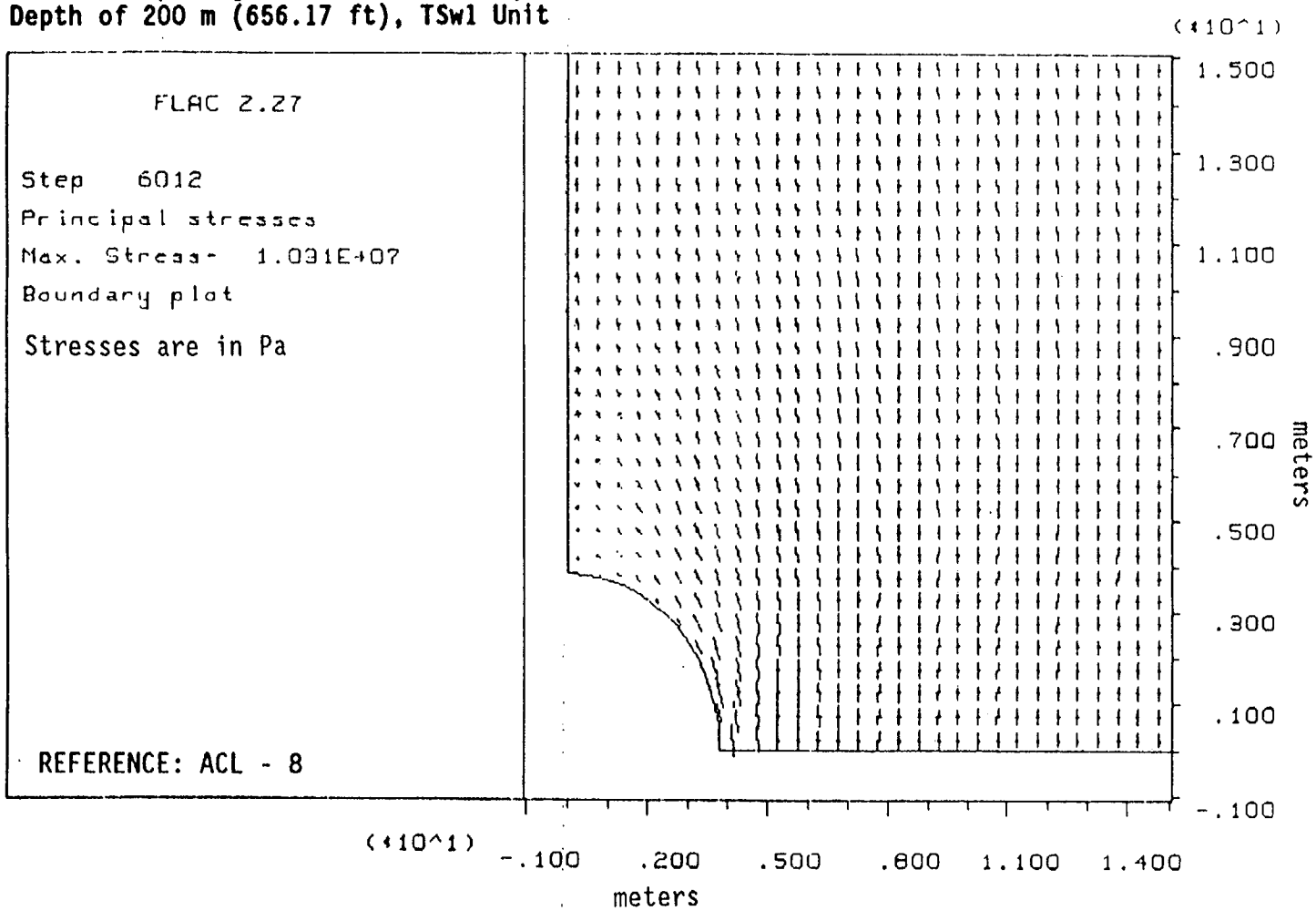


FIGURE 11a. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 1 (σ_h/σ_v = 0.3), Compression is Negative

Circular Opening of Radius 3.81 m (12.5 ft),with Centerline at the Depth of 200 m (656.17 ft), TSw1 Unit

