MOL.20010927.0072

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SYSTEM DESCRIPTION DOCUMENT COVER SHEET

1. QA: QA

2. SDD Title
Subsurface Ventilation System Description Document

3. Document Identifier (Including Rev. No. and Change No., if applicable)
SDD-SVS-SE-000001 REV 01 ICN 01

	Printed Name	Signature	Date
4. System Engineer	Eric Loros	[signature]	7/25/2001
5. Checker	Neal Pettit	[signature]	07/25/2001
6. Responsible Manager	Robert Boutin	[signature]	07/25/01

7. Remarks:

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

The following TBDs/TBVs are contained in this document:

TBD-0239; TBD-0406; TBD-3654.

TBV-0321; TBV-4655, TBV-4693, TBV-4710.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SYSTEM DESCRIPTION DOCUMENT REVISION HISTORY

1. SDD Title

Subsurface Ventilation System Description Document

2. Document Identifier (Including Rev. No. and Change No., if applicable)

SDD-SVS-SE-000001 Rev. 01 ICN 01

3. Revision	4. Description of Revision
00	Initial Issue. This document was previously issued using document identifiers BCA000000-01717-1705-00016. This document supersedes the previous issuances. This document is a complete rewrite of the superseded documents, driven largely by the use of an alternate source of regulatory requirements, the implementation of the License Application Design Selection effort, the use of a new document development procedure, and the combination of the waste emplacement and waste retrieval systems into a single system.
01	The purpose of this revision is to add Section 2 Design Description and incorporate the applicable changes in revision 01 of "Monitored Geologic Repository Project Description Document" (MGR PDD). Editorial changes (such as new table numbering scheme) and non-editorial changes (such as the addition and deletion of TBVs and TBDs) were made throughout the document.
01 ICN 01	The purpose of this ICN is to incorporate changes contained in Revision 02 ICN 02 of the "Monitored Geologic Repository Project Description Document" primarily to support the Flexible Operations Concept. All changes in the document that have been made as a result of this ICN are indicated by revision bars. Minor editorial changes have also been made.

CONTENTS

Page

TABLES

Page

FIGURES

Page

SUMMARY

The Subsurface Ventilation System supports the construction and operation of the subsurface repository by providing air for personnel and equipment and temperature control for the underground areas. Although the system is located underground, some equipment and features may be housed or located above ground. The system ventilates the underground by providing ambient air from the surface throughout the subsurface development and emplacement areas. The system provides fresh air for a safe work environment and supports potential retrieval operations by ventilating and cooling emplacement drifts.

The system maintains compliance within the limits established for approved air quality standards. The system maintains separate ventilation between the development and waste emplacement areas. The system shall remove a portion of the heat generated by the waste packages during preclosure to support thermal goals. The system provides temperature control by reducing drift temperature to support potential retrieval operations. The ventilation system has the capability to ventilate selected drifts during emplacement and retrieval operations.

The Subsurface Facility System is the main interface with the Subsurface Ventilation System. The location of the ducting, seals, filters, fans, emplacement doors, regulators, and electronic controls are within the envelope created by the Ground Control System in the Subsurface Facility System. The Subsurface Ventilation System also interfaces with the Subsurface Electrical System for power, the Monitored Geologic Repository Operations Monitoring and Control System to ensure proper and safe operation, the Safeguards and Security System for access to the emplacement drifts, the Subsurface Fire Protection System for fire safety, the Emplacement Drift System for repository performance, and the Backfill Emplacement and Subsurface Excavation Systems to support ventilation needs.

QUALITY ASSURANCE

The quality assurance (QA) program does apply to the development of this document. The ”Technical Work Plan For Subsurface Design Section FY 01 Work Activities” (WP#12112124MI) activity evaluation has determined that the development of this document is subject to DOE/RW-0333P “Quality Assurance Requirements and Description” requirements. Although the “Q-List” and “Classification of the Preliminary MGDS Repository Design” classifies the Subsurface Ventilation System as commercial quality, the subsurface ventilation system has the potential to adversely impact safe operation of the underground facility. This document was developed in accordance with AP-3.11Q, "Technical Reports."

