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Design Analysis Cover Sheet

Complete only applicable items.

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11. REMARKS

The following TBV/TBD are contained in the document:

TBV-321

TBD-240

QAP-3-9 (Effective 06/02/97)

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Design Analysis Revision Record

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2. DESIGN ANALYSIS TITLE

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FIGURES

TABLES

1. PURPOSE

The purpose of this analysis is to define how air quality is to be achieved and maintained during different modes of repository operation. The objective is to develop air quality control methods and strategies to support the License Application Design.

The scope of this analysis covers:

1) Identification of acceptable ranges of air quality indices for the following items: oxygen content; temperature; humidity; and concentrations of dust, silica, and other contaminants.

2) Description of technical and administrative approaches that establish and maintain acceptable air quality in the underground working places. This analysis will discuss methods to establish and maintain acceptable air quality, but the exact ventilation layout or equipment to accomplish this task will be covered in other analyses.

3) Specification of equipment and operating modes to establish and maintain air quality control.

4) Definition of potential normal and abnormal situations in which the air quality could be degraded.

5) Determination of the effect on repository operations or construction in the event that the air quality has been degraded.

Detection or control of nuclear contaminants is not included in the scope of this analysis. This analysis will not attempt to define all possible air quality control indices but will concentrate on those listed in item #1 above.

2. QUALITY ASSURANCE

This analysis discusses how the limits for air quality are developed and the process or equipment which will maintain air quality. Different processes and equipment are discussed and are subject to quality assurance controls. A preliminary classification of permanent items has been performed in accordance with Quality Administrative Procedure QAP-2-3, *Classification of Permanent Items*, and those classifications are found in the Q-List (Ref. 5.1). This analysis makes no selection of permanent equipment requiring classification. Activities were evaluated in accordance with QAP-2-0, *Conduct of Activities*, and it was determined that the activities will affect Q-List items (Ref. 5.1) and therefore is subject to the Quality Assurance Requirements and Description (Ref. 5.2).

This analysis may be used for License Application. The analysis will be used as an input to other analyses which will be used as the basis for construction, procurement, or fabrication. The formal

TBV and TBD tracking system described in Nevada Line Procedure NLP-3-15 *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System* is applicable to this analysis.

The use of design inputs and assumptions requiring confirmation (4.1.9, 4.1.12, 4.2.2, 4.2.4, 4.3.3, 4.3.4, and 4.3.5) in this analysis was necessary to establish characteristics for the design. The inclusion of this input does not disqualify the results of the analysis as the input was used to compare alternatives, not to select items for procurement, construction, or fabrication. Additionally, the design inputs and assumptions requiring confirmation do no affect waste isolation or nuclear safety.

3. METHOD

The analytical method was utilized in the development of this analysis. This method will be used in the following manner:

- An air quality level will be suggested. The level could be from industry practice or determined by governmental regulation.
- The effect of this level will be analyzed.
- The air quality level will either be adopted or a new level proposed to fit the particular situation found in the repository.
- Ways will be suggested as to how the air quality level can be met and maintained, although specific equipment layouts or arrangements will not be made.

4. DESIGN INPUTS

4.1 Design Parameters

4.1.1 Elevation and Air Pressure of the Repository

The elevation of the repository is approximately 1075m which is the average of elevations shown on Figure 7-1 in Reference 5.9 and has a barometric pressure of 89.0 kPa. (Ref. 5.3, Appendix A). As the East Main has been constructed, the elevation is a result of the Exploratory Studies Facility (ESF) design. The information from Reference 5.9 is existing data and does not need to be confirmed. The repository elevation was only used to select a barometric pressure. Barometric pressure changes gradually with elevation and is subject to meteorological fluctuations, thus an exact value is not critical.

4.1.2 Air Intake to Development Side of the Repository

The air intake to the Development Side of the repository is between 177 to 267 m^3/sec. This information from Reference 5.17, pages 95 and 98, is existing data and does not need to be confirmed. These are reasonable values for the air intake for the repository and reasonable values are all that are required for this analysis.

4.1.3 Minimum Required Air Volume

The minimum required air volume per underground worker is 5.7 m^3/min and 28.32 m^3/min per brake horsepower for diesel engines. (Code 4.4.2)

4.1.4 Specific Criteria for Gas and Dust Levels

This analysis will use the 1997 American Conference of Governmental Industrial Hygienists (ACGIH) criteria for gas and dust levels (Code 4.4.3). Code 4.4.2 refers to the 1970 ACGIH levels. These levels have stayed the same, been lowered, or new levels have been added by ACGIH over the 20+ years which have elapsed since the regulations were first promulgated and new substances have been added. In order to be conservative and to comply with the Department of Energy Order 440.1A (4.4.4), this analysis will use the 1997 values. Table 1 compares these values.

Table 1
Comparison of ACGIH Threshold Limit Values (TLV) Over Time

Substance	TLV-1970 mg/m^3(ppm)	TLV-1997 mg/m^3(ppm)
Aluminum- Welding Fume	--	5
Iron Oxide Fume	10	5
Copper Fume	0.1	0.2
Portland Cement (<1% SiO_2)	15	10
Particulate Not Otherwise Classified (Inhalable)(<1% SiO_2)	15	10
Particulate Not Otherwise Classified (Respirable)	--	3
Welding Fume	--	5
Quartz	Note A	0.1
Tridymite	--	0.05
Cristobalite	Note B	0.05
Carbon Monoxide	55 (50)	29 (25)
Carbon Dioxide	9000 (5000)	9000 (5000)
Nitrogen Dioxide	9 (5)	5.6 (3)
Nitrous Oxide	--	90 (50)
Ozone (Heavy Work)	0.2 (0.1)	0.1 (0.05)
Sulfur Dioxide	13 (5)	5.2 (2)

Notes: A. Threshold value calculated by the formula: $\frac{250}{\%SiO_2 + 5}$ = TLV millions of particles per cubic foot (mppcf)

B. 20 mppcf

4.1.5 Normal Oxygen Content of Air

The normal oxygen content of air is about 21%. (Ref. 5.3, pg 31)

4.1.6 Minimum Oxygen Content of Air

The allowable minimum oxygen content of air is 19.5% (Code 4.4.2)

4.1.7 Percent of Minerals for Repository Level

The average percent of quartz, cristobalite, and tridymite from four specific boreholes is 15.7%, 16.3%, and 3.48%, respectively (Attachment I). This information represents the mineralogical data for the Tptpll formation from Tables A1, A2, A3, and A4 in Reference 5.28. The average percent of cristobalite and tridymite from all borehole data between the elevations of 1000m to 1100m is 15.1% and 2.85%, respectively. (Ref. 5.31)

4.1.8 Average Depth to Repository

The average depth from the surface to the repository is about 250m. This value is approximated from Figures O-1 and O-2 in Reference 5.15.

4.1.9 Ambient Dust Conditions

The average and maximum dust conditions at Yucca Mountain are 0.01 mg/m^3 and 0.15 mg/m^3, respectively. This information from Reference 5.16, page 12 is existing data and does not need to be confirmed. The values are considered to be reasonable and reasonable values are all that are required for the purposes of this analysis. However, the Ventilation System Description Document(Ref. 5.6, 1.2.2.1.7) has requested this information(TBD-240).

4.1.10 Ventilation Rates

The East Main ventilation rate will be approximately 240 m^3/s during development. Each tunnel boring machine (TBM) and roadheader will require 17 m^3/s and 35 m^3/s, respectively, of this total flow. Only a portion of the 240 m^3/s flow is required by the TBM(s) and roadheader(s), the remainder is used to dilute dust generated during the excavation operations and to supply air to other operations. This information from Reference 5.17, page IV-7 is existing data and does not need to be confirmed. The values are considered to be reasonable and reasonable values are all that are required for the purposes of this analysis.

4.1.11 Ducting Leakage Rates

Ducting can have a 15% leakage rate even with good ventilation practice. The average leakage rate is 25%. Reference 5.3, page 529 quotes these values for overall ventilation systems, which includes airflow in excavated openings and ducts. However, air flow in the repository will not permit significant recirculation and therefore, these values were adapted for flow through ducting, ducting being the only way that recirculation could occur in the repository. These values are for short lengths of ducting; ducting lengths of 5,000m or 10,000m should produce much more leakage.

4.1.12 Predicted Respirable Dust Concentrations

The maximum predicted respirable dust concentration is 2.7 mg/m^3 during excavation (Ref. 22, Exhibit I). A representative dust concentration for drifts and mains of 0.04 mg/m^3 was selected from a day in Reference 5.22, Exhibit I, when no excavation activities were occurring. This dust concentration would thus be due to the movement of people and equipment around the drifts. This information from Reference 5.22 is existing data and does not need to be confirmed. The values are considered to be reasonable and reasonable values are all that are required for the purposes of this analysis. However, the Ventilation SDD (Ref. 5.6, 1.2.2.1.7) has requested this information be determined (TBD-240).

4.1.13 Dust Scrubber Efficiency

Comparative examples in this analysis use 90 or 95 % efficiency for most of the respirable dust range of <5 microns for both wet and dry scrubbers. Figure 7 in the analysis (Ref. 5.19, page 11-3), shows this graphically. Both types of scrubber can have a 90% efficiency for the respirable dust range using curves in Figure 7. If other scrubber curves are used, the efficiency increases to 95% for most of the respirable dust range. Higher efficiencies can be achieved by modern equipment. These efficiencies were chosen to be conservative values, but still reasonable.

4.1.14 Allowable Radon Exposure

The maximum allowable radon exposure is 1.0 Working Level (WL). The annual exposure limit is 4 Working Level Months (WLM). (Code 4.4.1)

4.1.15 Permissible Heat Exposure Threshold Limit Values - Wet Bulb Globe Temperature (WBGT)

Permissible heat exposure threshold limit values - WBGT (Celsius) from Code 4.4.3 are:

Work-Rest Regimen	Light	Moderate	Heavy
Continuous Work	30.0°C	26.7	25.0
75% Work, 25% Rest, Each Hour	30.6	28.0	25.9
50% Work, 50% Rest, Each Hour	31.4	29.4	27.9
25% Work, 75% Rest, Each Hour	32.2	31.1	30.0

4.1.16 Air Temperature at Stations 1 + 70 and 28 +26

The dry bulb air temperature variation for the period April 1996 to January 1997 was determined from daily temperature readings at two underground locations. At Station 1 + 70 the variation was 7°C to 28.8°C and for Station 28 +26 the variation was 22.2°C to 27.2°C.

This information from Reference 5.11 is existing data and does not require confirmation as the information is used only to establish the fact that underground temperature does not vary as much as surface temperature. Station 1+70 is near the South Portal and Station 28+26 is at the repository level.

4.2 Design Criteria

Reference used: *Subsurface Ventilation System Description Document (Ventilation SDD)* - Ref. 5.6.

4.2.1 The system shall comply with the applicable provisions of 29 CFR 1926, Safety and Health Regulations for Construction (Ventilation SDD, 1.2.6.2). The Ventilation SDD, 1.2.6.1 refers to 29 CFR 1910 (4.4.6). As applicable portions of 29 CFR 1910 which deal with air quality are duplicated in 29 CFR 1926, it is not considered further in this analysis.

4.2.2 The system shall limit the maximum dry bulb temperature to 48°C (118.4°F) (TBV-321) for subsurface areas during human access. For subsurface areas requiring human access for a full shift (i.e., not to exceed eight hours) without personnel heat stress protection, the system shall limit the maximum effective temperature to 25°C (77.4°F) (TBV-321). (Ventilation SDD, 1.2.1.3). The 48°C requirement is for human access for brief periods of time.

4.2.3 The system shall provide a minimum quantity of fresh air (surface ambient) to accommodate a maximum of 305 persons on the development side and a maximum of 152 persons on the emplacement side. (Ventilation SDD, 1.2.1.1)

4.2.4 The system shall meet all the performance criteria while subjected to the natural environments as shown:

Annual Temperature Range: -15 to 47°C (Ventilation SDD, 1.2.2.1.7)
Annual Humidity Range: (TBD-240)

4.2.5 The system shall be capable of controlling concentrations of radon daughters to less than 0.1 WL (working level) in the pre-filtered exhaust air sample for the development and emplacement areas. (Ventilation SDD, 1.2.1.9)

4.3 Assumptions

References used: *Controlled Design Assumptions Document (CDA)* - Ref. 5.5 and *Repository Layout Configuration Analysis* - Ref. 5.9. The basis for CDA information is included in the CDA.

4.3.1 Drift Diameter and Minimum Air Velocity

The emplacement drifts are 5.5m diameter (Ref. 5.9, Figure 7-20) and the minimum air velocity is 0.51 m/sec (100 ft/min) (Ref. 5.5, CDA, DCSS 017). This assumption is not confirmed as the information is used to establish a ventilation rate for an example. The example was used for comparison purposes. [Used in Attachment II]

4.3.2 Material Restrictions

Organic materials are restricted for use as rock support and other post-closure permanent materials in all openings. (Ref. 5.5, CDA, DCSS 027) [Used in Sec. 7.2 and 7.8.1]

4.3.3 Average Surface Humidity and Temperature

The average annual surface humidity and temperature are:

	Humidity	Temperature	
Annual Average:	54%	12.7°C	(Ref. 5.5, CDA, TDSS 021) (TBD-240)

[Used in Sec. 7.4]

4.3.4 Rock Thermal Gradient and Surface Rock Temperature

The rock surface temperature is an average of 18.7°C. (TBD-240)

The thermal gradient in the rock is: 0.020°C/m for depths of 0-150m
0.018°C/m for depths of 150-400m
0.030°C/m for depths of 400-541m
(Ref. 5.5, CDA, TDSS 002)

The thermal gradient information need not be confirmed as the information is used only to estimate the average rock temperature at the repository level. The rock temperature is used with the average humidity in Section 7.4 to show approximate underground conditions. [Used in Sec. 7.3]

4.3.5 Surface Humidity

Surface Air Humidity: Max. 71%, Min. 13% (Ref. 5.5, CDA, TDSS 021). (TBD-240) [Used in Sec. 7.4]

4.4 Codes and Standards

4.4.1 <u>30 CFR Part 57.5037-57.5040</u> (1997)

Safety and Health Standards- Underground Metal and Nonmetal Mines. Revised as of July 1, 1997. Although this code is not applicable to the repository, it is included for information and for guidance in certain areas not covered by codes 4.4.2 or 4.4.3.

4.4.2 29 CFR Part 1926 (1997)
Underground Construction. Revised as of July 1, 1997.

4.4.3 American Conference of Governmental Industrial Hygienists (ACGIH) (1997)
1997 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.

4.4.4 DOE Order 440.1A (1998)
Worker Protection Management for DOE Federal and Contractor Employees

4.4.5 10 CFR Part 60 (1997)
Disposal of High-Level Radioactive Waste in Geologic Repositories

4.4.6 29 CFR Part 1910 (1997)
Occupational Safety and Health Standards. Revised as of July 1, 1997.

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6. USE OF COMPUTER SOFTWARE

Computer software was not used for this analysis.

7. DESIGN ANALYSIS

Underground facilities have limited avenues of ingress and egress and thus a satisfactory level of air quality is very important to the maintenance of a safe working environment for personnel and a "clean" environment for equipment operation. The limits for oxygen content, temperature, humidity, concentrations of dust, silica and other contaminants have been established - either by Department of Energy Order (4.4.4) or by good operating practice. This analysis will evaluate and discuss these limits as to their effect on repository personnel and operations. This analysis will consider the unique operating environment in the repository and either adopt the limits as stated in Section 4 or propose new limits.