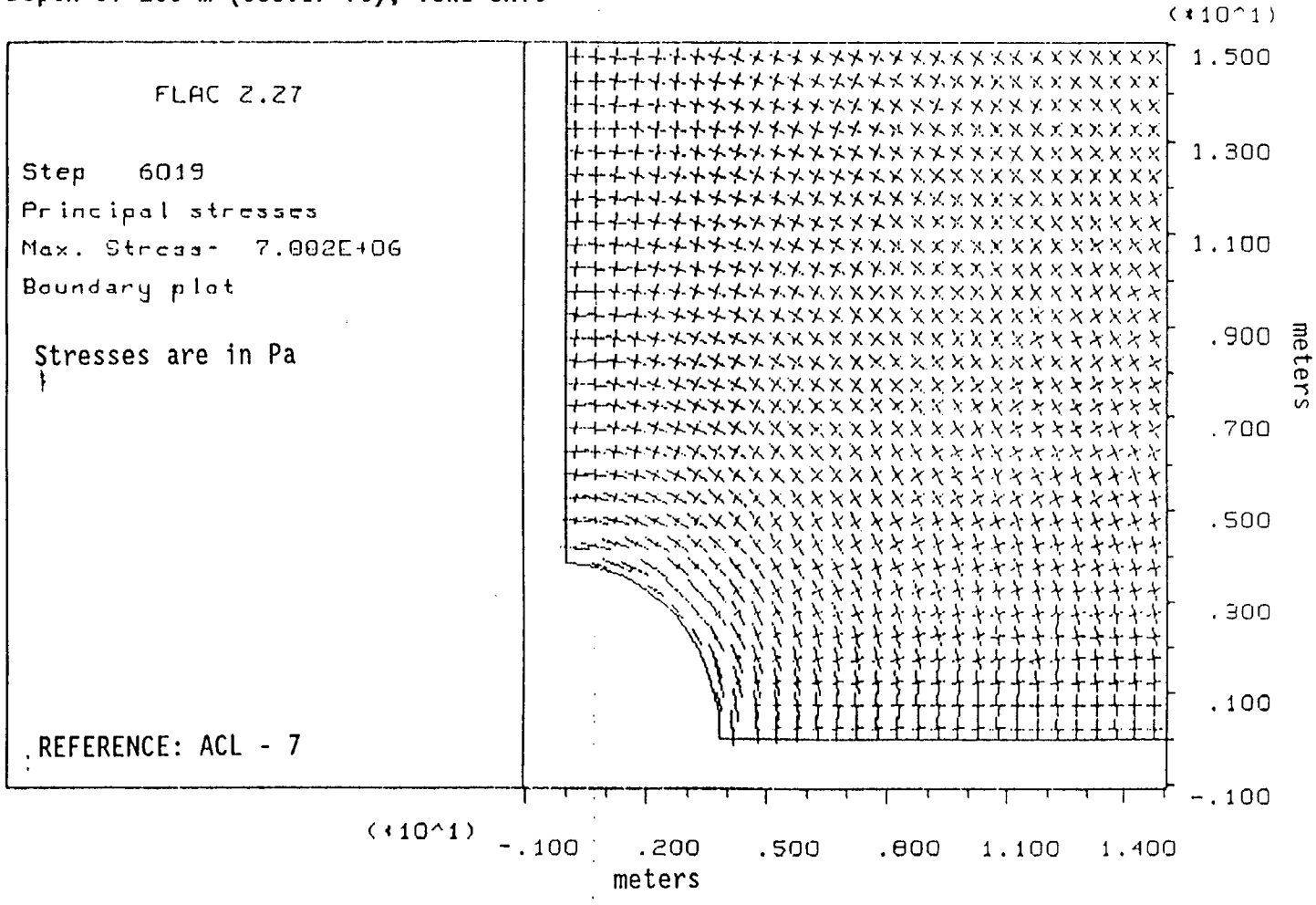


FIGURE 11b. Principal Stress Vectors Immediately After Excavation for Elasto-Plastic Model, Case 2 (σ_h/σ_v = 1.0), Compression is Negative

linear elasticity theory predicts that for the horizontal stress σ_h is

$$\sigma_h = \left(\frac{\nu}{1 - \nu}\right) \sigma_v \ . \qquad (2)$$

in which ν is the Poisson's ratio. This model assumes that σ_h is equal in all directions. In practice, the stress state within rock masses does not conform exactly to the simple linear elasticity model. The tectonic environment and nonlinear deformation together result in a stress state that typically exceeds that predicted by the elastic model. Several studies have been reviewed to estimate a relationship between horizontal and vertical stresses. Nolting and Schmidt (1990) assumed horizontal to vertical in situ stress ratio to be in the range of 0.3 and 1. Johnstone et al (1984) assumed horizontal to vertical stress ratio to fall in the range of 0.5 and 1.0 for underground openings. For the analyses presented here two loading cases corresponding to smallest (σ_h/σ_v = 0.3) and largest (σ_h/σ_v = 1.0) horizontal stresses, which give the most extreme stress conditions around the opening are considered. This range generally covers the range of the in situ stresses in RIB (Chap. 1, Sec. 2, Item 10, Page 3 of 5). In the remainder of the report, case 1 represents the smallest and case 2 indicates the largest horizontal stresses.