1. SYSTEM FUNCTIONS AND DESIGN CRITERIA

The functions and design criteria for the system are identified in the following sections. Throughout this document the term "system" shall be used to indicate the Subsurface Ventilation System. The system architecture and classification are provided in Appendix B.

1.1 SYSTEM FUNCTIONS

1.1.1 The system generates and controls subsurface airflow.

1.1.2 The system maintains air quality standards within established limits.

1.1.3 The system contributes to the control of subsurface air temperatures and the rate of air temperature change.

1.1.4 The system controls human access to the emplacement drifts.

1.1.5 The system provides monitored status of system and equipment operation.

1.1.6 The system provides operating parameters and air-related environmental data.

1.1.7 The system mitigates the spread of combustion products emitted from a subsurface fire.

1.2 SYSTEM DESIGN CRITERIA

This section presents the design criteria for the system. Each criterion in this section has a corresponding Criterion Basis Statement in Appendix A that describes the need for the criterion as well as a basis for the performance parameters imposed by the criterion. Each criterion in this section also contains bracketed traces indicating traceability, as applicable, to the functions (F) in Section 1.1, the "Monitored Geologic Repository Requirements Document" (MGR RD) and "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." In anticipation of the interim guidance being promulgated as a Code of Federal Regulations, it will be referred to as "10 CFR 63" in this system description document. For the applicable version of the codes, standards, and regulatory documents refer to Appendix E.

1.2.1 System Performance Criteria

1.2.1.1 The system shall provide a minimum quantity of fresh air (surface ambient) to accommodate a maximum of 353 (TBV-4710) persons on the development side and a maximum of 89 (TBV-4710) persons on the emplacement side.

[F 1.1.1, 1.1.2, 1.1.3][MGR RD 3.1.F]

1.2.1.2 The system shall be capable of regulating airflow through each emplacement drift.

[F 1.1.1]

1.2.1.3 The system shall minimize the dry bulb temperatures in the subsurface for areas requiring human access while limiting the maximum dry bulb temperature to 48 degrees C (TBV-0321). For subsurface areas requiring human access for a full shift (i.e., equal to or in excess of eight hours) without personnel heat stress protection, the system shall limit the maximum effective temperature to 25 degrees C.

[F 1.1.3]

1.2.1.4 The system shall maintain underground air temperatures during repository remote access (remote equipment) modes to within the values specified in Table 1.

Table 1. Remote Temperatures

Location	Operations	Maximum Temperature
Emplacement Drift	Remote Access*	50 degrees C Dry Bulb
Access Mains, Ramps, and Alcoves	Remote Access*	50 degrees C Dry Bulb
Performance Confirmation Drifts	Remote Access*	50 degrees C Dry Bulb
Exhaust Main	Remote Access*	50 degrees C Dry Bulb
Turnouts	Remote Access*	50 degrees C Dry Bulb

*Includes emplacement, retrieval, recovery, backfill, and abnormal modes of operation.

[F 1.1.3][MGR RD 3.3.A]

1.2.1.5 The system shall be capable of controlling the rate of air temperature change within the emplacement drifts during blast cooling to no greater than (TBD-0239) degrees C per day.

[F 1.1.1, 1.1.3][MGR RD 3.3.A]

1.2.1.6 The system shall provide ventilation for the development and emplacement areas by two separate and independent systems.

[F 1.1.1, 1.1.2]

1.2.1.7 The system shall maintain, at the interface of the emplacement and development areas, the air pressure on the development side at least 62.2 Pa (0.25 in. of water) greater than the air pressure on the emplacement side.

[F 1.1.1, 1.1.2]

1.2.1.8 The system shall limit the maximum emplacement drift wall temperature to 96 degrees Celsius during the preclosure period.

[F 1.1.3][MGR RD 3.2.M]

1.2.1.9 The system shall be designed to allow flexibility of operations within the following range of thermal modes during preclosure and postclosure:

- Maintain WP surface temperature below 85 degrees C (low end of range).
- Limit emplacement drift wall temperature to a maximum of 200 degrees C (high end of range).