The analysis will discuss how the air quality control limits will be established and maintained. The air quality limits will either be controlled by operational procedures or by equipment. These controls will be described.

An important consideration in the analysis is a determination of when and under what conditions (if any) the limits could be exceeded. That is, are they absolute limits or operating limits? The effects of going beyond these limits on the repository and personnel will be discussed.

7.1 Air Quality Control Limits

Table 2 shows the air quality control limits which have been established by regulation.

Table 2
Air Quality Control Limits

Air Quality Parameter	Limit	Sources of Limit
Oxygen Content	At least 19.5% by volume	4.4.2
Temperature	A maximum of 25° C(TBV-321) effective	4.2.2
Humidity	None	
Dust Concentration	Depends on dust type	4.4.3
SiO_2 (Silica) Concentration	0.1 mg/m³ Quartz, 0.05 mg/m³ Cristobalite*	4.4.3 (4.1.4)
Other Contaminant (Gas) Concentration	Varies by Contaminant	4.4.3

Notes: * Threshold Limit Value-Time Weighted Average (TLV-TWA) based on an 8 hour day, 40 hour week.

7.2 Oxygen Content

Normal air has an oxygen content of about 21% by volume (4.1.5). The oxygen in the air is affected by respiration of personnel, high temperature oxidation (internal-combustion engines), and low temperature oxidation of wood or minerals.

The use of organic materials for the repository will be limited (4.3.2) and thus will not be available for oxidation. The individual members of the Paintbrush Tuff along the Access Ramps and at the repository level (Ref. 5.8, page A1) are principally composed of basal crystal-poor rhyolite and capping crystal-rich quartz latite (Ref. 5.7, page F1). The composition of the phenocrysts are sanidine, oligoclase, biotite, clinopyoxene, and magnetite. Since the quartz (SiO_2) and other minerals are already oxidized (Ref. 5.13) - the oxygen in the air will have a limited ability to further oxidize the minerals. Therefore, low temperature oxidation in the repository will be limited and can be ignored in terms of air quality.

The use of internal-combustion engines in the repository is not banned but may be restricted to reduce the amount of combustion products which might be deposited on the underground surfaces. Therefore, high temperature oxidation will have a limited effect on overall oxygen demand. Internal-combustion engines, if used, would require additional air quantities than those sited below.

The oxygen content of the air will be reduced by respiration. However, the minimum amount of air required per worker is small compared to the total volume of air circulating in the repository. The volume of air required for development is:

305 workers (Criteria 4.2.3) x 5.7 m^3/min x 1 min/60 sec (4.1.3) = 29 m^3/sec
Air intake to Development Side (4.1.2) = 177 to 267 m^3/sec

The intake air will be split and divided in various areas in the repository, and thus the value cited above will be reduced. However, the requirement is small compared to the total air flow quantity of 177 m^3/sec+ and thus oxygen deprivation will not be a concern under normal operating conditions. Therefore, 19.5% (4.1.6) is a reasonable lower limit for oxygen content of the air. According to the above calculations, the limit should be easily achieved in the repository. Since the 19.5% (4.1.6) is mentioned in worker safety law (4.4.2) it should be considered an absolute lower limit. No work must occur below this level, and work in progress must stop if the level is reached. There should be no other effects that could result from a low level of oxygen other than stoppage of work. Work should be able to resume when the oxygen level is raised by improving the ventilation flowing through the affected area.

Good operating practice would impose a margin above the 19.5% oxygen level to ensure that no workers were exposed below the 19.5% level. An action level of 20.25% is recommended as a level when continuous monitoring should begin. This level is chosen as it is half way between 21% and 19.5%. The continuous monitoring will provide information to assess whether or not the work should be restricted or stopped. This action level will ensure that repository management will have sufficient time to react to conditions which might deplete the oxygen content of the air.

7.3 Temperature

Table 3 has been taken from Design Parameter 4.1.15.

Table 3
Permissible Heat Exposure Threshold Limit Values (WBGT)*

Work-Rest Regimen	WBGT (Celsius) (4.1.15) Work Load		
	Light	Moderate	Heavy
Continuous Work	30.0	26.7	25.0
75% Work, 25% Rest, Each Hour	30.6	28.0	25.9
50% Work, 50% Rest, Each Hour	31.4	29.4	27.9
25% Work, 75% Rest, Each Hour	32.2	31.1	30.0

Note: * Wet Bulb Globe Temperature Index (WBGT) = 0.7 x Wet-Bulb + 0.3 x Globe Temp. This table is for acclimatized workers working an 8 hour day/40 hour week and should be adjusted downward for unacclimatized workers. This table is the current recommendation of the ACGIH. A proposed change by this organization would lower some values slightly. However, this analysis will use the recommended values until such time as the change is made. The proposed change should generate comments from industrial hygienists and others which may cause a revision to the proposed values.

Table 3 presents a concise picture of temperature versus level of effort. The WBGT is more difficult and time consuming to acquire than effective temperature (Ref. 5.10, page 1031) and so may not be suitable for use in the repository. A more commonly used measure of temperature is effective temperature. The effective temperature is not the same as the WBGT although it is similar. The WBGT is determined as shown in the note above. The effective temperature is a comparison of the wet-bulb, dry-bulb, and air velocity. Both scales automatically account for humidity by their collection method.

The effective temperature is an empirically based scale as shown in Figure 1. An example is given in the Figure to show how the effective temperature is derived from temperature and air velocity.

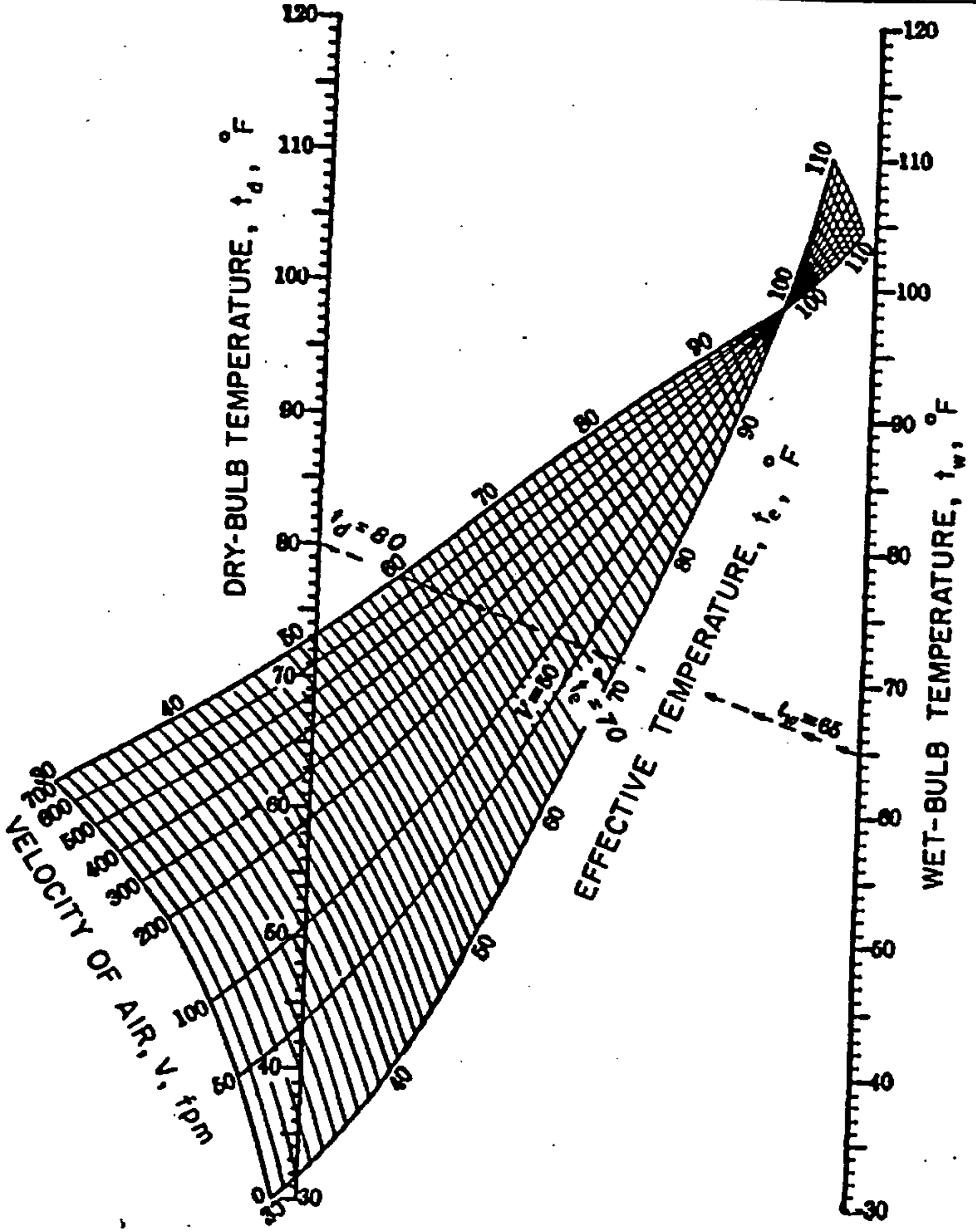

Figure 1 Effective Temperature Scale

Basic chart for men stripped to the waist and at rest or doing light work. Example: given t_d = 27°C (80°F), t_w = 18°C (65°F), V = 0.25 m/s (50 fpm); read t_e = 21°C (70°F) (Ref. 5.3, pg. 613)

Reference 5.10, page 1031 gives the following guideline for effective temperature:

> "A good standard to use is to try to maintain effective temperature between 21°C and 26.5°C. Between 26.5°C and 30°C, some means should be taken to provide cooling, and 30°C should be the maximum ET allowed before cooling is provided."

The 25°C (TBV-321) mentioned in Design Criteria 4.2.2 as the maximum effective temperature allowed under most conditions appears to follow this rule. Code 4.4.4 indicates that the ACGIH is to be followed for temperature. Since an effective temperature value of 25°C (TBV-321) (4.2.2) matches the lowest temperature given in Table 3, using effective temperature for the repository should meet the intent of Code 4.4.4. Therefore, an effective temperature of 25°C (TBV-321)(4.2.2) should be the maximum temperature allowed before some form of cooling should be provided. Cooling could include colder ventilation air, ice vests, or limited exposure for the workers. Since personnel can work at effective temperatures above 25°C (TBV-321) (4.2.2) with some discomfort, the 25°C (TBV-321) (4.2.2) level should be considered an operating limit. This limit could, with appropriate controls, be exceeded without adversely affecting the health or safety of the workers.

The average rock temperature at the repository level is calculated as follows:

Average surface rock temperature:	18.7°C (TBD-240) (4.3.4)
Average depth from surface to repository:	250m (4.1.8)
Rock thermal gradients:	0.020°C/m 0-150m, 0.018°C/m 150-400m (4.3.4)

$$18.7 + (150 \times 0.020) + (100 \times 0.018) = 23.5°C$$

The rock at the repository level will act as a moderating influence on the temperature. Design Parameter 4.1.16 demonstrates this by comparing the temperature in two different alcoves, one at Station 1+70 and the other at Station 28+26. The temperature at Station 1+70 varied between 44.6°F and 83.9°F (7.0°C and 28.8°C) dry bulb for the period April 1996 to January 1997. The temperature at Station 28+26 varied between 72.0°F and 81.0°F (22.2°C and 27.2°C) dry-bulb during the same period. The thermometer at Station 1+70 was more affected by the temperature outside the portal (as it is closer to the surface) than the one at Station 28+26. In the absence of other factors that could change air temperature, proximity to the portal would govern.

After the start of emplacement of the waste packages, the rock temperature on the emplacement side of the repository will increase. The air will generally increase in temperature as it goes through the repository. This increase in heat load may require cooling of the air, but specific recommendations for air cooling are outside the scope of this analysis. Additional analyses must be performed to determine the expected rock temperature before any conclusions can be drawn concerning cooling requirements for the emplacement side of the repository.

Equipment and lighting will contribute greatly to the heat load on the construction or development side of the repository. The ventilation air and dust suppression water will remove the majority of the heat generated by equipment and lighting. However, the operating environment near the equipment will be warmer than other subsurface areas as the heat removal is a constant flow process. Heat is being generated and removed continuously from the TBM in semi-equilibrium with cooler parts of the repository.

A recommendation for the lower limit for the effective temperature is not made. That is, no arbitrary temperature will be set for the lower limit. Workers should dress appropriately for the work they will perform underground. Some jobs will be more strenuous than others and thus have different clothing requirements to provide the appropriate level of worker comfort.

A recommendation for a maximum dry-bulb temperature limit will follow the Ventilation SDD value of 48°C (4.2.2).

7.4 Humidity

This section of the analysis will show that humidity should not be a problem for the repository under most operating conditions.

There are no mining regulations concerning humidity nor what constitutes an acceptable level of humidity. High humidity can affect electronic equipment as it makes it susceptible to corrosion and condensation induced problems. However, humidity is not expected to be an area of concern in the repository as shown in Figure 2. Figure 2 is a Psychrometric Chart for 90 kPa (Ref. 5.14), which is the closest chart for the 89.0 kPa barometric pressure found at the repository (4.1.1). The temperature range for the air outside the repository varies between -15 and 47°C (4.2.4) and humidity varies between 13 and 71% (TBD-240) (4.3.5). In order to provide a bounding case the air humidity will be changed to 0 and 100% as these are the minimum and maximum values for humidity. The chart is limited in its range and can not show the bounding conditions in all cases. In the discussion below, some points are different than the bounding conditions for this reason and will be noted with this symbol (^). In order to simplify the following discussion no moisture will exchange between the air and the rock mass. This allows relative humidity and temperature changes to be shown as horizontal lines. All temperatures are dry-bulb and all humidity is relative, unless noted.

Point #1 on the chart represents the average annual air conditions of 12.7°C and 54% humidity (TBD-240) (4.3.3) at the site. As the air travels down the ramp into the repository it will be heated to the average rock temperature of 23.5°C (calculated in Section 7.3) and decrease in humidity as shown at Point #2. If the air continues in an access main, it will exit the repository at about this temperature (it may cool slightly as it rises toward the surface). If the air enters an emplacement drift it will be further heated and will decrease in humidity, Point #3.