In the analyses presented in this report, the symmetry conditions for the openings are introduced by considering the one-half of the hole for horse shoe shape and one-quarter of the hole for the circular and the rectangular (with concave ribs) shape openings. The rectangular and horseshoe shape openings are considered only for the MTA level (TSw2 unit). The circular opening is modeled for PTn, TSw1, and TSw2 units. The boundary conditions are set to account for

symmetry, horizontal stresses along the right hand side and vertical stresses due to the overburden pressures on the top of the model. The in situ field stresses are calculated using Eq. 1 and horizontal to vertical stress ratios of 0.3 (case 1) and 1.0 (case 2).

The results of the analyses indicates that neither of the three shapes, considering both cases (small and large horizontal stresses), presents any yield zones. It should be remembered that the analyses presented here are preliminary and only represent the average ground conditions. Future analyses will consider worst possible ground conditions which may be encountered during ESF construction. For the analyses presented here, considering both the low and the high horizontal stress conditions, the distribution of stresses around the openings (all three shapes) appears reasonably smooth. Figures 7a&b, 8a&b, 9a&b 10a&b and 11a&b show stress vectors around the openings while the maximum and minimum principal stress contours are shown in Figures 7e-7h, 8e-8h and 9e-9h. Figures 7c&d, 8c&d and 9e&d show the shear stress contours around the openings. The results of the analyses are in agreement with general theoretical solutions. For example, for the horseshoe shape as expected, tangential stress at the crown is low, with a small zone of tension. The wall stress is much higher (tangential stress about 15 MPa) and is concentrated at the intersection of wall and the arc of the crown and the corner of the floor. The existence of the relatively large tensile stress at the floor is due to the lack of curvature. This is also the case for the flat roof conditions. The tension in the floor cannot result in a plausible failure mode and thus is not critical for the stability of the opening. Nevertheless, the floor tension could have an effect on other performance aspects of an opening such as rock mass permeability and must be

addressed. The initial tangential crown stress is lower than the in situ stress which lowers the normal stress. This causes a reduction in the strength along vertical or near-vertical joints indicating the potential need for reinforcement of the crown. Stress risers which are noted near the intersection of crown and the wall could be reduced by smoothing the corner with a second arc of smaller radius. The use of a smaller radius arc at the corner was implemented in rectangular (with concave ribs) opening model which indicated a reduction in the stresses.

A detailed discussion of all the analyses and the results is beyond the scope of this report. The objective here was to perform some preliminary analyses to show the applicability of the analytical method and its advantages. These analyses were also first of a kind to implement RSN SQAP which was successfully accomplished. A series of detailed analyses are underway which consider the joint models. Also a series of analyses are being performed to consider the worst possible ground conditions especially in the expected fault regions.

It should be noted that all of the calculations in this report reflect the current understanding of the in situ conditions, thermal and mechanical properties, and structure of the rock at the proposed site as reported in the ESFDR and RIB. If any of these parameters change, the results of the calculations will change which may affect the conclusions. Because the analyses are preliminary, no attempt was made in this study to determine the effects of uncertainties in the parameters on the predicted thermal/mechanical response.

As mentioned earlier, analytical methods will play an important role in development and implementation of some of the Steps presented in the design

approach (Figure 1). The future analyses, to have named a few, will include thermal stresses, seismic effects, and plausible failure mode determinations.

6.0 EMPIRICAL METHODS (STEP 3)

The empirical approach relies on rock mass classification systems. Generally, these systems allow the rock properties and geologic conditions shown in samples taken from drillholes and certain outcrops at the planned site to be compared with similar information compiled and categorized from existing underground facilities. From this comparison, a relative estimate of the excavation stability of the planned site can be obtained.

Hoek and Brown (1980), recommend two common classification methods for use in the preliminary design of underground excavations, namely: South African Council for Scientific and Industrial Research (CSIR) Classification system developed by Bieniawski (1976), and the Norwegian Geotechnical Institute (NGI) Classification system developed by Barton et al. (1974). Nolting and Schmidt (1990), also recommend the use of both CSIR and NGI rock mass classification systems for the design of the support systems for underground openings in tuff.

Landgkopf and Gnirk (1986) applied both CSIR and NGI methods to the potential waste emplacement horizon of Yucca Mountain. The results of their study shows how the tuff units at Yucca Mountain and those at G-Tunnel compare with other rock units that have been evaluated using the CSIR and the NGI systems. It also provides an estimate of rock support requirements for the units at Yucca Mountain.

For the ESF design, the CSIR and NGI rock mass classification systems shall be used for development of a customized rock mass classification appropriate for tuff formations. These two systems are chosen because both are based on numerous case histories, both can easily be used to quantify rock mass quantities applicable to excavation stability, and both are directed toward the present conventional support techniques of rock bolts, mesh, and shotcrete. The CSIR and NGI classification systems "are of particular interest because they include sufficient information to provide a realistic assessment of the factors which influence the stability of an underground excavation" (Hoek and Brown, 1980, Langkopf and Gnirk, 1986).