[F 1.1.3]

1.2.1.10 The system design shall be based on the outside design conditions as indicated in Table 2.

Table 2. Outside Design Conditions

Parameter	Design Data
Site: Mercury, Nevada	Latitude: 36o 37' 12" Longitude: 116o 01' 12" Elevation: 3310 ft
Heating Dry-Bulb	99.6%: 24o F (Note 1) 99%: 28o F (Note 2)
Cooling Dry-Bulb	0.4%: 102o F (Note 1) 1%: 100o F (Note 2)
Cooling Mean Coincident Wet-Bulb	0.4%: 65o F (Note 1) 1%: 64o F (Note 2)
Wet-Bulb	1%: 67o F (Note 3)
Dew-Point	0.4%: 64o F 1%: 60o F
Mean Coincident Dry-Bulb	0.4%: 72o F 1%: 77o F
Range of Dry-Bulb Temperature	25.9o F

Note 1: Use where close temperature and humidity control is required.
Note 2: Use for personnel comfort systems.
Note 3: Use for cooling towers.
For definition of acronyms, symbols, and units see Appendix C.

[MGR RD 3.3.A]

1.2.1.11 The system shall have a maintainable service life of at least 30 years following final waste emplacement, with appropriate monitoring and maintenance.

[F 1.1.1, 1.1.2]

1.2.1.12 The system shall include provisions for upgrades and refurbishments designed to increase the system's operational life to support a deferral of closure for up to 300 years.

[F 1.1.1, 1.1.2][10 CFR 63.111(e)(2), 63.111(e)(3)]

1.2.1.13 The system shall limit the relative humidity to less than 50% when WP surface temperature exceeds 85 degrees C.

[F 1.1.1, 1.1.3]

1.2.1.14 The system shall maintain operational flexibility to achieve a range of thermal performance by varying the duration of repository operation, ventilation duration, flow rate, and method; WP spacing, WP heat output, and the duration of surface aging.

[F 1.1.1, 1.1.3]

1.2.2 Safety Criteria

1.2.2.1 Nuclear Safety Criteria

This system contains no nuclear safety criteria.

1.2.2.2 Non-nuclear Safety Criteria

1.2.2.2.1 The system shall locate main intake airways a minimum of 100 m (TBV-4693) away from surface air exhaust airways.

[F 1.1.1, 1.1.2, 1.1.6][MGR RD 3.3.A]

1.2.2.2.2 The system shall be designed to maintain ventilated air within the air quality limits of the more stringent "Occupational Safety and Health Standards" (29 CFR 1910.1000), or the "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices."

[F 1.1.2][MGR RD 3.1.E, 3.1.G]

1.2.2.2.3 The system shall secure the emplacement drift entrances to limit unauthorized personnel access to high radiation areas.

[F 1.1.4][MGR RD 3.1.B, 3.1.C][10 CFR 63.112(e)(5)]

1.2.2.2.4 The system shall be designed to prevent reverse airflow in the emplacement drifts (i.e., from emplacement drifts to the turnouts).

[F 1.1.1][MGR RD 3.3.A]

1.2.2.2.5 The system shall be designed to ensure that occupational doses are ALARA (as low as is reasonably achievable) in accordance with the project ALARA program goals (TBD-0406) and the applicable guidelines in "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable" (Regulatory Guide 8.8).

[F 1.1.2][MGR RD 3.1.B, 3.1.G][10 CFR 63.111(a)(1)]

1.2.2.2.6 The system shall be capable of controlling average concentrations of radon daughters to levels that will not result in worker exposure exceeding the limits specified in "Occupational Safety and Health Standards" (29 CFR 1910.1096) in potentially occupied area.

[F 1.1.2][MGR RD 3.1.E, 3.3.A]

1.2.3 System Environmental Criteria

1.2.3.1 The system components that are exposed to outside wind conditions shall be designed for a maximum wind speed of 121 miles per hour.

[MGR RD 3.3.A]

1.2.3.2 The applicable surface system components (air intake louvers, dampers, outdoor units, stack, etc.) shall be protected from and designed to operate in the external environment with a maximum daily snowfall of 10 in. and maximum snowfall accumulation of 17 in.

[MGR RD 3.3.A]

1.2.3.3 The system components that are exposed to the outside temperature environment shall be designed to a temperature of 5 degrees F to 117 degrees F.