As air enters the repository during winter conditions of 0°C(^) and 100% humidity as shown by Point #4, it will undergo heating. Using the same temperature increase as shown above

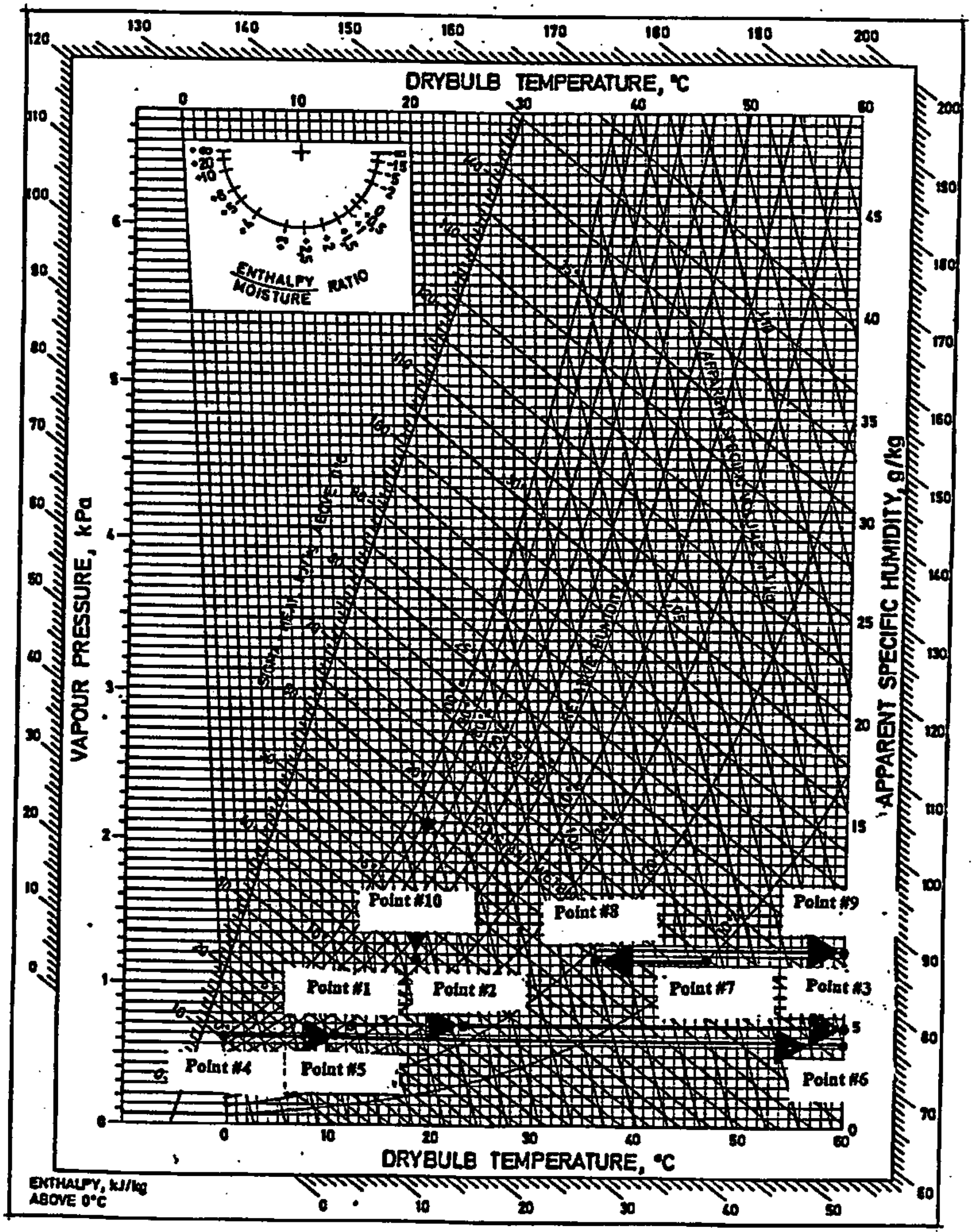

Figure 2 Psychrometric Chart for 90.0 kPa (Ref. 5.14, pg. 90.0)

(23.5-12.7= 10.8°C), the air will be heated (Point #5). The same temperature increase is selected to compare the examples given. To determine the actual temperature increase would require extensive calculations which are outside the scope of this analysis. If the air were to enter an emplacement drift, it would be further heated (Point #6). Air entering the repository during summer conditions of 47°C and 10%(^) humidity, Point #7 would undergo cooling (Point #8). The decrease in temperature is 10.8°C or 36.2°C for Point #8. If the air then entered an emplacement drift, it would be heated (Point #9).

Since the air has been cooled to Point #8 its dew point must be checked to determine if condensation occurs. If the air is cooled below its dew point condensation will occur. In this case the dew point is about 17°C and so moisture will remain in the air. The dew point is reached by traveling up the constant wet-bulb line to 100% humidity and then reading the temperature at that location. Point #10 is the intersection of the dew point temperature line and the extension of the line from Point #8.

Points #1, #2, and #3 are duplicated on Figure 3 for reference. Point #11 represents 0°C and 10% humidity. As this air undergoes 10.8°C heating its humidity will decrease (Point #12). As it undergoes further heating in an emplacement drift (Point #13) it will become even dryer.

Point #14 represents 35°C (^) and 100% humidity. If air at these conditions undergoes cooling to 35-10.8 = 24.2°C, its humidity will remain at 100% but it will lose moisture as it cools (Point #15). If air at 24.2°C and 100% humidity enters an emplacement drift, it will undergo heating and a corresponding decrease in humidity (Point #16).

The right hand part of the Figure 3 shows that the moisture in the air decreases from 41.4 g/kg of air to 21.7 g/kg of air from Point #14 to Point #15. The difference of 19.7 grams of moisture per kilogram of air would theoretically be deposited along the North Ramp as the air travels down to the repository level. If the humidity is temporarily increased due to rain fall, it will cause the air temperature to decrease due to evaporative cooling. Air entering the repository will thus be cooler and still at 100% humidity. This cooler and humid air could condense moisture in the repository but the amount it could condense would be reduced from the figure quoted above. However, the conditions of 35°C (^) and 100% moisture are unlikely to occur because the air is generally hot and dry in Nevada. Therefore, condensation of moisture in the repository is unlikely.

In all the likely examples given, the air flowing through the repository will tend to adsorb moisture and dry out the rock mass. Therefore, the repository should become dryer over time.

There will be high humidity when working near the tunnel boring machine (TBM) but this should be a localized phenomenon. The TBM will generate heat and this heat, combined with the water used for dust suppression, will make the area around the TBM warm and humid. Ventilation air will be used to cool the TBM and to moderate the humidity. Additional sources of water such as scrubbers and dust suppression sprays on conveyors will make the development side of the repository more humid than the emplacement side. The analysis of relative humidity discussed

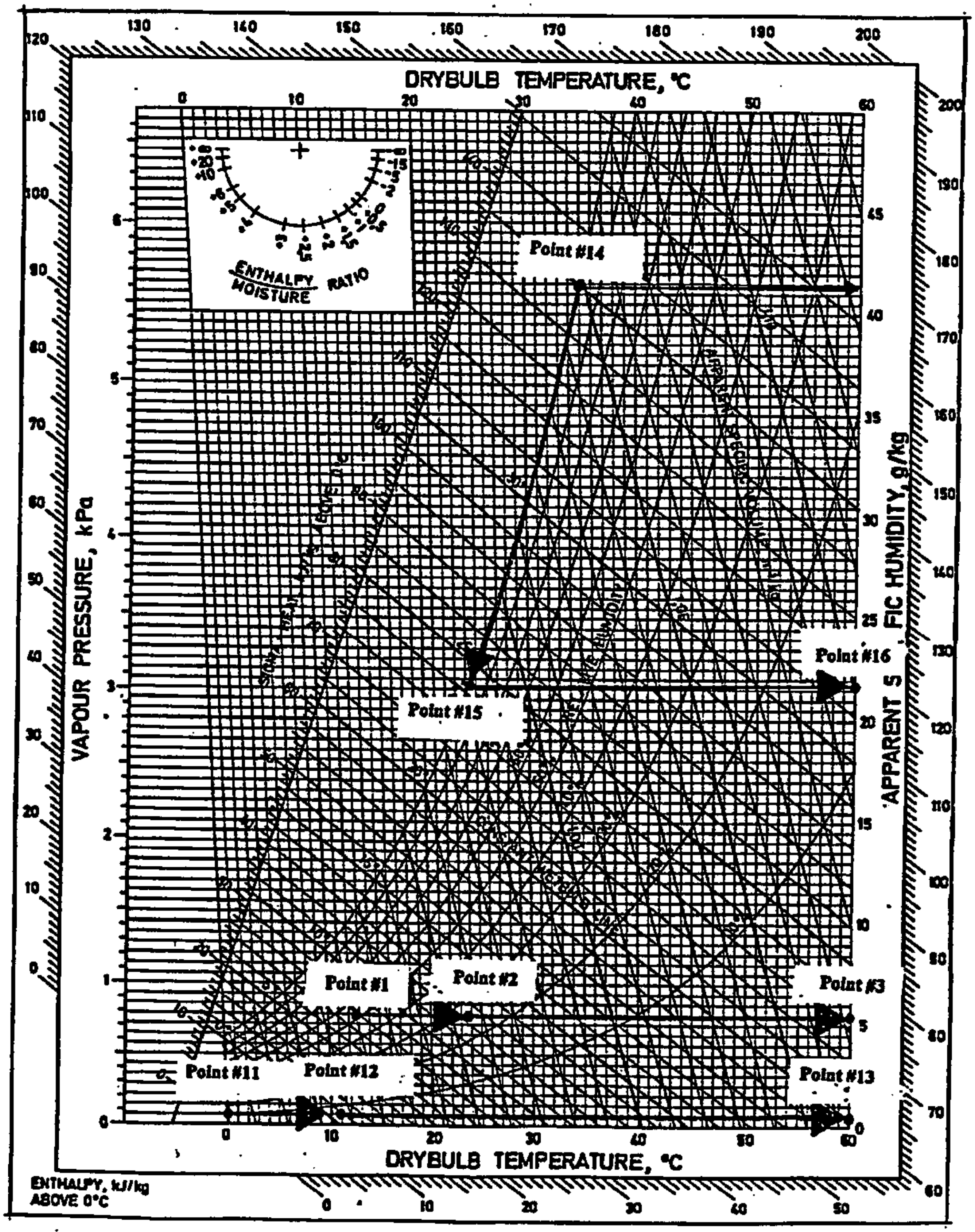

Figure 3 Psychrometric Chart for 90.0 kPa (Ref. 5.14, pg. 90.0)

previously should still apply and, therefore, moisture will be removed from the work areas.

The surface air varies between 13 and 71% relative humidity (TBD-240) (4.3.5). This air will generally be heated and dried when entering the repository during most of the year. Therefore, excess humidity should not be a problem for the repository. Since humidity could theoretically vary between 0 and 100% and, as this range of humidity will have little or no effect on the repository, there should be no limit set for humidity. In addition, the effect of humidity is automatically taken into account by the use of effective temperature.

7.5 Dust Concentration (Dusts Other Then SiO_2)

As per Code 4.4.4, the concentration of dusts will follow the standards of the ACGIH. A representative sampling of these standards is presented in Table 4 for the dusts, other than SiO_2, which are most likely to be encountered in repository construction and operation.

Table 4
Various Permissible Dust Concentrations

Type of Dust	8 Hour Threshold Limit Value (TLV) mg/m^3 (4.1.4)
Aluminum- Welding Fumes	5
Iron Oxide Fume	5
Copper Fume	0.2
Portland Cement (w/no asbestos & < 1% silica)	10
Particulate Not Otherwise Classified (inhalable)	10
Particulate Not Otherwise Classified (respirable)	3
Welding Fumes (not otherwise classified)	5

These ACGIH threshold limit values are limits imposed by Department of Energy Order (4.4.4) and should therefore be considered absolute limits and should not be exceeded unless workers are protected. The protection can be achieved by using portable fan units to disperse the fumes away from the workers and thus dilute the contamination in the general air supply. If fans are impractical or dilution would pose a threat to workers downwind from the fans, then the workers could use a portable oxygen supply, respirator or work only a short time at their tasks to ensure the time weighted average threshold limit values are not exceeded.

7.6 SiO_2 Concentration

Silica or SiO_2 is given a separate section in this analysis because of its toxicity and low TLV level and because of the high percentage of silica in the Paintbrush Tuff (Ref. 5.7, page F1) in which the repository will be located (Ref. 5.8). The low TLV will require special measures to achieve when excavating at the repository level. Because of the importance of achieving low levels of silica in the air, a description of the different forms of silica and its effects on workers is made.

Crystalline silica comes in several forms - among them are Quartz, Tridymite, and Cristobalite (Ref. 5.3, page 89). When small particles of these minerals become trapped in the alveoli in the lungs, the particles become covered in fibrous tissue and thus reduce overall lung capacity. When lung capacity has been reduced, the result is the disease silicosis (Ref. 5.3, page 90). Crystalline silica inhaled in the form of quartz or cristobalite has been identified as carcinogenic to humans (Ref. 5.4).

Standard 4.4.3 sets TLV limits of 0.1 mg/m^3 for Quartz and 0.05 mg/m^3 for Cristobalite and Tridymite. These limits are for the respirable portion of silica. The respirable portion of dust is all particles smaller than 5μm in size (Ref. 5.3, page 86). Codes 4.4.4 and 4.4.2 indicate that the ACGIH values will be followed, and thus these limits should be adopted. Therefore, the time weighted average limits set by the ACGIH are absolute ones and should not be exceeded. If the limits are being exceeded as a result of some activity, that activity must be shut down or additional engineering controls provided.

The limits are based upon an 8 hour day, 40 hour week and therefore could be exceeded for a short period - as long as the average time spent by a worker is below the limit. The composite limit is modified by the amount of Quartz, Cristobalite, Tridymite, and other respirable dust in the air. The limits could be further modified if the gradation of the respirable dust is not similar to the "ideal" distribution given in the ACGIH standard (4.4.3) or if the working day is longer then 8 hours.

The establishment of a limit for silica is further complicated by the difficulty in measuring the composition of dust. A standard method for collecting respirable dust (Ref. 5.21) is National Institute for Occupational Safety and Health (NIOSH) Analytical Method 7500 (Ref. 5.32) which uses a cyclone and filter for sample collection (Ref. 5.27, page 1). The collection point of the sampler is placed in the breathing zone of a worker. The sample is collected over a complete work day so it will include the total exposure of the worker to silica. However, the collected sample is composed of all respirable sized dust, not just silica. Therefore, the sample must be examined by X-ray diffraction techniques which requires days to obtain the concentration of silica.

Direct reading instruments (Ref. 5.29, page 2) are available, but these instruments measure total dust concentration. It is desirable to have the information for silica readily available so that a decision could be made regarding respiratory protection for the workers. The excavation of the mains and drifts will be dynamic events and a dust exposure or limit must be found which responds to changing conditions during excavation. A way to obtain this limit is to develop a value for total respirable dust which takes into account the amount of silica found in the Topopah Spring Tuff (TSw2) formation.

Reference 5.28, page 5 indicates that the composition of the dust samples will be similar to the composition of the wall rock which has been excavated. Reference 5.15 shows that the repository will be located largely in the Topopah Spring lower lithophysal (Tptpll) formation. Borehole data are summarized in Attachment I and average values of minerals (4.1.7) determined as shown below:

Quartz	15.7% (Q)	Tridymite	3.5% (T)
Cristobalite	16.3% ©	Other	64.5% (O)

Reference 5.28, Table 3 gives different values, but the basis of those values was only seven samples. The values from Attachment I are based on more data and should therefore be more accurate.

Using the formula for Threshold Limit Value found in Code 4.4.3 and the TLV limits mentioned above yields the following expression for TLV of the mixture:

$$TLV_{AVG} = \frac{1}{(\%Q/TLV_Q) + (\%C/TLV_C) + (\%T/TLV_T) + (\%O/TLV_O)}$$

$$TLV_{AVG} = \frac{1}{(0.157/0.1) + (0.163/0.05) + (0.035/0.05) + (0.645/3.0)} = 0.174 \text{ mg/m}^3$$

This TLV value was calculated using the average values for the concentrations of the minerals.

For crystalline silica the Permissible Exposure Limit (PEL) is calculated as shown below (Ref. 5.27):

$$PEL_{AVG} = \frac{10 \text{ mg/m}^3}{\%Q + (2 \times \%C) + (2 \times \%T)} = \frac{10}{15.7 + (2 \times 16.3) + (2 \times 3.5)} = 0.181 \text{ mg/m}^3$$

The PEL is a term similar to TLV and has a legal connotation (Ref. 5.3, page 60). The PEL value is very similar to the average TLV calculated and for purposes of this analysis are considered to be the same.