The Strength of Intact Rock Material, RQD, Spacing of Joints, Condition of Joints, Groundwater Condition, and Orientation of Joints are the six parameters included in the CSIR rock mass classification system. A value is assigned to each of these parameters using a table developed by Bieniawski (1976), and the values are added to obtain a final classification rating called the Rock Mass Rating (RMR), (Table 2). Joints are the major factor in this classification system in which four of the six parameters (RQD, Spacing of Joints, Condition of Joints, and Orientation of Joints) are related to joint characteristics.

The six parameters included in the NGI rock mass classification system include the following: RQD, Joint Set Number (J_n), Joint Roughness Number (J_r), Joint Alteration Number (J_a), Joint Water Reduction Factor (J_w), and Stress Reduction Factor (SRF). A value is assigned to each of these parameters using a table developed by Barton et al. (1974), (Table 3). A final classification value (Q value) is obtained by combining the six parameters using Equation 3.

TABLE 2. CSIR Classification System

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

PARAMETER			RANGES OF VALUES						
1	Strength of intact rock material	Point-load strength index	> 8 MPa	4 - 8 MPa	2 - 4 MPa	1 - 2 MPa	For this low range – uniaxial compressive test is preferred		
		Uniaxial compressive strength	> 200 MPa	100 - 200 MPa	50 - 100 MPa	25 - 50 MPa	10-25 MPa	3-10 MPa	1-3 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of joints		> 3 m	1 - 3 m	0.3 - 1 m	50 - 300 mm	< 50 mm		
	Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation < 1 mm Hard joint wall rock	Slightly rough surfaces Separation < 1 mm Soft joint wall rock	Slickensided surfaces OR Gouge < 5 mm thick OR Joints open 1-5 mm Continuous joints	Soft gouge > 5 mm thick OR Joints open > 5 mm Continuous joints		
	Rating		25	20	12	6	0		
5	Ground water	Inflow per 10m tunnel length	None		< 25 litres/min	25 - 125 litres/min	> 125 litres/min		
		Ratio joint water pressure / major principal stress	OR 0		OR 0.0 - 0.2	OR 0.2 - 0.5	OR > 0.5		
		General conditions	OR Completely dry		OR Moist only (interstitial water)	OR Water under moderate pressure	OR Severe water problems		
	Rating		10		7	4	0		

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations of joints		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK MASS CLASSES

Class No	I	II	III	IV	V
Average stand-up time	10 years for 5 m span	6 months for 4 m span	1 week for 3 m span	5 hours for 1.5 m span	10 minutes for 0.5 m span
Cohesion of the rock mass	> 300 kPa	200 - 300 kPa	150 - 200 kPa	100 - 150 kPa	< 100 kPa
Friction angle of the rock mass	> 45°	40° - 45°	35° - 40°	30° - 35°	< 30°

Source: Bieniawski, 1976, p. 102.

TABLE 3. NGI Classification System

1.	ROCK QUALITY DESIGNATION	(RQD)	
A.	Very poor	0— 25	Note: (i) Where RQD is reported or measured as $\leqq 10$ (including 0) a nominal value of 10 is used to evaluate Q in Eq. (1) (ii) RQD intervals of 5, i. e. 100, 95, 90, etc. are sufficiently accurate
B.	Poor	25— 50	
C.	Fair	50— 75	
D.	Good	75— 90	
E.	Excellent	90—100	
2.	JOINT SET NUMBER	(J_n)	
A.	Massive, no or few joints	0.5—1.0	
B.	One joint set	2	
C.	One joint set plus random	3	
D.	Two joint sets	4	
E.	Two joint sets plus random	6	
F.	Three joint sets	9	
G.	Three joint sets plus random	12	Note: (i) For intersections use ($3.0 \times J_n$) (ii) For portals use ($2.0 \times J_n$)
H.	Four or more joint sets, random, heavily jointed, "sugar cube", etc.	15	
J.	Crushed rock, earthlike	20	
3.	JOINT ROUGHNESS NUMBER	(J_r)	
	(a) *Rock wall contact* and (b) *Rock wall contact before 10 cms shear*		
A.	Discontinuous joints	4	Note: (i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m (ii) $J_r = 0.5$ can be used for planar slickensided joints having lineations, provided the lineations are favourably orientated
B.	Rough or irregular, undulating	3	
C.	Smooth, undulating	2	
D.	Slickensided, undulating	1.5	
E.	Rough or irregular, planar	1.5	
F.	Smooth, planar	1.0	
G.	Slickensided, planar	0.5	
	(c) *No rock wall contact when sheared*		
H.	Zone containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)	
J.	Sandy, gravelly or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)	