[MGR RD 3.3.A]

1.2.3.4 The system shall be designed for the ambient relative humidity environment defined in Table 3.

Table 3. Ambient Relative Humidity Environment

Parameter	Value
Annual mean value	28%
Minimum summer mean value	13%
Maximum winter mean value	46%

[MGR RD 3.3.A]

1.2.3.5 The applicable system components shall be designed to operate in 12 $\mu g/m^3$ Background Particulate Matter, 10 µm or less for 24 hours.

[MGR RD 3.3.A]

1.2.3.6 The applicable system components shall be designed to operate in 30 µg/m^3 Background Particulate Matter, 50 µm or less for 24 hours.

[MGR RD 3.3.A]

1.2.3.7 The applicable system components shall be designed to operate in (TBD-3654) in situ rock temperature (pre-emplacement).

[MGR RD 3.3.A]

1.2.3.8 The applicable system components shall be designed to operate in air temperatures up to 96 degrees C.

[MGR RD 3.3.A]

1.2.3.9 The system shall be designed for a minimum distance of 10 cm between adjacent WPs within individual emplacement drifts, defined as a maximum linear heat load that shall not exceed 1.5 kW/m, averaged over a fully loaded emplacement drift at the time of completion of loading an entire emplacement drift**.**

[MGR RD 3.2.M]

1.2.4 System Interfacing Criteria

1.2.4.1 The system shall accommodate the Monitored Geologic Repository Operations Monitoring and Control System in providing system measurements and equipment status as listed in Table 4 and Table 5, as a minimum. The type of monitoring capabilities (i.e., continuous versus intermittent) is dependent on the final system design and will be specified before system design is complete.

Table 4. Monitoring Parameters

System Parameter	Location of Monitoring
Airflow Rate (or Velocity)*	Main Intake, Exhaust, and Underground Working Areas
Air Pressure Differential*	Air Locks and Ventilation Fans
Air Temperature*	Main Intake, Exhaust, and Underground Working Areas
Relative Humidity of Airflow*	Main Intake, Exhaust, and Underground Working Areas
Concentration of Airborne Particulates*	Main Intake, Exhaust, and Underground Working Areas
Concentration of Radon daughters	Underground Working Areas
Concentration of CO*	Main Intake, Exhaust, and Underground Working Areas

* Anticipated ranges for normal operation, for anticipated operational occurrences, and accident conditions will be provided for these parameters as part of final design.

Table 5. Equipment Status

Equipment	Parameter Indicated
Valves (Dampers)	Open/Close Position
Fans	RPM, Voltage, Current, On-Off
Emplacement Doors	Open/Close Position
Air locks	Open/Close Position

[F 1.1.5, 1.1.6][MGR RD 3.1.F, 3.1.G, 3.3.A]

1.2.4.2 The system shall interface with the Subsurface Fire Protection System to comply with subsurface fire protection requirements.

[F 1.1.1, 1.1.7][MGR RD 3.3.A]

1.2.4.3 The system shall interface with the Subsurface Electrical Distribution System to ensure appropriate power supply.

[F 1.1.1]

1.2.4.4 The system shall interface with the Subsurface Facility System to ensure that subsurface layout, arrangement, and opening sizes support ventilation.

[F 1.1.1][MGR RD 3.3.A]

1.2.4.5 The system shall interface with the Emplacement Drift System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3][MGR RD 3.2.M]

1.2.4.6 The system interfaces with the Subsurface Excavation to accommodate ventilation needs for subsurface excavation operations.

[F 1.1.1, 1.1.2][MGR RD 3.3.A]

1.2.4.7 The system interfaces with the Backfill Emplacement System to accommodate ventilation needs for backfill operations.

[F 1.1.3][MGR RD 3.3.A]

1.2.4.8 The system interfaces with the Safeguards and Security System to accommodate for alarms and controls for the emplacement drift doors.

[MGR RD 3.3.A]

1.2.4.9 The system interfaces with the Site Radiological Monitoring System to accommodate the installation of radiation monitors.