In a worst case situation, where all silica was cristobalite and tridymite, the TLV then becomes:

$$TLV_{WC} = \frac{1}{(0.355/0.05) + (0.645/3.0)} = 0.137 \text{ mg/m}^3$$

This analysis proposes a maximum respirable dust composite TLV of 0.15 mg/m³ be used as guidance during excavation. The 0.15 mg/m³ is an approximate value based upon the amount of silica anticipated to be found in the rock excavated for the repository. This value would be modified if it is found that the respirable dust produced during excavation contains a different percentage of silica than mentioned above. It may be advisable to adjust the TLV based upon daily or weekly sampling conducted during excavation operations as the rock at the repository level is not homogeneous as shown in Attachment I.

The amount of respirable dust would be determined by NIOSH Analytical Method 7500 (Ref. 5.32). This value is different than the set point for direct reading instruments which might be used to monitor the dust created during excavation. The direct reading instruments measure total dust concentration or more properly total small particle concentration. These small particles could include diesel fumes, water droplets or atmospheric dust (which may not contain silica). The mg/m^3 measured by a direct reading instrument could therefore be different then the 0.15 mg/m^3 mentioned above.

The 0.15 mg/m^3 value is the average value which a worker can continuously be exposed to for 8 hours without ill effects. This value could be exceeded for part of a day - as long as the average was not exceeded over the course of a day. It will still be necessary to perform laboratory work on collected samples to confirm compliance with standards. If this value is consistently exceeded then additional engineering controls should be implemented to reduce the exposure. A respirator could be used as a temporary solution to protect the workers until additional controls are put in place.

7.7 Other Contaminant Concentration

Other contaminant concentration means concentrations of gases. As per Code 4.4.4, the concentration of gases will follow the standards of the ACGIH. A representative sampling of these standards is presented in Table 5 for the gases which would most commonly be encountered in mining applications. Radon is not listed in the table, but it is discussed separately below because its permissible exposure is measured differently.

Table 5
Various Permissible Gas Concentrations

Type of Gas	8 Hour Threshold Limit Value (TLV) mg/m^3 (*ppm*) (4.1.4)
Carbon Monoxide	29 (*25*)
Carbon Dioxide	9000 (*5000*)
Nitrogen Dioxide	5.6 (*3*)
Nitrous Oxide	90 (*50*)
Ozone (Heavy Work)	0.1 (*0.05*)
Sulfur Dioxide	5.2 (*2*)

The ACGIH threshold limit values are imposed by the Department of Energy (4.4.4), and are therefore considered absolute time weighted average limits, not to be exceeded without protection for the personnel.

Radon is a gas formed from the decay of radium. This gas forms in rock containing radioactive elements and escapes into the atmosphere thru joints or cracks. Radon is a chemically inert gas but it decays and produces alpha and beta particles plus gamma-ray activity. The alpha and beta particles can become trapped in the lungs or throat and cause cancer. Code 4.4.1 indicates that the maximum radon exposure for personnel is 1.0 working-level (WL) (4.1.14) with a cumulative yearly exposure of 4 working-level months (WLM) (4.1.14). A working-level is defined as the concentration of radon decay products per liter of air which will produce 1.3×10^5 million electron volts (Ref. 5.3, page 47). Code 4.4.1 indicates that samples for radon must be taken in the exhaust air stream. If the sample is greater than 0.1 WL, then additional samples must be taken in work areas. This analysis proposes that the 0.1 WL be considered an action level for the repository and that the maximum annual exposure allowed be 4 WLM or 0.33 WLM on a monthly basis (4 WLM/12 months). The 0.1 WL action level conforms to the Ventilation SDD requirement (4.2.5).

7.8 Maintenance of Air Quality Control Limits by Equipment

The maintenance of air quality for gases and dusts can be achieved by (Ref. 5.10):

- Preventing formation at its source
- Preventing dispersal of the dust cloud
- Providing dilution ventilation
- Avoiding the dust

The most practical solution to maintaining gas levels within acceptable limits is dilution. Diesel exhaust scrubbers could also be employed if diesel equipment is used. Dust can be prevented or controlled by any of the methods mentioned above.

The most restrictive TLV is for the respirable fraction of silica dust, and if this limit can be met, all other limits for gases and dusts should also be met. Dust is the most widespread contaminant under normal operations. Other contaminants may pose local problems and these can be controlled at their point of origin. Therefore, the balance of this section will concentrate on the control of dust.

There are five main sources of dust in the repository:

- Dust from excavation
- Dust due to muck transportation
- Dust due to personnel/supply transportation
- Atmospheric dust
- Recirculation of dust from ventilation ducting

Each of these dust sources will be discussed in the balance of this section.

7.8.1 Dust from Excavation

Figures 4 and 5 (Ref. 5.17, pages 56 & 57) show two possible schemes for the control of dust associated with the TBM excavation of an emplacement drift. Both schemes use water sprays at the TBM to suppress dust formation and prevent its dispersal. A scrubber and fan are provided to funnel and collect the dust to prevent dispersal of the dust cloud. The exhausting system sends the dust laden air through a flexible tube to the main drift and thus avoids the drifts' working areas. The blowing system brings fresh air to the drift working areas in a tube and the air exhausted flows back through the drift. The blowing system is preferred as cleaner air is sent to the working areas (Ref. 5.17, page 54) and recirculation of dust laden air can be avoided.

Attachment II is an illustration of five situations or schemes for TBM ventilation. The purpose of Attachment II is to devise different ways to supply air to the TBM and to determine which method produces the least amount of dust in the air at the TBM face. As shown in Attachment II the blowing system schemes produce a lesser amount of dust at the face. These ventilation situations use similar flow rates, scrubber efficiencies, and leakages. The amount of dust produced by the TBM is the same in all cases. This is done only for comparison purposes as the actual rates, efficiencies, leakages and dust concentrations may be different.

The scrubber could include an internal water spray to assist in the removal of dust. Figure 6 is an illustration of one type of wet scrubber. This type of unit requires less maintenance than most other dust filters and a respirable dust removal efficiency of 90%+ can be achieved (Ref. 5.20). As shown in Figure 7 wet and dry scrubbers are ideal for removing the respirable fraction of dust. As shown in the figure dry scrubbers provide a somewhat higher efficiency than wet scrubbers. The ventilation air must be used several times in different operations and therefore if the dust is not removed, the total dust load in the air will increase as the air moves from operation to operation. Recirculation of dust can be avoided by cleaning the air as soon as possible after dust creation.

Surfactant can be added to the water spray to enhance the dust capturing ability of the spray. These agents reduce water surface tension and thus permit more atomization of the water spray. Surfactant also coat the dust particle and counteract electrostatic forces permitting more coagulation of the dust particles (Ref. 5.20, page 793). Organic surfactant should be restricted (4.3.2).