Table 2. Descriptions and Ratings for the Parameters J_a and J_w

4.	JOINT ALTERATION NUMBER	(J_a)	φ_r (approx.)	
	(a) *Rock wall contact*			
A.	Tightly healed, hard, non-softening, impermeable filling i. e. quartz or epidote	0.75	(—)	Note: (i) Values of $(\varphi)_r$ are intended as an approximate guide to the mineralogical properties of the alteration products, if present
B.	Unaltered joint walls, surface staining only	1.0	(25°—35°)	
C.	Slightly altered joint walls. Non-softening mineral coatings, sandy particles, clay-free disintegrated rock etc.	2.0	(25°—30°)	
D.	Silty-, or sandy-clay coatings, small clay-fraction (non-softening)	3.0	(20°—25°)	

TABLE 3. (Continued)

E.	Softening or low friction clay mineral coatings, i. e. kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1—2 mm or less in thickness)	4.0	(8°—16°)
	(b) *Rock wall contact before 10 cms shear*		
F.	Sandy particles, clay-free disintegrated rock etc.	4.0	(25°—30°)
G.	Strongly over-consolidated, non-softening clay mineral fillings (Continuous, < 5 mm in thickness)	6.0	(16°—24°)
H.	Medium or low over-consolidation, softening, clay mineral fillings. (Continuous, < 5 mm in thickness)	8.0	(12°—16°)
J.	Swelling clay fillings, i. e. montmorillonite (Continuous, < 5 mm in thickness). Value of J_a depends on percent of swelling clay-size particles, and access to water etc.	8.0—12.0	(6°—12°)
	(c) *No rock wall contact when sheared*		
K, L, M.	Zones or bands of disintegrated or crushed rock and clay (see G, H, J for description of clay condition)	6.0, 8.0 or 8.0—12.0	(6°—24°)
N.	Zones or bands of silty- or sandy clay, small clay fraction (non-softening)	5.0	
O, P, R.	Thick, continuous zones or bands of clay (see G, H, J for description of clay condition)	10.0, 13.0 or 13.0—20.0	(6°—24°)

5.	JOINT WATER REDUCTION FACTOR	(J_w)	Approx. water pressure (kg/cm²)	
A.	Dry excavations or minor inflow, i. e. < 5 l/min. locally	1.0	< 1	Note:
B.	Medium inflow or pressure occasional outwash of joint fillings	0.66	1.0— 2.5	(i) Factors C to F are crude estimates. Increase J_w if drainage measures are installed
C.	Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5—10.0	(ii) Special problems caused by ice formation are not considered
D.	Large inflow or high pressure, considerable outwash of joint fillings	0.33	2.5—10.0	
E.	Exceptionally high inflow or water pressure at blasting, decaying with time	0.2—0.1	> 10.0	
F.	Exceptionally high inflow or water pressure continuing without noticeable decay	0.1—0.05	> 10.0	

TABLE 3. (Continued)

6.	STRESS REDUCTION FACTOR			(*SRF*)	
	(a) *Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated*				Note: (i) Reduce these values of *SRF* by 25—50% if the relevant shear zones only influence but do not intersect the excavation
A.	Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)			10.0	
B.	Single weakness zones containing clay, or chemically disintegrated rock (depth of excavation ≦50 m)			5.0	
C.	Single weakness zones containing clay, or chemically disintegrated rock (depth of excavation >50 m)			2.5	
D.	Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)			7.5	
E.	Single shear zones in competent rock (clay free) (depth of excavation ≦50 m)			5.0	
F.	Single shear zones in competent rock (clay free) (depth of excavation >50 m)			2.5	
G.	Loose open joints, heavily jointed or "sugar cube" etc. (any depth)			5.0	
	(b) *Competent rock, rock stress problems*				
		σ_c/σ_1	σ_t/σ_1		
H.	Low stress, near surface	>200	>13	2.5	(ii) For strongly anisotropic stress field (if measured): when $5 \leqq \sigma_1/\sigma_3 \leqq 10$, reduce σ_c and σ_t to $0.8\,\sigma_c$ and $0.8\,\sigma_t$; when $\sigma_1/\sigma_3 > 10$, reduce σ_c and σ_t to $0.6\,\sigma_c$ and $0.6\,\sigma_t$ where: σ_c = unconfined compression strength, σ_t = tensile strength (point load), σ_1 and σ_3 = major and minor principal stresses
J.	Medium stress	200—10	13—0.66	1.0	
K.	High stress, very tight structure (Usually favourable to stability, may be unfavourable to wall stability)	10—5	0.66—0.33	0.5—2.0	
L.	Mild rock burst (massive rock)	5—2.5	0.33—0.16	5—10	
M.	Heavy rock burst (massive rock)	<2.5	<0.16	10—20	
	(c) *Squeezing rock;* plastic flow of *incompetent rock under the influence of high rock pressures*				(iii) Few case records available where depth of crown below surface is less than span width. Suggest *SRF* increase from 2.5 to 5 for such cases (see H)
N.	Mild squeezing rock pressure			5—10	
O.	Heavy squeezing rock pressure			10—20	
	(d) *Swelling rock; chemical swelling activity depending on presence of water*				
P.	Mild swelling rock pressure			5—10	
R.	Heavy swelling rock pressure			10—15	

Source: Barton et al., 1974a, pp. 194-196.

$$Q = (RQD/J_n)\ (J_r/J_a)\ (J_w/SRF) \qquad (3)$$

The nature of the joints play a major role in the value of the Q as it did in the value of the RMR in CSIR system.