[MGR RD 3.3.A]

1.2.4.10 The system shall interface with the Uncanistered SNF Disposal Container System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3][MGR RD 3.2.L]

1.2.4.11 The system shall interface with the Defense High Level Waste Disposal Container System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3]

1.2.4.12 The system shall interface with the Naval Spent Nuclear Fuel Disposal Container System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3]

1.2.4.13 The system shall interface with the DOE Spent Nuclear Fuel Disposal Container System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3]

1.2.4.14 The system shall interface with the Canistered Spent Nuclear Fuel Disposal Container System to ensure ventilation capacity and availability to support temperature constraints.

[F 1.1.3][MGR RD 3.2.L]

1.2.5 Operational Criteria

1.2.5.1 The system shall be designed with an inherent availability of .9825 (TBV-4655).

[F 1.1.1][MGR RD 3.3.A]

1.2.5.2 The system shall maintain operational flexibility to achieve a range of thermal performance by varying the duration of repository operation, ventilation duration, flow rate, and method; WP spacing, WP heat output, and the duration of surface aging.

[F 1.1.1, 1.1.3]

1.2.6 Codes and Standards

1.2.6.1 The system shall be designed in accordance with the applicable sections of "Occupational Safety and Health Standards" (29 CFR 1910).

[MGR RD 3.1.E]

1.2.6.2 The system shall comply with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926).

[MGR RD 3.1.F]

1.2.6.3 The system shall comply with the applicable design provisions in Section 14.5 of "Radiation Protection in Uranium Mines" (ANSI N13.8-1973) to control concentrations of radon daughters in the potentially occupied areas of the repository.

[MGR RD 3.3.A]

1.2.6.4 The system design shall comply with the applicable requirements in the ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) "Fundamentals" handbook.

[MGR RD 3.3.A]

1.2.6.5 The system ductwork shall be designed in accordance with the applicable provisions of "Standard for the Installation of Air Conditioning and Ventilating Systems" (NFPA 90A).

[MGR RD 3.3.A]

1.2.6.6 The system shall be designed in accordance with applicable sections of the “Department of Defense Design Criteria Standard, Human Engineering" (MIL-STD-1472E).

[MGR RD 3.3.A]

1.2.6.7 The system shall be designed in accordance with applicable sections of "Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities" (UCRL-15673).

[MGR RD 3.3.A]

1.2.6.8 Reserved

1.2.6.8 The system shall comply with the applicable sections of “Standards for Protection Against Radiation” (10 CFR 20).

[MGR RD 3.1.B]

1.2.6.10 The system shall comply with the applicable sections of the “Monitored Geologic Repository Project Description Document.”

1.2.6.11 The system shall comply with the applicable provisions of “1997 Uniform Building Code” (Volume 1, “Administrative, Fire- and Life-Safety, and Field Inspection Provisions”).

[MGR RD 3.1.G, 3.3.A]

1.2.6.12 The system shall comply with the applicable provisions of “1997 Uniform Building Code” (Volume 2, “Structural Engineering Design Provisions”).

[MGR RD 3.1.G, 3.3.A]

1.2.6.13 The system shall comply with the applicable provisions of “1997 Uniform Building Code” (Volume 3, “Material, Testing and Installation Standards”).

[MGR RD 3.1.G, 3.3.A]

1.3 SUBSYSTEM DESIGN CRITERIA

There are no subsystem design criteria for this system.

1.4 CONFORMANCE VERIFICATION

This section will be completed in a later revision.

2. DESIGN DESCRIPTION

Section 2 of this SDD summarizes information which is contained in other references. By assembling system specific information contained elsewhere (i.e., analyses, technical reports, etc.), Section 2 provides insight into the current state of the design of this system. However, due to the nature of design development, the information contained in this section will continue to change as the design matures.

2.1 SYSTEM DESIGN SUMMARY

This system includes the design of separate ventilation systems for the development and waste emplacement operations. The Subsurface Ventilation System will be designed to ensure compliance with approved air quality standards, to ensure that occupational exposures are ALARA, and controlling average concentrations of radon daughters to acceptable level. The ventilation system will remove a portion of the heat generated by the waste packages during preclosure to support thermal goals. The system will accommodate the Monitored Geologic Repository Operations Monitoring and Control System in providing system measurements and equipment status.