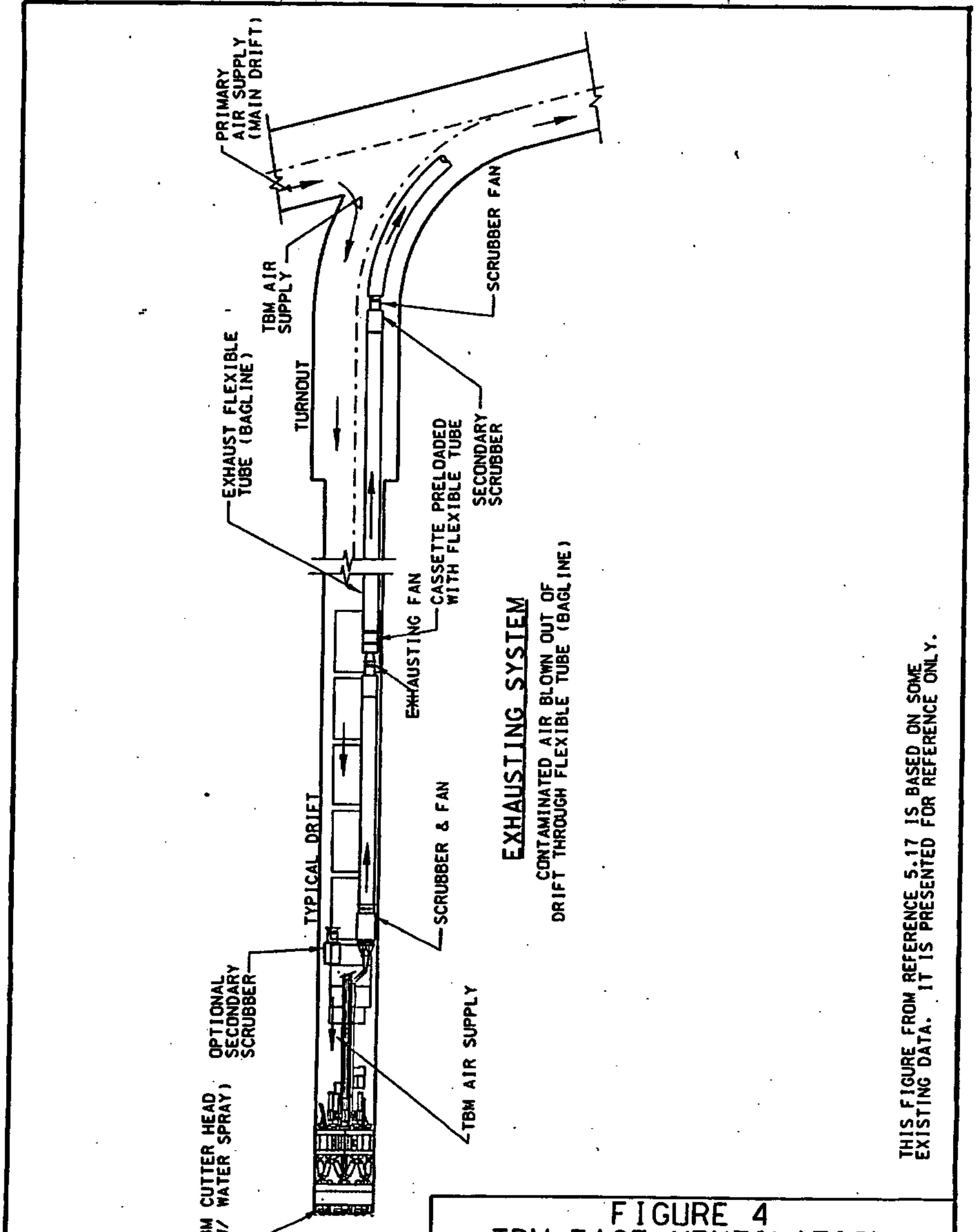

FIGURE 4
TBM FACE VENTILATION
BAGLINE EXHAUSTING SYSTEM

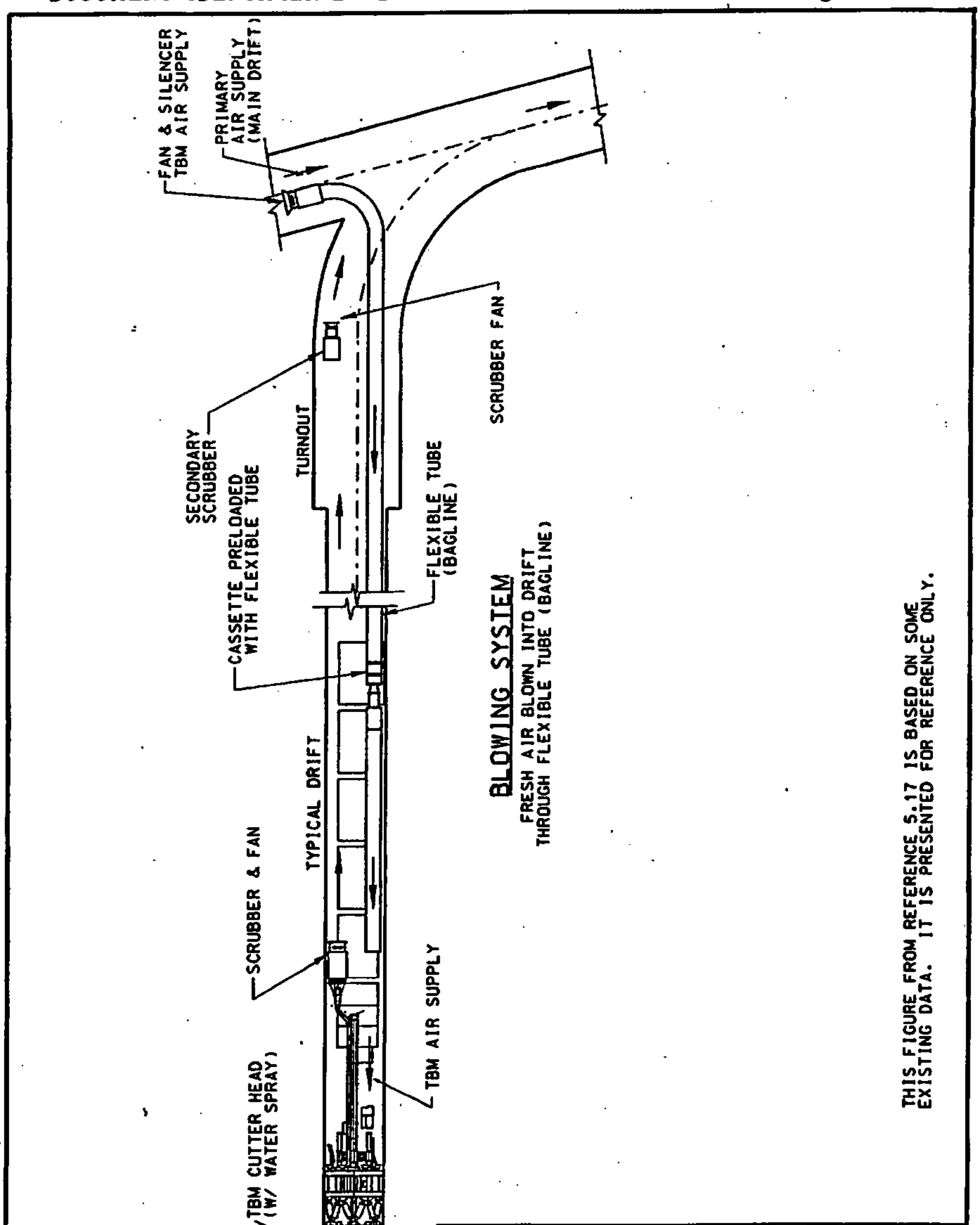

FIGURE 5
TBM FACE VENTILATION
BAGLINE BLOWING SYSTEM

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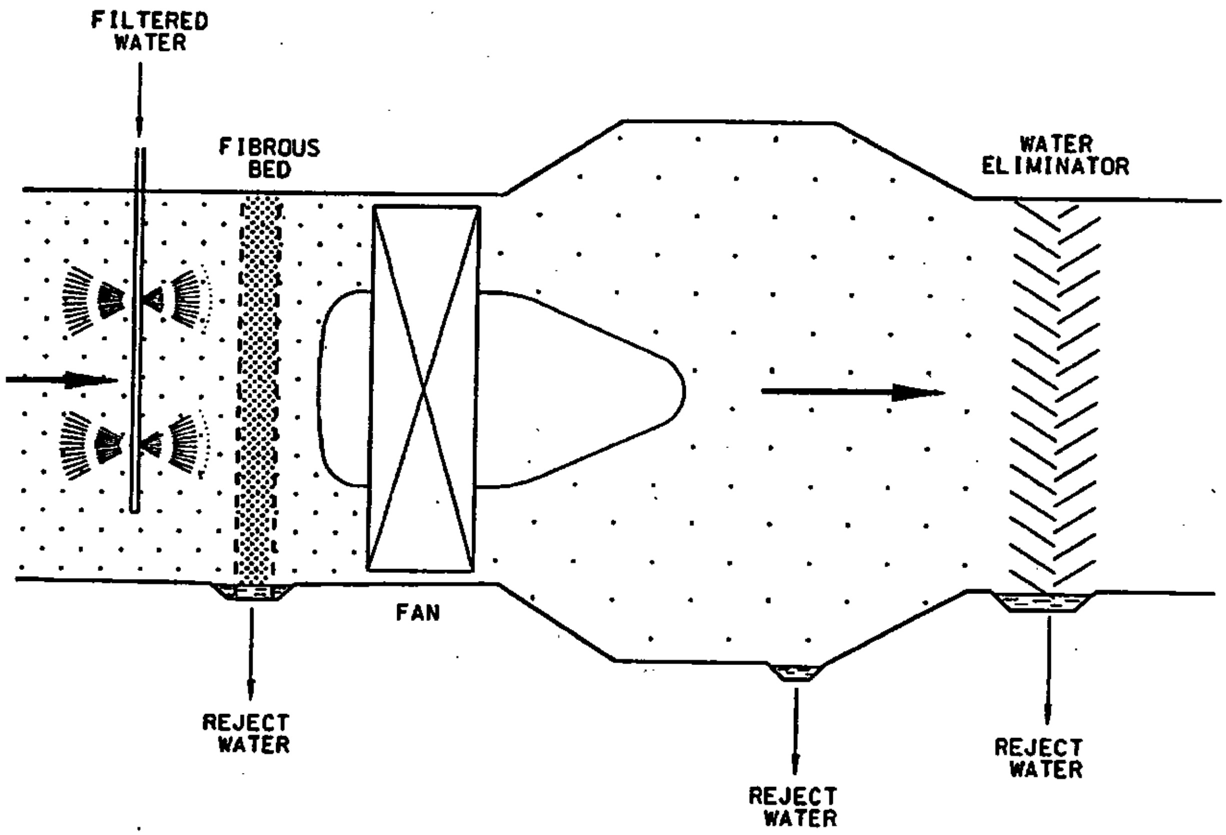
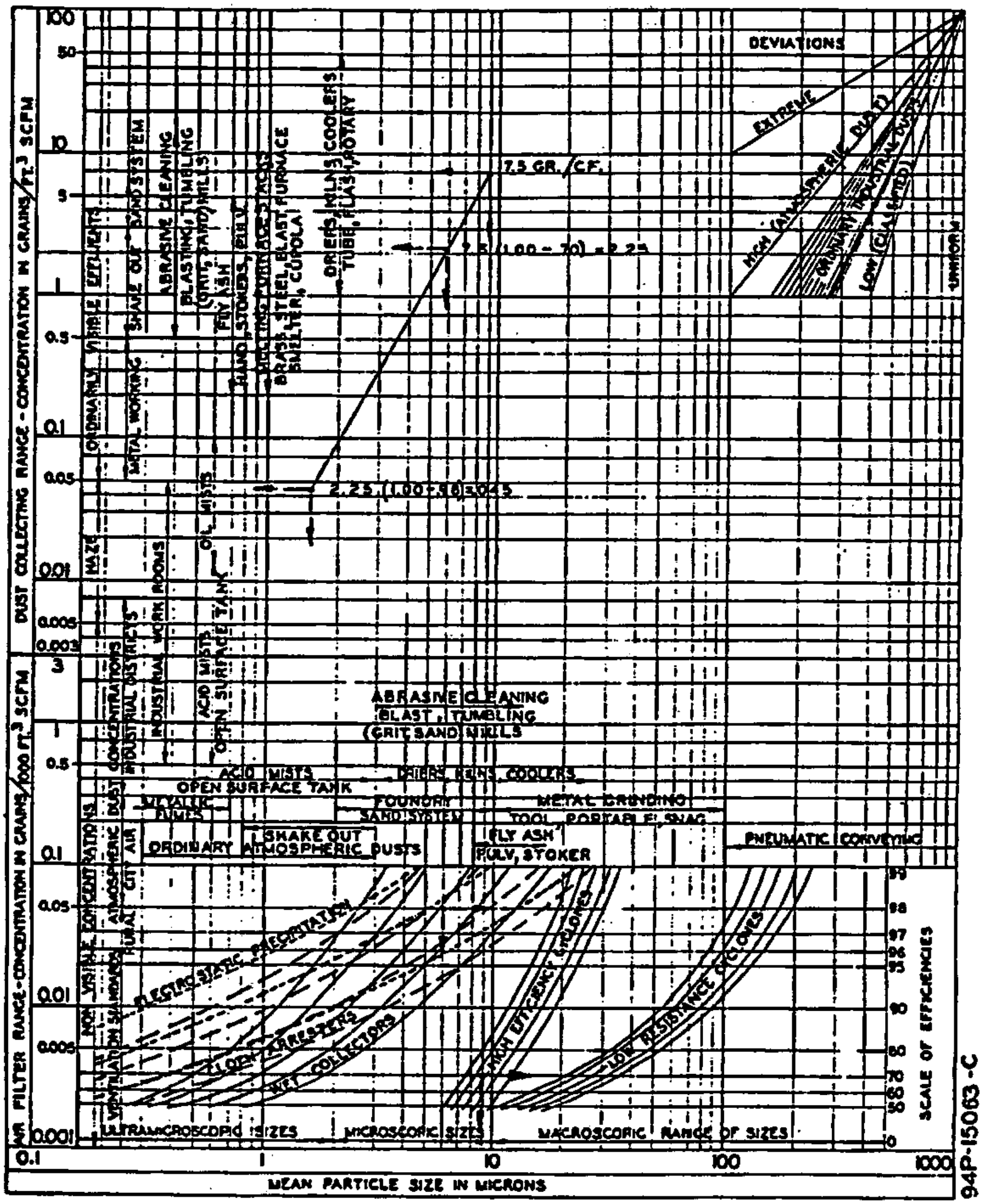


(REF. 5.20)

FIGURE 6
FIBROUS (FLOODED) BED
WET SCRUBBER



RANGE OF PARTICLE SIZES, CONCENTRATION, & COLLECTOR PERFORMANCE

COMPILED BY S. SYLVAN APRIL 1952 : COPYRIGHT 1952 AMERICAN AIR FILTER CO. INC.

ACKNOWLEDGEMENTS OF PARTIAL SOURCES OF DATA REPORTED:

FRANK W.G. - AMERICAN AIR FILTER - SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS - 1931
FIRST AND DRINKER - ARCHIVES OF INDUSTRIAL HYGIENE AND OCCUPATIONAL MEDICINE - APRIL 1952

Figure 7 Range of Particle Sizes, Concentrations and Collector Performance (Ref. 5.19, pg.11-3)

Figure 7 also shows that cloth arresters or cloth filters can be an effective method of controlling dust. Figure 8 illustrates one type of filter (Ref. 5.20, page 804). This filter does not use water and this could be an advantage if the supply of water is limited or if the total amount of water introduced into the repository needs to be controlled. During operation the dust will build up inside the filter forming a filter cake. The filter cake accomplishes most of the filtering and efficiencies of over 95% can be achieved.

Tables 6 and 7 illustrate how much respirable dust could be introduced into the ventilation air due to excavation activities. The tables show two cases using different leakage rates. The tables show respirable dust levels of 0.142 mg/m^3 and 0.178 mg/m^3. These values should be compared to the 0.15 mg/m^3 level discussed in Section 7.6. The figures are for illustration purposes only as actual leakages, scrubber efficiencies, and dust concentrations can be quite different. These tables highlight the importance of low leakage rates and high scrubber efficiencies.

Tables 6 and 7 are not meant to show absolute values of respirable dust. The purpose of these tables is to show that under some conditions the dust concentrations will approach or be higher than the 0.15 mg/m^3 level and that changes could be warranted in the ventilation system. Curtailing operations or providing intermediate dust scrubbers are mentioned above. Other ventilation schemes could decrease the leakage or reduce the amount of dust produced by the TBM by increasing the amount of dust suppression water.

The dust values shown for the exhaust air in Tables 6 and 7 are slightly higher than they should be. The air which is used to supply the TBM's and roadheaders will include dust as part of the air. This dust will be partly removed when it is cleaned by the dust scrubber. No credit has been taken for this removal and thus the exhaust air values are slightly higher (and therefore conservative). The respirable dust level for the roadheader was chosen to be the same as the TBM. The roadheader dust level should be more than the TBM because it is a more open piece of equipment. In this instance equating the roadheader and TBM levels of dust produced does not change the conclusion of the paragraph below.

Tables 6 and 7 are predicated upon an air flow system similar to Figure 5. A positive pressure system similar to Figure 4 would cause recirculation of dust. A blowing type system is preferred as it brings the freshest air to workers at the face (as shown in Attachment II).

The water spray and scrubber arrangement for the access main TBM will be similar to that shown in Figure 5.

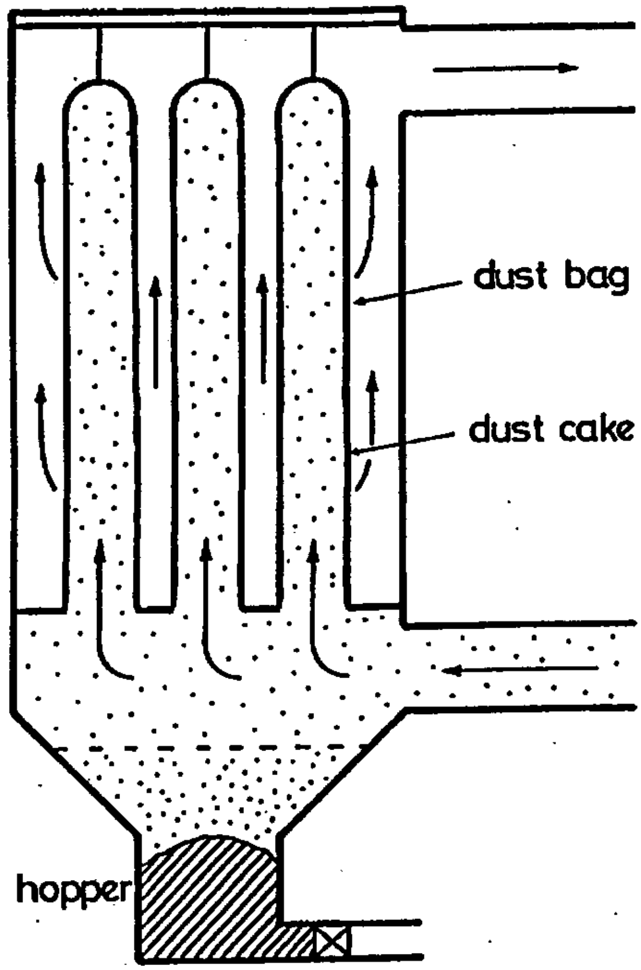


Figure 8 Cloth Filter (Ref. 5.20, pg. 804)

Table 6[10]
Amount of Respirable Dust in Ventilation Air @ 15% Leakage[8]

Source of Dust	Volume (m^3/sec)	Dust (mg/m^3)	Dust (mg/sec)[6]
Outside Air[5]	240[1]	0.01[3]	2.40
Access Mains	240	0.04[4]	9.60
TBM#1			
Leakage @15%[8]	17[1] x .15= 2.55	---	---
Dust Scrubber	17 - 2.55= 14.45	0.135[2]	1.95
TBM#2			
Leakage @15%	17[1] x .15= 2.55	---	---
Dust Scrubber	17 - 2.55= 14.45	0.135[2]	1.95
Roadheader			
Leakage @ 15%	35[1] x .15= 5.25[9]	2.70[7]	14.18
Dust Scrubber	35 - 5.25= 29.75	0.135[2]	4.02
		TOTAL DUST	34.10
Exhaust Air	240	0.142	34.10

Notes: 1) Air volumes from 4.1.10.
2) Dust scrubber is 95% efficient. (4.1.13) (2.7[7] mg/m^3 x 5% = 0.135mg/m^3)
3) Outside air dust concentration from 4.1.9.
4) Access main dust concentration from 4.1.12.
5) Outside air which has been drawn into the repository.
6) Product of column 2 times column 3.
7) Total respirable dust from 4.1.12.
8) Leakage rate from 4.1.11
9) Leakage which bypasses the roadheader scrubber.
10) Calculations using a TBM ventilation system similar to Figure 5 and a roadheader ventilation system similar to Figure 10.

Table 7[10]
Amount of Respirable Dust in Ventilation Air @ 25% Leakage[7]

Source of Dust	Volume (m^3/sec)	Dust (mg/m^3)	Dust (mg/sec)[6]
Outside Air[5]	240[1]	0.01[3]	2.40
Access Mains	240	0.04[4]	9.60
TBM#1			
Leakage @25%[8]	17[1] x .25= 4.25	---	---
Dust Scrubber	17 - 4.25= 12.75	0.135[2]	1.72
TBM#2			
Leakage @25%	17 x .25= 4.25	---	---
Dust Scrubber	17 - 4.25= 12.75	0.135	1.72
Roadheader			
Leakage @25%[9]	35[1] x .25= 8.75	2.7[7]	23.63
Dust Scrubber	35 - 8.75=26.25	0.135	3.54
		TOTAL DUST	42.61
Exhaust Air	240	0.178	42.61

Notes: 1) Air volumes from 4.1.10.
2) Dust scrubber is 95% efficient. (4.1.13) (2.7[7] mg/m^3 x 5% = 0.135mg/m^3)
3) Outside air dust concentration from 4.1.9.
4) Access main dust concentration from 4.1.12.
5) Outside air which has been drawn into the repository.
6) Product of column 2 times column 3.
7) Total respirable dust from 4.1.12.
8) Leakage rate from 4.1.11
9) Leakage which bypasses the roadheader scrubber.
10) Calculation using a TBM ventilation system similar to Figure 5 and a roadheader ventilation system similar to Figure 10.

In Figure 9 the raise connecting the exhaust main with an emplacement drift is shown being reamed. Water sprays are provided at the cutter head and near the gate regulating muck loading into rail cars. Brattice cloths are installed to reduce the velocity of the air flow. During construction ventilation dust will be controlled by local air scrubbers.

Figure 10 shows the roadheader excavating an emplacement turnout. The roadheader will be equipped with water sprays. Strategically placed brattice clothes and fans will direct the air containing dust to dust scrubbers. This activity will take place near the primary access mains and therefore dilution will also be used to reduce the dust concentration. Figure 11 shows an alternative dust control scheme. The roadheader is bracketed by barriers to prevent dust dispersal. A tube between the barriers conveys the majority of ventilation air and keeps this air relatively free of dust.