The CSIR and NGI systems each have one strength related parameter. The CSIR system groups values for strength of intact rock to associate each group with a numerical rating. The NGI system uses a ratio of the uniaxial compressive strength to the in situ stress to rate competent rock. The ratios are grouped and associated with a numerical rating called the Stress Reduction Factor (SRF).

Details of the CSIR and NGI systems can be found in Langkopf and Gnirk (1986) and other rock mechanics text books.

The empirical methods as described here have certain limitations that will have to be explored for the ESF design. For example, neither the CSIR nor the NGI classification system has a factor that accounts for thermal stresses. The possible effect of added thermal stresses on the rock mass classification system will be evaluated and adjustments will be made to incorporate this phenomenon. The empirical methods also do not present an assessment of plausible failure modes. Development of plausible failure modes of underground openings will be aided by the use of numerical codes to supplement empirical methods. The effects of excavation techniques also are not incorporated in the empirical methods. Access ramps will be excavated by TBM while the MTA will be developed using other mechanical methods. Some openings and alcoves in the ESF might be excavated by controlled drill and blast methods. An adjustment factor will be devised to account for the differing excavation methods.

6.1 ROCK MASS CLASSIFICATION AND PRELIMINARY RECOMMENDATIONS

Langkopf and Gnirk (1986) applied CSIR and NGI rock mass classification systems to classify the tuff units at Yucca Mountain. The four tuff units considered in this study were (1) the welded, devitrified, nonlithophysal portion of the Topopah Spring Member of the Paintbrush Tuff; (2) the zeolitized, nonwelded portion of the Tuffaceous Beds of Calico Hills; (3) the welded devitrified portion of the Bullfrog Member of the Crater Flat Tuff; and (4) the welded, devitrified portion of the Tram Member of Crater Flat Tuff. In this study, it was determined how the tuff units at Yucca Mountain and G-Tunnel compare with each other and with other units that have been evaluated using the CSIR and NGI systems. An estimate of rock support requirements for each unit was obtained and then compared to the support presently used at the G-Tunnel complex. The summary of quantitative description of the rock mass classification of Langkopf and Gnirk is presented in Table 4.

The report by Langkopf and Gnirk provides rock mass classification data only for thermal/mechanical units of TSw2 and CHn and does not consider the other units of interest namely TCw, PTn, TSw1, and TSw3. Nolting and Schmidt (1990) estimated Q and RMR values for the TCw, PTn, TSw1, and TSw3 units. They incorporated the general format of Langkopf and Gnirk with few simplifications. Table 5 shows the CSIR ratings, and Table 6 represents the NGI ratings for each tuff unit. Another set of results was recommended in this study for the NGI rating in which Q values were calculated for all combinations of high and low rating values without considering the highest and lowest 12.5% of the numbers.

TABLE 4. Summary of Qualitative Descriptions of the Rock Mass Classification of the Tuff Units

Group	Tuff Unit	CSIR Description	NGI Description
1	Topopah Spring	Very good to fair rock (Very good to fair rock)*	Very good to poor rock
	Grouse Canyon	Good to fair rock (Good to fair rock)	Good to poor rock
2	Calico Hills	Good to fair rock (Good rock)	Very good to very poor rock
	Tunnel Bed 5	Good to fair rock (Good rock)	Very good to very poor rock
3	Bullfrog	Good to poor rock (Good to fair rock)	Fair to extremely poor rock
	Tram	Good to poor rock (Good to fair rock)	Fair to extremely poor rock

*The CSIR descriptions in parentheses are based on the assumption that the drifts can be oriented "very favorably" with respect to the joints.

Source: Langkopf and Gnirk (1986), page 92

TABLE 5. CSIR Classification of the Units at the Proposed Site

Parameter	TCw	PTn	TSw1	TSw2	TSw3	CHn
Intact strength	12-15	2	2-12	12	est. 12	2-4
RQD	8-17	20	17-20	8-17	17	17-20
Joint spacing	10-20	20-25	10-20	10-20	10-20	20-25
Joint condition	20-25	12	20-25	20-25	20-25	12
Groundwater	10	10	10	10	10	10
Rock mass rating	60-87	64-69	59-87	60-84	69-84	61-71
Description	Good/ Very Good	Good	Fair/ Very Good	Good/ Very Good	Good/ Very Good	Good