The Subsurface Ventilation System is comprised of:

- Intake/exhaust air mains, ramps, ventilation shafts, shaft access drifts, and ventilation raises, which serve as conduits for airflow during construction and emplacement operations

- Ventilation fans (intake and exhaust), isolation doors, louvers, portable shadow shield, and exhaust main partition

2.2 DESIGN ASSUMPTIONS

An assumption is considered to be a statement or proposition that is taken to be true or representative in the absence of direct confirming data or evidence. Assumptions pertaining to the ventilation system strategy that were presented in the "Monitored Geologic Repository Project Description Document," "Overall Subsurface Ventilation System," and "Site Recommendation Subsurface Layout" are reproduced in this section. All assumptions are considered accepted data, existing, or TBV, respectively, where noted.

2.2.1 Controlled Project Assumptions

The following assumptions and technical requirements, from the "Monitored Geologic Repository Project Description Document," have been incorporated into this document.

2.2.1.1 Decontamination Concept

Per "Monitored Geologic Repository Project Description Document," Section 5.1.2.2: The MGR design will provide means for controlling the spread of potential contamination and performing decontamination, consistent with applicable codes and standards, by selecting design features and decontamination operations that will comply with ALARA requirements and, to the extent practical, minimize effects on operations. MGR radiological, waste handling, and maintenance operations will be supported by equipment designed to decontaminate the handling equipment, waste containers, and personnel as near the source of contamination as practicable. Portable or mobile decontamination equipment will be provided where appropriate to support area cleanup and for preliminary equipment decontamination for the purposes of safe handling to final decontamination. Major decontamination operations will be centralized where confinement of the contaminant and movement to the centralized facility is dictated by ALARA considerations. Decontamination equipment will be designed to collect and confine the contamination byproducts in a way that can be safely transported or transferred for processing.

2.2.1.2 Emplacement Drift Entrance

The "Monitored Geologic Repository Project Description Document," Section 2.5, discusses the placement of double doors at the entrances to the emplacement drifts. These doors will be normally in the closed and locked position to prevent unauthorized personnel access and to regulate airflow.

2.2.2 Other Assumptions

The assumptions used in the "Overall Subsurface Ventilation System" or the "Site Recommendation Subsurface Layout" are identified and explained in this section.

2.2.2.1 Empty Drifts During Emplacement

In the "Site Recommendation Subsurface Layout," Section 5.2.1, it is assumed that a certain number of drifts, excavated within the pillar of two adjacent emplacement drifts, will be left empty during emplacement operations. These drifts are excavated within the pillar of adjacent emplacement drifts so as not to impact the required emplacement area. Some of the empty drifts will be cross-block drifts for ventilation, monitoring, emergency egress, and/or the Test and Evaluation Program.

2.2.2.2 Blast Cooling Air Volume

Airflow of 47 m^3/s for an emplacement drift split is assumed to be available for off-normal (blast) cooling. This capacity would provide airflow for a single blast cooling operation. This assumption is presented in the "Overall Subsurface Ventilation System," Section 5.7, and is used in Section 6.1.4 of that analysis.

The emplacement drift ventilation flow can be varied to allow limited-time for equipment access for evaluating and remediation work to deal with operational upsets. The "Overall Subsurface Ventilation System," Attachment III, shows a peak air temperature for the emplacement drift at 60 degrees C. Therefore, additional airflow will be required to lower the temperature below 50 degrees C to allow remote equipment access. For a maximum linear heat load of 1.5 kW/m ("Monitored Geologic Repository Project Description Document," Criterion 5.2.10), the outlet air temperature would be slightly higher and blast cooling would still be required.

2.2.2.3 Human Access In The Exhaust Main

In the "Site Recommendation Subsurface Layout," Section 5.2.7.5, it is assumed that human access will be required in the Exhaust Main to service ventilation controls located at the bottom of the ventilation raises.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.3, to establish the partitioning of the Exhaust Main into an exhaust side and a service side within the Subsurface Facility.

2.2.2.4 Ventilation Stopping

In the "Site Recommendation Subsurface Layout," Section 5.2.7.6, it is assumed that a typical mine stopping, a physical barrier used for separating ventilation airflow, is approximately 0.2 m thick. This mine stopping is typical for the mining industry ("Mine Ventilation and Air Conditioning," p. 463) where permanent or long-term control of airflow is required.