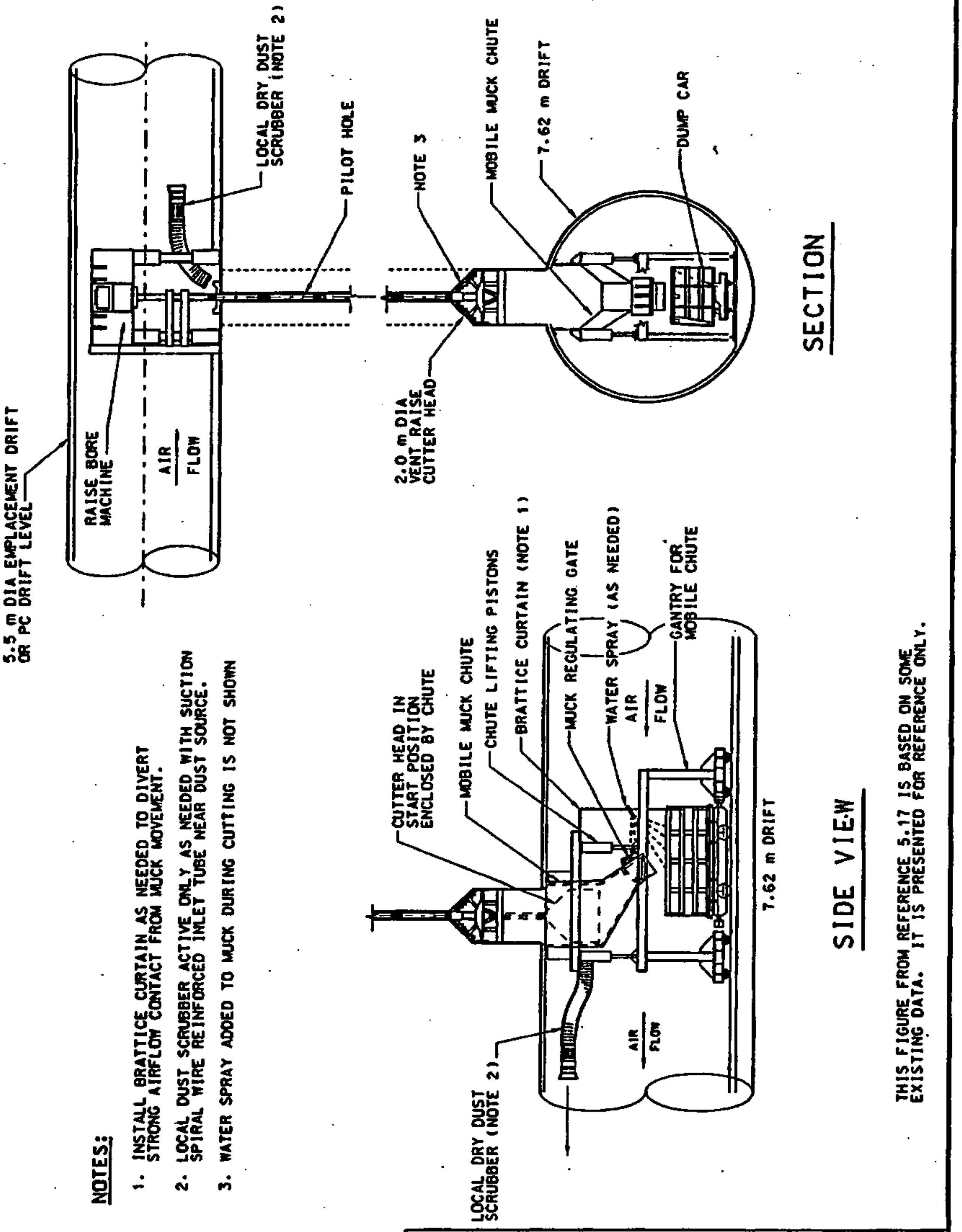
Figure 12 (Ref. 5.30, page 48) shows the excavation of a shaft for the repository. Water sprays will be used extensively to suppress dust formation by the V-mole shaft sinking machine. Ventilation air will be ducted down the shaft to supply workers in the shaft. The muck pile will not be allowed to increase until it closes off the raise as this could cause muck to block the raise. A sump is provided to catch excess water from the muck pile.

Drilling and blasting may be used for excavation. Drilling and blasting activities can be a major source of dust creation and this dust must be suppressed. Drilling operations can use both water or individual dust collectors (for dry drilling) to decrease dust dispersion. During blasting, workers should be moved away from the path dust and fumes might take on their way to the surface. Portable dust collectors could be used to capture the dust after it has been created by blasting. Section 7.9 discusses administrative controls which could be used to avoid worker exposure to dust.

7.8.2 Dust Due to Muck Transportation

Muck will be transported in the repository via conveyor belt and by railcar (Ref. 5.30, page 49). Dust can potentially be generated by the transportation system at any point to include: initial loading point, transfer points, areas of spillage, and by moving the material on the belt or car. Water spray will be the primary method of dust suppression as it is the easiest and most practical method of control. Additional mitigation would be to cover the railcars to suppress dust being generated as they are being transported from the repository.

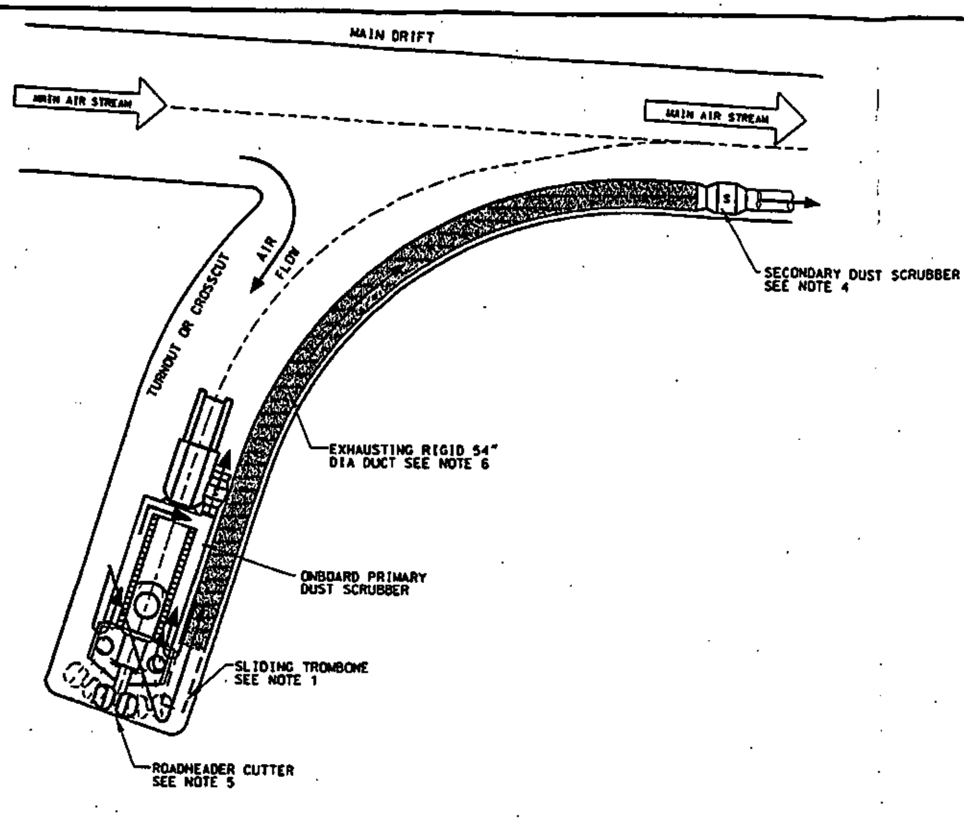
Muck leaving the face is sprayed with water as it is loaded into rail cars. The muck is again sprayed with water when it is loaded onto conveyor belts for removal from the repository. Water sprays are periodically used along the conveyor belt to suppress dust formation as the muck travels out of the repository. Water sprays will be used before and at transfer stations to reduce dust formation (Ref. 5.20, pages 794-799) as shown in Figure 13. Transfer stations should have dust collectors to reduce the amount of dust associated with the transfer operation. If a wet scrubber is used, the dust laden water can flow to the waste water collection line. If a dry scrubber is used the dust can be



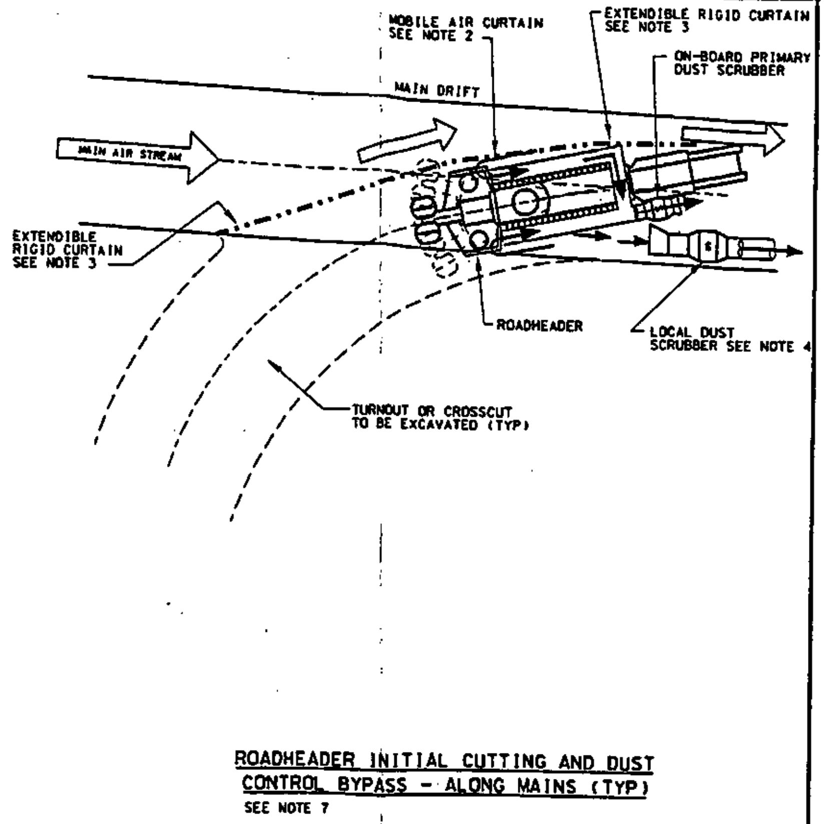
NOTES:

1. INSTALL BRATTICE CURTAIN AS NEEDED TO DIVERT STRONG AIRFLOW CONTACT FROM MUCK MOVEMENT.
2. LOCAL DUST SCRUBBER ACTIVE ONLY AS NEEDED WITH SUCTION SPIRAL WIRE REINFORCED INLET TUBE NEAR DUST SOURCE.
3. WATER SPRAY ADDED TO MUCK DURING CUTTING IS NOT SHOWN

FIGURE 9
MOBILE CHUTE & DUST CONTROL FOR RAISE UPREAMING



ROADHEADER FACE VENTILATION



ROADHEADER INITIAL CUTTING AND DUST CONTROL BYPASS - ALONG MAINS (TYP)

SEE NOTE 7

TYPICAL RELATIONSHIP OF AIRFLOW AND ROADHEADER ADVANCE

NOTES:

1. SLIDING TROMBONE EXTENDS AS CLOSE AS FEASIBLE TO THE FACE. DUST BACKFLOW FROM ROADHEADER CUTTING HEAD WILL EXHAUST INTO DUCT AND INTO DUST SCRUBBER WITHOUT PASSING THROUGH PERSONNEL BREATHING AREA NEAR FACE.
2. MOBILE AIR CURTAIN MOUNTED ON FLAT CAR TO MOVE IN POSITION NOT TO DISTURB ROADHEADER ACTIVITY.
3. RIGID CURTAIN WALL WITH EXTENDIBLE HEIGHT AND LENGTH TO FIT NEEDS OF BLOCKING HIGH VELOCITY AIR INTO ROADHEADER ACTIVITY. CURTAIN HAS GRIPPERS TO STABILIZE POSITION.
4. LOCAL DUST SCRUBBER INSTALLED ALONG DRIFT AS NEEDED.
5. ROADHEADER CUTTING WITH WATER SPRAY ARRANGEMENT WILL BE INCLUDED IN ROADHEADER SPECIFICATION.
6. AIR QUANTITY DELIVERY INSIDE DUCT IS DESIGNED TO PRODUCE NOMINAL 0.6 m/s (118 fpm) OF AIR VELOCITY ALONG DRIFT.
7. ROTATE IMAGE AS NEEDED FOR SPECIFIC ROADHEADER FACE VENTILATION ARRANGEMENT.

THIS FIGURE FROM REFERENCE 5.17 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

FIGURE 10
ROADHEADER FACE VENTILATION

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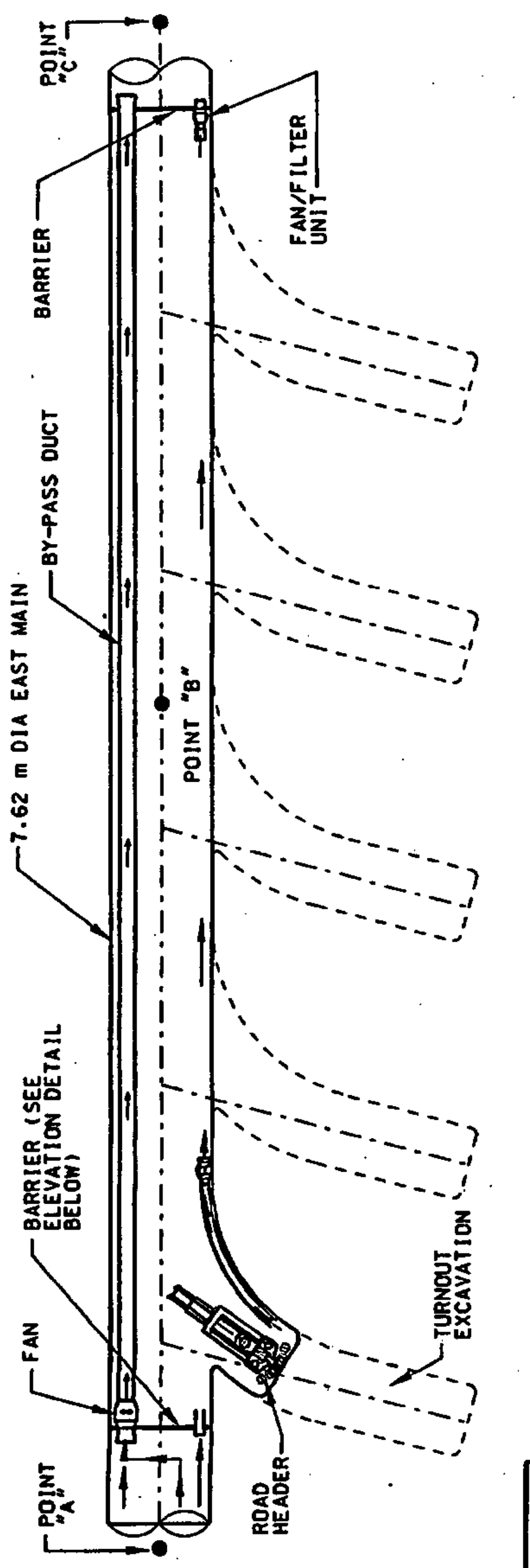
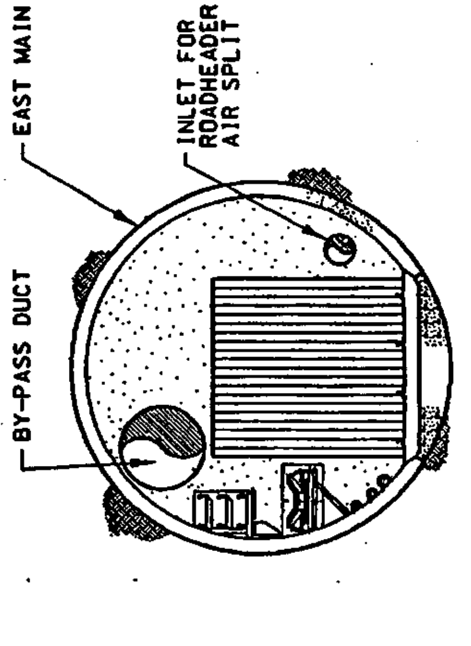


	AIR VOL m^3/s	MG/m^3	MG/sec
FLOW BEFORE BYPASS (POINT "A")	240	0.05	12.0
FLOW IN BYPASS (DUCT) (POINT "B") (DRIFT)	205 35	0.05 0.1355	10.25 4.73
FLOW AFTER BYPASS (POINT "C")	240	0.062	14.98

NOTES:

1. ROADHEADER ARRANGEMENT FOR CUTTING WITH A WATER SPRAY WILL BE INCLUDED IN THE ROADHEADER SPECIFICATION.
2. THIS VENTILATION SCHEME WILL ALLOW THE MAJORITY OF VENTILATION AIR TO BYPASS THE TURNOUT BEING CUT BY THE ROADHEADER.
3. NOTES SAME AS TABLE 6.