Source: Nolting and Schmidt (1990), page A-10

TABLE 6. NGI Classification of the Units at the Proposed Site

Parameter	TCw	PTn	TSw1	TSw2	TSw3	CHn
RQD	25-80	100	89	35-80	82	85-99
Joint set number, J_n	6-12	0.5-1.0	3-6	6-12	3-6	0.5-1.0
Joint roughness J_r	2-4	1-2	2-4	2-4	2-4	1-2
Joint alteration J_a	1-4	1-4	1-4	1-4	1-4	1-4
Joint water J_w	1	1	1	1	1	1
Strength reduction SRF	1-2.5	1-1.5	1-8	1	est. 1	9-11
Q	0.42-53	16.7-400	0.93-119	1.46-53	6.8-109	1.93-44
Rock mass quality	Very Poor/ Very Good	Good/ Extremely Good	Very Poor/ Extremely Good	Poor/ Very Good	Fair/ Extremely Good	Poor/ Very Good

Source: Nolting and Schmidt (1990), page A-11

This resulted in a narrower NGI rating range but the median value remained the same. Table 7 shows the results of NGI rating adapting this procedure. This table shows a better correlation with the CSIR rating presented in Table 5, mainly due to the effect of the stress reduction factor, which is not represented in the CSIR system.

The observations in G-Tunnel provide additional insight into the constructibility and initial support requirements of the ESF openings. Faults and associated shear zones are expected to be encountered during ESF construction. Rock with similar mechanical properties has been excavated in the G-Tunnel complex at Rainier Mesa using comparable methods of excavation and ground control. The environmental assessment (DOE, 1986c) has documented tunneling experience in the welded Grouse Canyon Member at the G-Tunnel. A nearly vertical fault with at least 1 meter of vertical displacement was encountered during excavation in the welded Grouse Canyon Member in G-Tunnel. The mining inspector made no comments in his daily log which indicates there were no appreciable variations in the tunneling conditions. The fault brought welded and nonwelded tuff together along a nearly vertical contact; no water influx was noted. The tunnel with the fault was initially mined on November 19, 1981 according to the inspection record. Preliminary 2.5 m (8 ft) rock bolts were installed in the faulted area on November 20,1981, and then roughly 3 months later, on February 16,1982, 5 m (16 ft) resin anchored hardening rock bolts were installed on a 1.3 by 1.3 m (4 by 4 foot) pattern across the back in the area of the fault. There was no record that the faulted area produced ground support problems, and no special bolting was installed in the area of the fault. Such observations in G-Tunnel provide additional important information which will be

TABLE 7. Modified NGI Classification of the Units at the Proposed Site

Unit	Narrower Q-Range	Median Value	Description of Range (Median)
TCw	1.4-13.3	4.8	Poor to good (fair)
PTn	33-200	83	Good to extremely good (very good)
TSw1	1.9-59	11	Poor to very good (good)
TSw2	2.9-27	9	Poor to good (fair)
TSw3	13.7-55	27	Good to very good (good)
CHn	3.9-22	9	Poor to good (fair)

Source: Nolting and Schmidt (1990), page A-12

useful for preliminary ground support recommendations.

For the implementation of Step 3 of the design approach, for the main part, reports of Nolting and Schmidt (1990) and Langkopf and Gnirk (1986) will provide preliminary input. The new site data and experiences in the G-Tunnel will be incorporated to update the results of these reports. At the present time, an effort is underway to incorporate the results of the both above mentioned studies into the RIB (Ref. 12).

7.0 DISCUSSION OF THE REMAINING STEPS

The final four steps of the design approach as presented in Figure 1, will be developed prior or during the Title II design. These steps will be briefly addressed in this section.

Once the preliminary support recommendations are made for each rock class in Step 3, a series of investigations and analyses will be performed (Step 4). Adjustment factors will be determined to account for plausible failure modes, excavation methods, thermal effects, seismic effects and constructibility issues. Analytical methods will be used to accomodate a majority of these issues.

Step 5 of the design approach will basically address the maintainability and reliability issues of the ground support components. Selection of the material for the components including its corrosion or deterioration behavior and temperature compatibility are considered in this step. A program for inspection and maintenance of the ground support components will also be developed.

In Step 6, practical definitions of rock classes and opening classes are formulated. In this step different support schemes are matched to the class and the quality of the rock mass, and to the opening size, function, and environment. A system is developed to classify the rock during construction so that the ground support class can be selected or verified for each local environment encountered. Nolting and Schmidt (1990) recommend the following methodology which is normally used.

- "For each drift, a set of support designs (3-5 support classes, classes 1,2,3, and so on) are defined, covering the expected range of ground conditions.
- The expected range of ground conditions or rock classes(classes A, B, C, and so on) is established.
- For the same rock class, drifts of various size, shape, function, or environment (various drift classes) would require a somewhat different support design. In practice, the support class would not be changed for minor rock class variations, but only when significant change occurs."