This assumption was used in the "Site Recommendation Subsurface Layout," Attachment IV, Section IV.3, since the partitioning of the Exhaust Main will require a physical containment barrier for separating ventilation airflows.

2.3 DETAILED DESIGN DESCRIPTION

This section contains summaries of the design description details for the ventilation system components as described in the "Overall Subsurface Ventilation System" and "Emplacement Ventilation System" Analyses. Per the "Monitored Geologic Repository Project Description Document," Criteria 5.1.4.1 and 5.1.4.2, the MGR shall accommodate up to 70,000 MTHM or equivalent, while not precluding the capability of accommodating either 97,000 MTHM or 115,000 MTHM or equivalent.

The subsurface ventilation system consists of two separate and independent fan systems and flow networks separated by isolation airlocks. One system provides airflow to the emplacement operations (exhaust system) and one system provides airflow to the development operations (blowing system). Air pressure in the development side is maintained at a higher pressure than in the emplacement side (see Criterion 1.2.1.7). In the unlikely event that radioactive particulates are released into the subsurface air stream on the emplacement side, the pressure differential will prevent the spread of contamination to the development side. If the emplacement exhaust air is contaminated, the airflow could be isolated and a mobile filtration unit would be used to treat the emplacement drift air.

2.3.1 Emplacement Ventilation

The existing Exploratory Studies Facilities is integrated into the "Site Recommendation Subsurface Layout," Section 6.2.1.1. All other subsurface repository openings will be developed from the Exploratory Studies Facilities. As described in the "Overall Subsurface Ventilation System," Section 6.1, in the basic emplacement ventilation concept, fresh air enters through an intake shaft, or one of the ramps, and is distributed to the East and West Main. The intake shafts are connected to the East and West Mains by a shaft access drift. From the mains, the air enters emplacement, performance confirmation, or empty drifts and travels to centrally located exhaust raises. The exhaust raise effectively divides each respective drift in half, referred to as a split. Each split in the repository will be ventilated during preclosure. Air entering the performance confirmation drift, cross-block drift, or empty emplacement drifts (see Section 2.2.2.1) is directed to the service side of the Exhaust Main and air flowing through emplacement drifts containing waste packages is directed to the exhaust side of the Exhaust Main. The Exhaust Main carries the airflow to exhaust shaft access drifts where it is then carried to the surface by the exhaust shafts.

Figure 1 provides a picture of the general airflow configuration described above. The airflow volume allocations for each intake and exhaust shaft are provided in Figures 2 through 5. Figure 2 provides the intake airflow volume allocation for the 70,000 MTU case. Figure 3 provides the exhaust airflow volume allocation for the 70,000 MTU case. Figure 4 provides the intake airflow volume allocation for the 97,000 MTU case. Figure 5 provides the exhaust airflow volume allocation for the 97,000 MTU case. The figures show ventilation for the emplacement mode only.

Fans located on the exhaust shafts provide the motive force for the subsurface repository airflow. Figure 6 provides a cross section picture of the airflow from the emplacement drifts to the fans, which are located on the surface. The fans are designed to have enough power to exhaust the maximum amount of air that will be required during the emplacement, monitoring, off-normal, and closure phases. The airflow volume produced by the fans is variable; thereby ensuring there is sufficient ventilation capacity to support the temperature constraints. The air volumes provided must be able to remove sufficient heat generated by the waste packages during preclosure to meet thermal management goals via operational flexibility. Air distribution within the repository is controlled by air doors located at each emplacement drift, performance confirmation drift, cross-block drift, and standby emplacement drift. The doors will control access (see Section 2.2.1.2) and contain regulators (louvers) to control the flow of ventilation air through the drift. The opening and closing of the doors and regulators will be remotely controlled. There will also be a method of regulating airflow at the bottom of each exhaust raise. To prevent recirculation from inside the emplacement drifts out to the main drifts, the surface fan installations are operated in an exhaust mode at each exhaust shaft to create a negative air pressure on the Exhaust Main level that is more negative than on the emplacement level. As the activities in the emplacement drifts vary so will the demand for airflow. For example, the emplacement drift airflow can be adjusted for drip shield installation, backfill placement, or to react to off-normal events that may occur. This ability to regulate airflow demonstrates the ventilation system's capability to interface with the emplacement drift system and satisfy meeting the temperature requirement for remote access. The installation of regulators at the entrances and/or exits of the emplacement drifts provide the method to meet these requirements.