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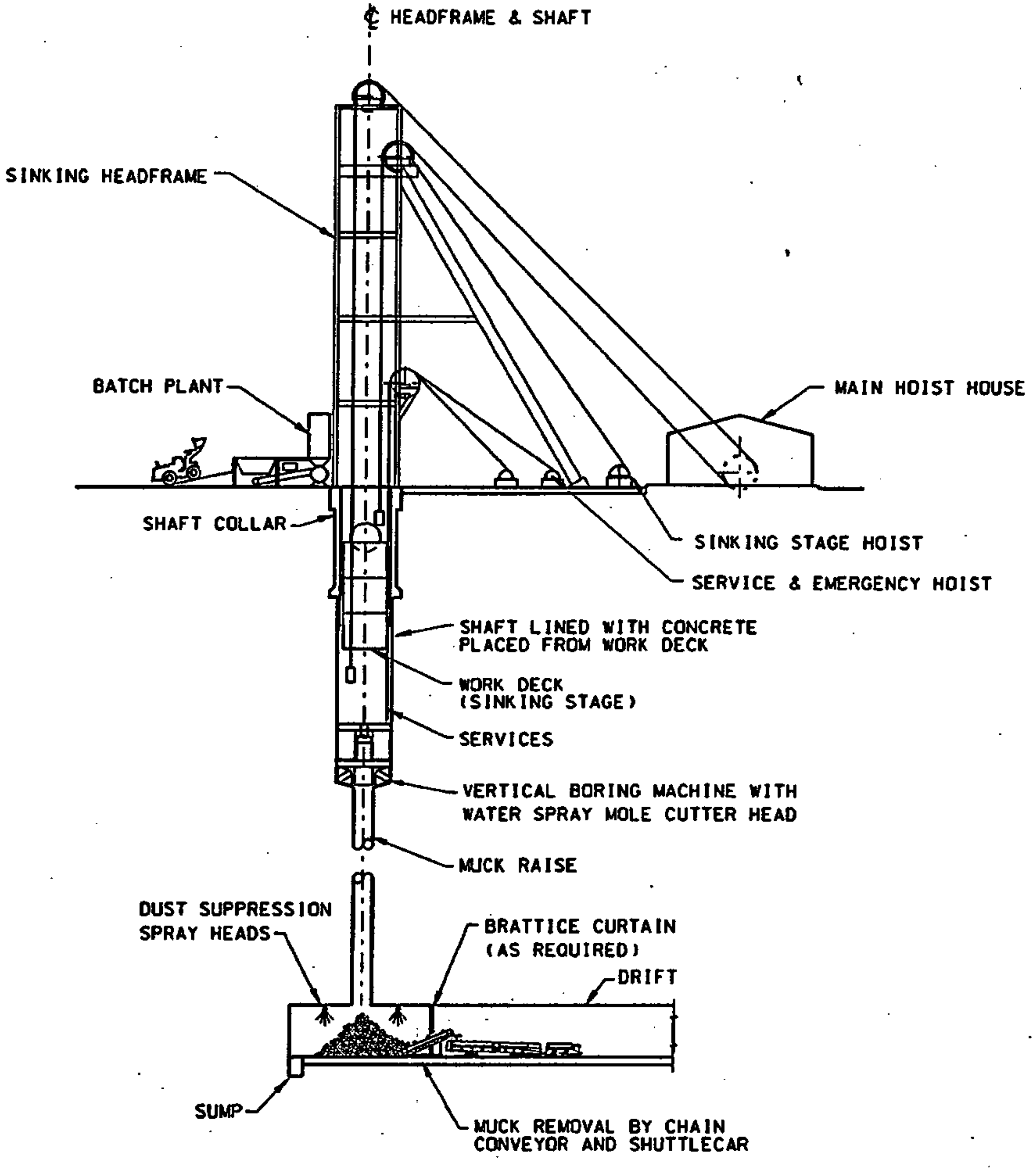
IT IS PRESENTED FOR REFERENCE ONLY.

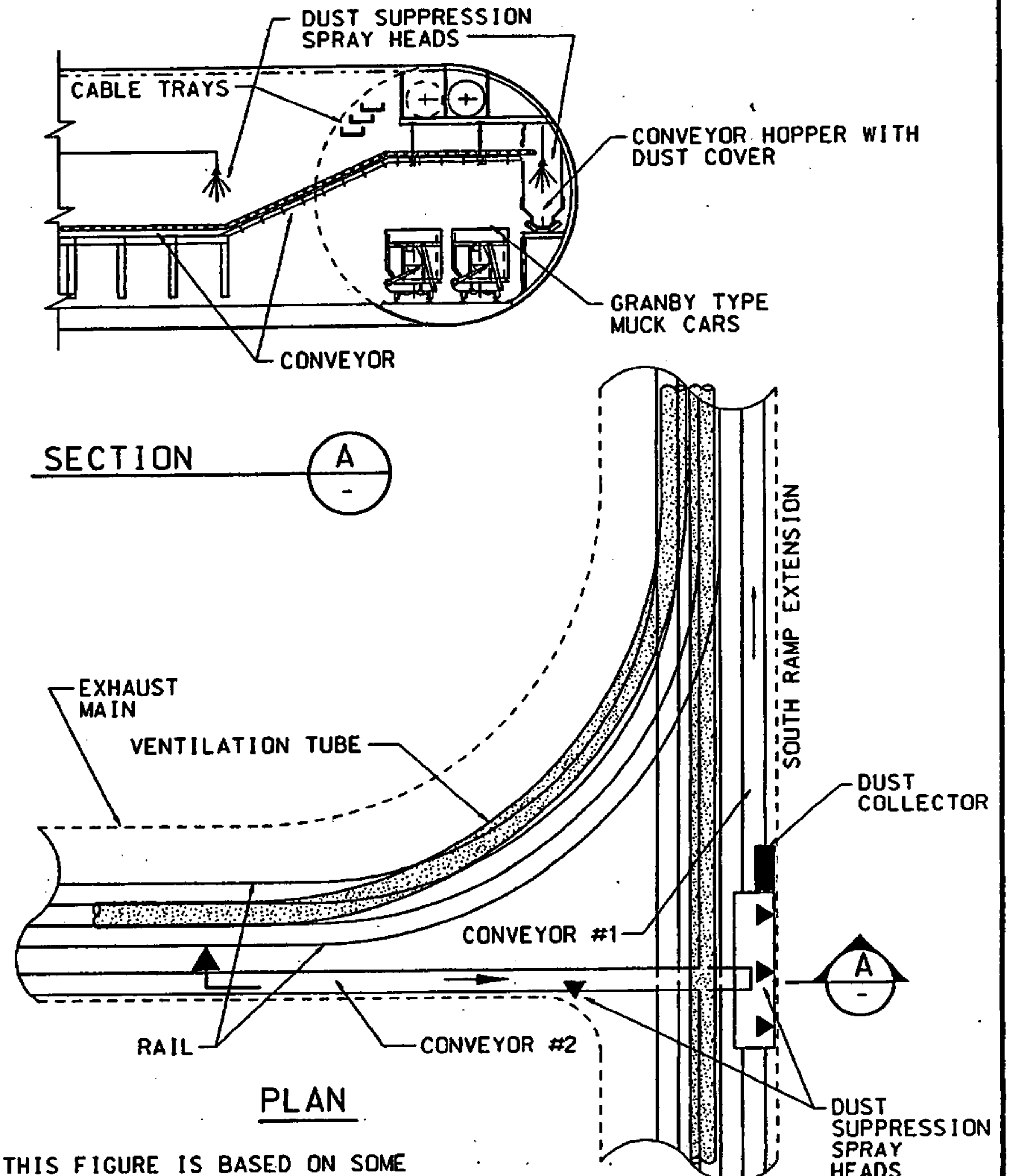
FIGURE 11
ROADHEADER VENTILATION BYPASS SYSTEM



THIS FIGURE FROM REFERENCE 5.30 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

FIGURE 12

SHAFT EXCAVATION SCHEME



THIS FIGURE IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

FIGURE 13
DUST SUPPRESSION AT CONVEYOR TRANSFER STATION

transported out of the repository by railcar as opposed to being dumped onto the conveyor belt. Muck dump points can have portable dust collectors in addition to water sprays to collect dust created by the dumping operation.

Railcars will be regularly cleaned to reduce the amount of dust which will collect on the car. Conveyor belts will be continuously cleaned by belt cleaners after the muck they are transporting is dumped on the surface. The belt cleaner will include a water spray as well as a belt scraping mechanism to ensure the conveyor belt is cleaned prior to its return to the repository.

Dust will be deposited in the drifts due to muck spillage and settlement of dust from the air. Periodic cleaning by vacuuming and washing of drifts and mains is recommended to reduce potential sources of dust.

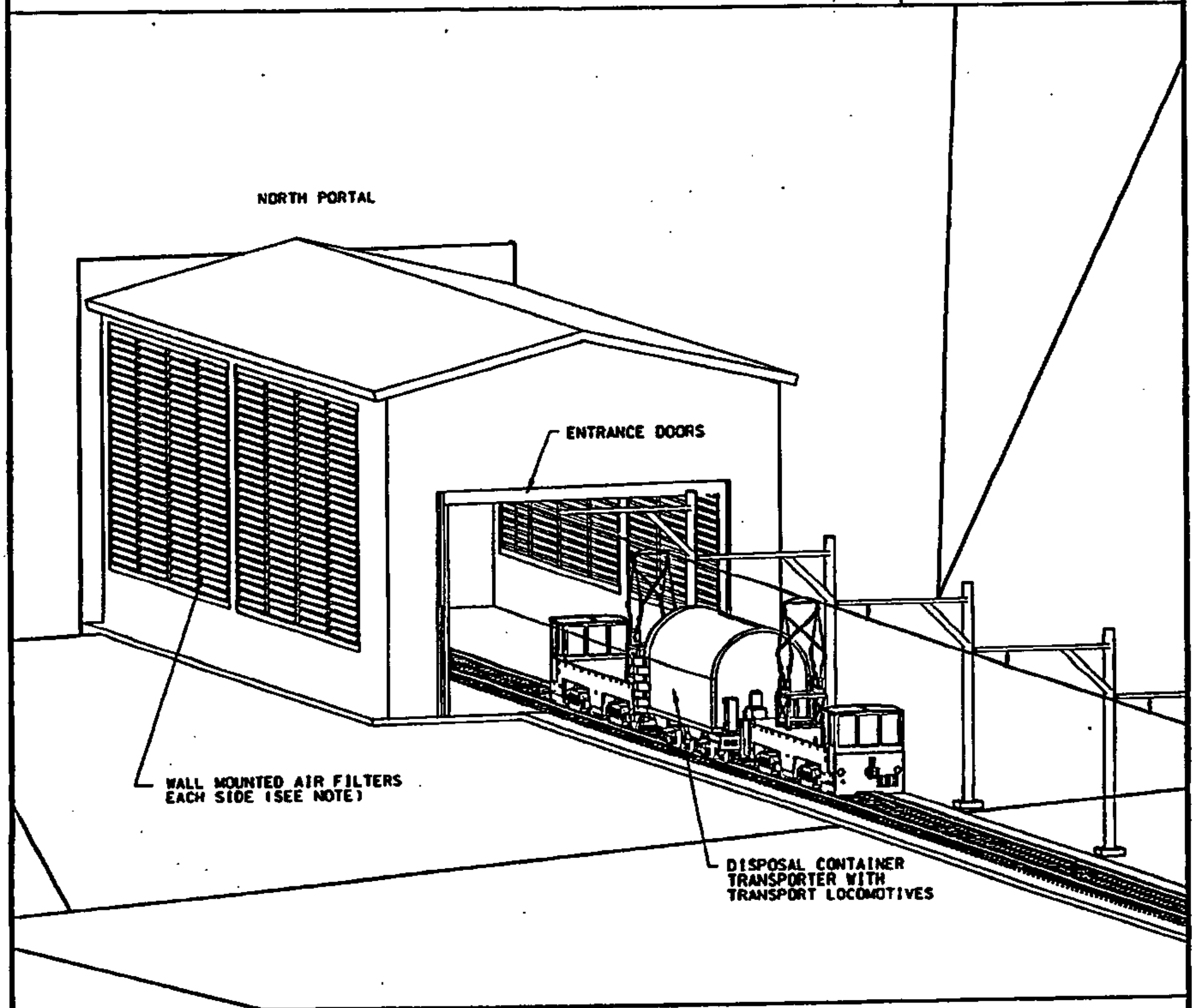
7.8.3 Dust Due to Personnel/Supply Transportation

The movement of personnel or supplies by train or simply by personnel walking will cause dust to become airborne. To reduce the amount of dust stirred up by personnel and supply movements, periodic cleaning of the access mains and drifts is recommended. Portable dust collectors could be located at strategic travel points throughout the repository to ensure the maximum amount of dust is collected.

7.8.4 Atmospheric Dust

Another source of dust will be the ambient conditions found at the site. Reference 5.16, page 12 shows that dust concentrations as high as 0.15 mg/m^3 (4.1.9) were experienced near the repository during the period 1989 to 1996. This dust will be sucked into the repository through the ventilation system, contributing to the dust load in the access mains. To reduce this dust a filtering system could be considered at the intake of ventilation air at the North Portal (Ref. 5.17, page 85) as shown in Figure 14. It would be impractical and expensive to remove all atmospheric dust. However, a series of coarse filters could remove a portion of the dust. The filters will also remove most of the pollen in the air along with the dust. The filter would only be activated during periods of high dust, such as wind storms. A recommendation for intake air dust filtration is outside the scope of this analysis but it should be considered when more information becomes available about the silica content of atmospheric dust.

An alternative proposal would be the periodic vacuuming or washing of the emplacement side to remove the atmospheric dust and pollen which enters the repository through the ventilation system.



NOTES:

1. DURING HIGH WIND/DUST CONDITIONS THE DOORS WILL CLOSE AND AIR WILL BE DRAWN IN THROUGH THE FILTERS ON THE SIDES OF THE BUILDING.

THIS FIGURE IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

FIGURE 14
NORTH PORTAL
INTAKE FILTER

7.8.5 Recirculation of Dust from Ventilation Ducting

As shown in Attachment II, there can be recirculation of dust depending upon which ventilation scheme is chosen. .Dust recirculation is caused when dust laden air being removed from a working area leaks and returns to the working area and thus must be removed again. The dust is typically removed from the working area via ducting. A fan is provided for the ducting to supply a motivating force to move the dust laden air. The fan produces a pressure differential between the inside and outside of the duct and this pressure differential causes the leakage of dust. The differential is greatest around the fan, is both positive and negative in sign, and depends upon the direction the air is being moved.