An example of a recommended rock support for a drift in the ESF (previously configured ESF with two shafts) is presented in Table 8. This example was developed by Nolting and Schmidt (1990) for the Ghost Dance Fault drift to illustrate how the rock is classified and what type of support is recommended.

In Step 7, the end product of the ground support design effort will be presented as a set of construction documents to be used by the contractor during the construction. Construction documents will consist of drawings, specifications and procedures that detail what is required of the contractor.

TABLE 8. Example of Recommended Rock Support for Ghost Dance Fault Exploratory Drift, ESF (ESF Configuration with Two Shafts)

Rock Class	I	II	III
Description	Densely welded, unaltered to slightly altered tuff, RQD=75-80, Q=10-53 (good to very good rock; RQD/J_n=13, J_r/J_a=4, span/ESR=6.4m), 1 to 2 widely spaced joint sets, joints tight and generally unaltered, dry.	Densely welded, slightly to moderately altered tuff, RQD=50-75, Q=4-10 (fair rock; RQD/J_n=7, J_r/J_a=1, span/ESR=6.4m), 2 or more joint sets, vertical joint set may dominate, joints generally tight with some alteration, dry to damp.	Densely welded, slightly to highly altered tuff, RQD=35-50, Q=1.5-4 (poor rock; RQD/J_n=4, J_r/J_a=.5, span/ESR=6.4 m), 3 joint sets to random, tight to open, dry to wet, lower Q values represent off-normal, fault zone conditions.
Support for Initial Safety	Friction bolts as required.	Friction bolts and wire mesh as required.	Friction bolts and wire mesh as required.
Support for Excavation Stability (Case 1)	Dowels as required to secure isolated blocks, fully cement grouted, 2-3 m long, 22-mm diam., straps and mesh as required to secure isolated blocks.	Dowels in crown, fully cement grouted, 2-3 m long, 1-1.5-m pattern, 22-mm diam., mesh in crown (welded wire mesh tied to bolts, chainlink o.k. where observation not required). Straps in crown as needed, especially across dominant joint set where parallel to drift.	Shotcrete in crown 50-mm minimum, fiber or wire mesh reinforced, in sidewalls as required. Dowels, fully cement grouted, 1-m pattern, 2-3 m long in crown, 2 m long in sidewall, 22-mm diam.
Support for Long-term Stability (Case 2)	No additional support required. Maintain system recommended for Case 1.	Dowels, fully grouted, in sidewalls as required, 2-m length. Maintain system recommended for Case 1.	No additional support required. Maintain system recommended for Case 1.

Source: Nolting and Schmidt (1990), page 5-25

Instructions for monitoring opening performance and procedures for inspection are also prepared. Long-term monitoring, inspection, and maintenance procedures will also be developed in this step.

8.0 CONCLUSIONS

The design approach presented in this report integrates empirical methods, analytical modeling, evaluation of fundamental rock behavior, practical considerations of constructability and durability, observations during construction, and consideration of long term maintainability. During this complex design process empirical and analytical methods are performed iteratively and dependently. The use of observation and monitoring during and after construction is essential to verify rock properties and opening performance, and to implement ground support modifications when required.

The preliminary computer analyses, considering average ground conditions, show reasonably smooth stress distribution around the openings. Considering both the low and the high horizontal stress conditions (σ_h/σ_v=0.3 and σ_h/σ_v=1.0, respectively), for three different opening shapes assessed in the analyses there were no indication of any plastic zones based on Mohr-Coulomb yield criterion. Future analyses will include strength criterion based on an empirical assessment of the tuff units to look at potential failure modes. These analyses will further aid in understanding of the possible shape and depth of failed rock, as well as the effect of stress redistribution.

Finally, a preliminary ground support approach has been outlined in this report which incorporates elements of empirical and numerical analyses. The use

of observation and monitoring during and after construction to verify rock properties and opening performance is equally emphasized. In this approach, the analyses serve as a basis for the development of flexible rock reinforcement systems capable of accommodating various rock conditions anticipated underground. Ground support requirements for each segment of an underground opening may vary over relatively short distances, depending on the local geologic conditions. Based on visual inspection carried in-place by qualified professionals, local ground conditions are classified in terms of the rock mass categories. In turn, each rock mass category is assigned a specific rock support system, including the procedures and the hardware necessary for its proper implementation.

The performance objectives specified in 10 CFR 60 require development of a consistent design methodology accommodating computer-generated results of numerical modeling. Implementing the preliminary design approach presented in this report will accommodate the requirements of the 10 CFR 60.

Rock support for the potential shaft is not considered in this report and shall be addressed in future reports.

9.0 REFERENCES

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20) For computer analyses presented in this report refer to RSN certified computer runs of ACL-2, ACL-3, ACL-4, ACL-5, ACL-6, ACL-7, ACL-8, ACL-9 ACL-10, ACL-11 at the RSN Design Record Center.