Dust leakage rates and recirculation potential are greater in metal ducting versus flexible tubing (Ref. 5.17, page 58) because of the number of joints and the inflexibility of ducting compared to flexible tubing. Recirculation of the air increases costs as the air must be handled by the same equipment more than once. Air with recirculating dust is of poorer quality than air with no recirculation as shown in Attachment II.

Recirculation of dust can be reduced by choosing a blowing system of ventilation (instead of an exhausting system), reducing leakage rates by well maintained ducting, and intermediate stages of dust scrubbers. These intermediate stages could be in-line with the ducting or set parallel in the mains.

7.9 Maintenance of Air Quality by Operating Mode

The preceding section discussed the maintenance of air quality by using equipment to obtain low levels of dusts and gases. This section will discuss how different operating modes can achieve the same result. For example, blasting could be accomplished during an off-shift to ensure that the noxious (and toxic) fumes produced do not affect workers in the repository (assuming that drilling and blasting can be used for construction). If blasting is performed, adequate time must be allowed for fumes to exit from the repository. Water sprays will be needed to suppress fine dust created by the blast and for dust suppression during removal of the broken rock.

The preceding sections have primarily discussed air quality during construction activities as these activities will most likely degrade air quality. The repository will also have emplacement operations. Construction activities are required to be performed expeditiously to maintain cost and schedule goals. Emplacement activities have more latitude in their exact mode or method of operation. This analysis will not recommend methods of operation for the repository, such as periodic vacuuming or cleaning, as this is the purview of other analyses.

Some emplacement operations are to conducted remotely (Ref. 5.18, page 66) and thus issues of air quality for personnel protection become moot. Construction activities cannot be conducted remotely and thus will be required to maintain air quality at an acceptable level whenever workers are present.

An acceptable level means that the TLVs for dusts and gases are not exceeded. To maintain this level at all times will be difficult because of the low TLV for SiO_2 and because construction activities (TBM and roadheader excavation) can generate large amounts of dust. The dust will settle from the air stream and thus create the potential for more dust when it is disturbed. It would therefore be prudent to keep the access mains and air ways as free of dust as possible - perhaps by periodic cleaning or vacuuming of the mains.

7.10 Effect of Air Quality Degradation in Normal and Abnormal Situations

Air quality may be degraded during the course of emplacement and development operations. These degradations could occur because of normal or abnormal situations. In these instances the air quality is degraded by going beyond limits which have been mentioned in other sections of this report. In general when an air quality level has been degraded during normal operations, work should stop and the immediate work area should be vacated until the air quality improves or else some form of worker protection must be provided (4.2.1). The nature of the degradation will vary but the effect of the degradation is expected to be temporary in nature because the air supply is continuously renewed by ventilation fans.

Air quality degradation caused by abnormal events can be much more serious because they are unplanned. The most probable abnormal events which could affect air quality are:

- Fire or smoke
- Fan stoppage
- Access main blockage
- Ventilation duct damage

The possible release of nuclear contaminants would be on this list but this scenario is not in the scope of this analysis.

The repository will have limited avenues of ingress and egress and the ventilation system will continuously operate. The overall repository ventilation system does not recirculate the air and therefore combustion products can be carried far from their point of origin to degrade air quality. Air quality can be degraded because fires consume oxygen and produce carbon monoxide plus other noxious gases. These factors make occurrences of fire or smoke very serious events. A complete description of the fire protection scheme for the repository is outside the scope of this analysis, but in general the following sequence of events is likely (Ref. 5.12, page 55):

1) A fire event is detected - either by sensors or by workers.
2) An alarm is given.
   a) All workers evacuate the repository.*
   b) All workers use their self-rescuer.
   c) Fire doors close and the main fan slows down or stops to limit the spread of smoke.

3) The fire could be fought by an internal fire extinguisher or by a fire fighting crew which would go into the repository to the source of the fire.
4) After the fire is extinguished the combustion products are allowed to clear the repository .
5) Workers can then return to their jobs after repository is deemed safe to enter.

* Workers unable to evacuate should report to the refuge chambers in various locations about the repository.

In the event of a fan stoppage or an access main blockage the repository would only be evacuated if directed by the repository operations manager. The repository operations manager will be responsible for determining how long the evacuation will last. A fan stoppage or blockage would reduce the flow of air (and oxygen) to the workers. However, it will take some time before the oxygen level is reduced to the 19.5% value discussed in Section 7.2 and therefore evacuation of the repository should not be automatic. However, all work should cease until the stoppage or blockage is corrected.

Damage to ventilation ducting could occur because of blasting or an accident involving equipment. Damage to ventilation ducting could stop the flow of ventilation air to the repository. The response should be the same as a fan stoppage, to cease all work until the ducting is repaired.

Damage resulting from a fire would be concentrated in the area of the fire. This damage could include: loss of equipment, rock support weakening, ventilation tube destruction, and discoloration from smoke. This damage could be expensive to repair but should have no long-team effects on the repository. The most severe consequence from a fire would be the distribution of partially combusted particles through the Mains and Ramps. These particles would have an unknown effect on the repository over its lifetime.

8. CONCLUSIONS

The oxygen content of the air should not be less then 19.5% by volume. This is an absolute limit and all work must stop in an area if the oxygen level goes below this value. An action level of 20.25% oxygen is recommended to ensure that the 19.5% level is not reached. The maximum effective temperature should not exceed 25°C (TBV-321). The 25°C (TBV-321) is an operating temperature and could be exceeded provided appropriate safety and health precautions are taken. A recommendation for a lower temperature limit is not made. A recommendation is made for a maximum dry-bulb limit of 48°C (TBV-321). The humidity could vary between 0 and 100% and not adversely impact the workers in the repository. For dusts other than silica (Section 7.4) and for gases other then oxygen (Section 7.6) recommendations of the ACGIH are followed and are listed in their respective sections.

Guidance is suggested for respirable dust. The approximate maximum concentration for respirable dust is 0.15 mg/m^3 and this time weighted average value should not be exceeded. This value was based on the mineralogical content of the rock, which could be different than the mineralogical content collected by air sampling. This value is for respirable dust as determined in NIOSH Analytical Method 7500.

Dust generated due to excavations, muck transport, personnel transportation, atmospheric dust, and recirculation can be moderated by the use of engineering controls. These controls include: water sprays, scrubbers, surfactants, and dilution. The repository should rely upon periodic cleaning of the drifts to maintain air quality within acceptable limits. Both dry and wet scrubbers could be used and would give similar dust collection efficiency, but dry scrubbers can provide somewhat higher efficiency. A blowing type air system (Figure 5) is recommended as it produces less dust at the working face than the exhausting system (Figure 4). Leakage of dust from ventilation ducting and the recirculation of this dust can be a problem but it can be reduced by installation of additional air scrubbers in the mains. An intake filter at the North Portal could reduce the amount of atmospheric dust which enters the repository - especially during windy conditions on the surface.

Worker exposure to poor air quality can be affected by the way operations are conducted. Workers can be protected, for example, by blasting during an off shift.

Some information in this analysis required a TBV or TBD label. The eventual determination of these TBV or TBD values may change the numbers cited in this analysis but should not change the overall conclusion of the analysis. Many Design Parameters and Design Inputs did not require confirmation as they were used for comparison purposes in the analysis and will not be used for procurement, fabrication or construction.

This analysis mentioned other analyses which should be performed at a later time. These analyses are: expected rock temperature in the repository after emplacement, air filter at the North Portal, repository operations analysis, and repository fire protection scheme .

9. ATTACHMENTS

Attachment I (1 page):	Summary of Minerals from Borehole Data
Attachment II (2 pages):	Dust Concentrations for Five Ventilation Situations

Attachment I - Summary of Minerals from Four Boreholes

Borehole	Depth (m)	%Tridymite	%Quartz	%Cristobalite	%Other
USW G-4	249	--	25	7	68
(from core)	284.7	8	16	11	65
	312.7	5	9	20	66
	331.9	16	12	10	62
	340.5	--	16	14	70
USW H-3	268.2	--	29	3	68
(from drill	286.5	--	14	16	70
cuttings)	304.8	4	--	23	73
	317	--	3	24	73
USW H-5	353.6	--	26	10	64
(from core	368.8	3	22	11	64
and cuttings)	378.0	--	7	23	70
	396.2	--	10	18	72
	414.5	3	15	16	66
	423.7	--	15	20	65
USW SD-12	246.1	3	10	27	60
(from core)	253.5	3	33	6	58
	260.2	14	13	16	57
	268.7	3	23	17	57
	275.4	4	12	25	59
	283.5	7	24	10	59
	291.1	4	16	22	58
	298.7	3	11	26	60
	Average	3.48	15.70	16.30	
	Use	3.5	15.7	16.3	64.5

These averages were developed using the data points from four boreholes (4.1.7). As a check on the values for Cristobalite and Tridymite a summary was made for all mineralogical data between the elevations of 1000m and 1100m (Ref. 5.31). This information contained data from boreholes both inside and outside the repository block. Values of 15.10% and 2.85% (4.1.7) were developed for Cristobalite and Tridymite, respectively. Since the values are similar to the averages calculated above for four boreholes, it is concluded that the above average values are reasonable.

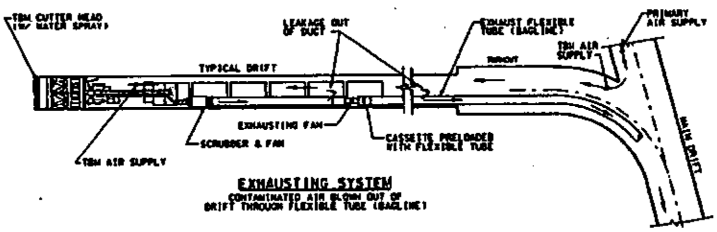
Attachment II -Dust Concentrations for Five Ventilation Situations

Figure II-1 shows five ventilation situations or schemes for suppling air to the TBM. The amount of air supplied to the TBM is from 4.1.10. The value of 17 m^3/sec includes all leakages and losses. This value remains constant in all the situations. The TBM ventilation air is supplemented or reduced depending upon the location of the fan. A leakage rate of 25% was chosen for all examples (4.1.11). Dust concentrations are from 4.1.12. Scrubber efficiency was set at 90% (4.1.13)

The purpose of Figure II-1 is not to provide absolute data for the ventilation situations but to provide a comparison between the schemes. The figure shows that the blowing system provides better quality air to the working face than other systems.

General Notes:

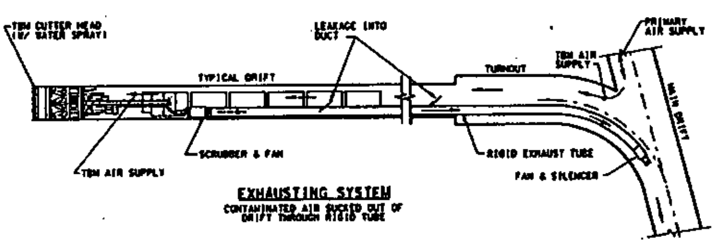
1) 17 m^3/sec x 25% = 4.25 m^3/sec (leakage), 17 - 4.25 = 12.75 (volume to TBM).
2) Dust @ 2.7 mg/m^3 x 10% = 0.27 mg/m^3 (concentration of dust in the air after it has been scrubbed) with a scrubber efficiency of 90%.
3) Dust concentrations will be given at the working face and just before the drift ventilation air returns to the Main. In the Access Main, dust in this air will be diluted.
4) Minimum quantity of ventilation air in an emplacement drift =
   π x $(5.5m)^2/4$ x 0.51 m/sec (100 ft/min)(4.3.1) = 12.1 m^3/sec say 12 m^3/sec.
5) Recirculating load of dust is the summation of the series-
   0.27(.1) + 0.27(.01) + 0.27(.001) + ... = 0.03



AT FACE	VOL (m^3/s)	DUST (mg/m^3)	DUST (mg/sec)
IN DRIFT	12.75	0.04	0.51
LEAKAGE	4.25	(0.27+.03)	1.275
TOTAL	17	0.105	1.785
IN TURNOUT			
TOTAL	12.75	0.27	3.44

THIS FIGURE FROM REFERENCE 5.17 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

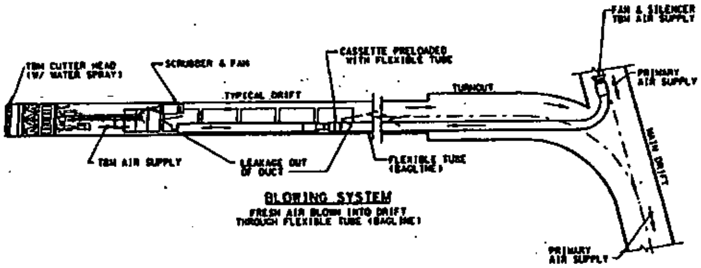
SITUATION # 1



AT FACE	VOL (m^3/s)	DUST (mg/m^3)	DUST (mg/sec)
TOTAL	12.75	0.04	0.51
IN TURNOUT			
IN DUCT	12.75	0.27	3.44
LEAKAGE	4.25	0.04	0.17
TOTAL	17	0.212	3.61

THIS FIGURE FROM REFERENCE 5.17 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

SITUATION # 2



AT FACE	VOL (m^3/s)	DUST (mg/m^3)	DUST (mg/sec)
TOTAL	12.75	-	-
IN TURNOUT			
IN TUBE	12.75	(0.27+.04)	3.95
LEAKAGE	4.25	0.04	0.17
TOTAL	17	0.242	4.12

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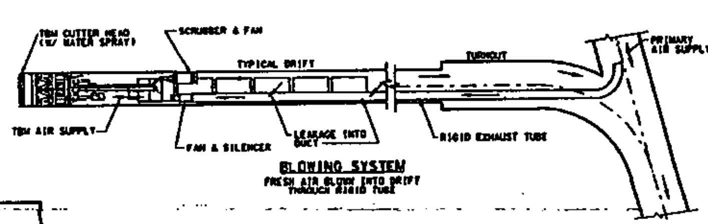
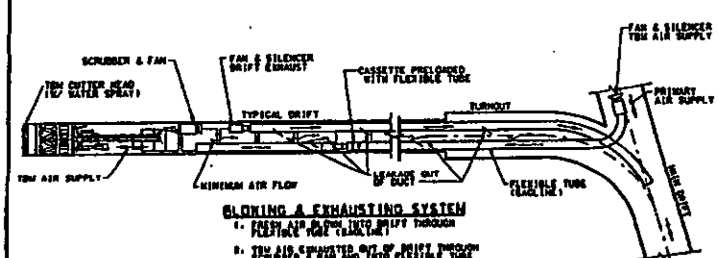
SITUATION # 3



AT FACE	VOL (m^3/s)	DUST (mg/m^3)	DUST (mg/sec)
IN TUBE	12.75	-	-
LEAKAGE	4.25	(0.27+.03)	1.275
TOTAL	17	0.075	1.275
IN TURNOUT			
TOTAL	12.75	(0.27+.04)	3.95

THIS FIGURE FROM REFERENCE 5.17 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

SITUATION # 4



AT FACE	VOL (m^3/s)	DUST (mg/m^3)	DUST (mg/sec)
TOTAL	12.75	-	-
IN TURNOUT			
LEAKAGE	4.25	0.04	0.17
IN DRIFT	12.00	(0.27+.04)	3.72
IN EXHAUST	0.75	0.27	0.203
TOTAL	17	0.241	4.093

THIS FIGURE FROM REFERENCE 5.17 IS BASED ON SOME EXISTING DATA. IT IS PRESENTED FOR REFERENCE ONLY.

SITUATION # 5

FIGURE II-1
DUST CONCENTRATIONS FOR FIVE VENTILATION SITUATIONS

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