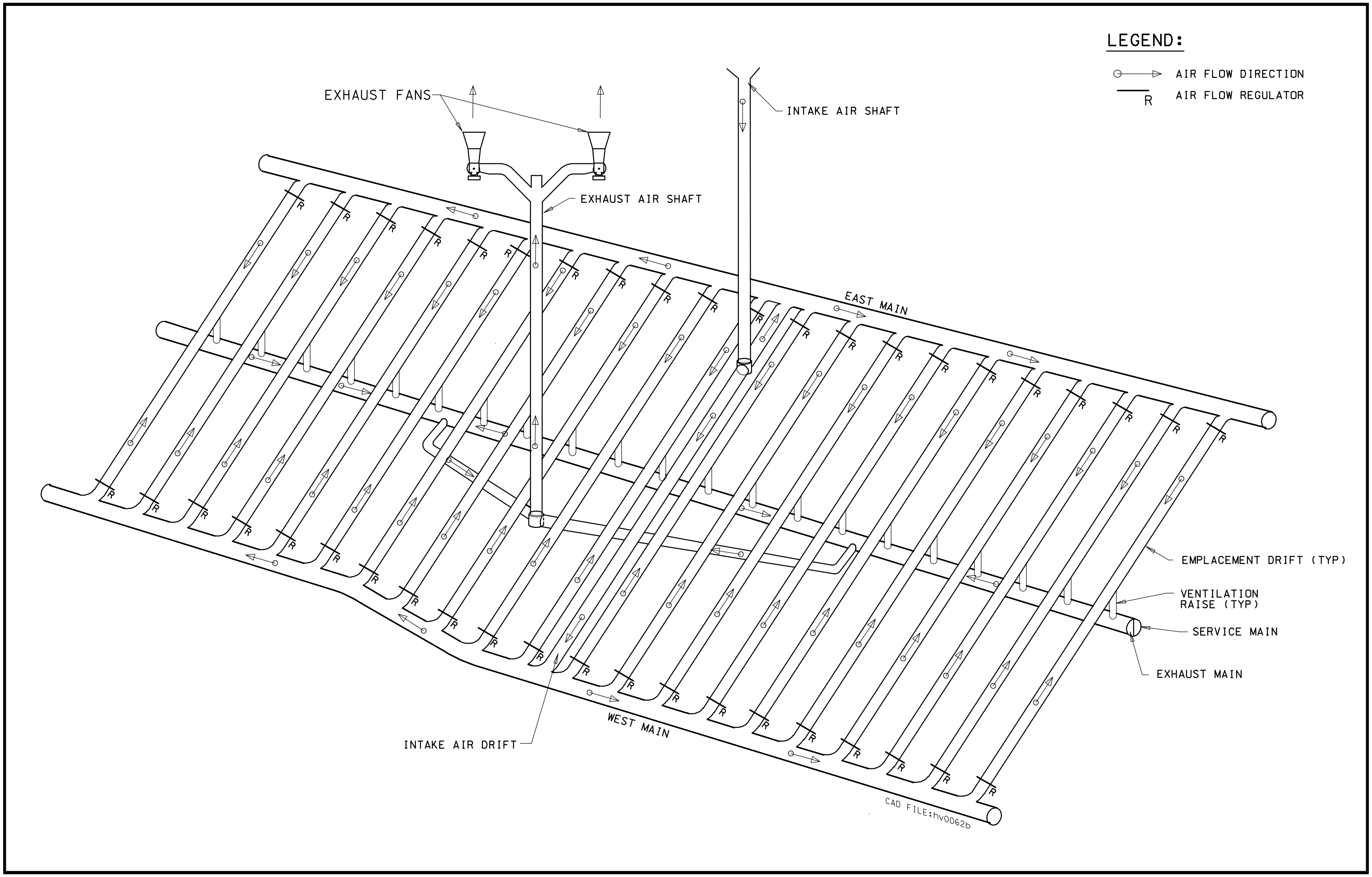

Figure 1. General Airflow Pattern

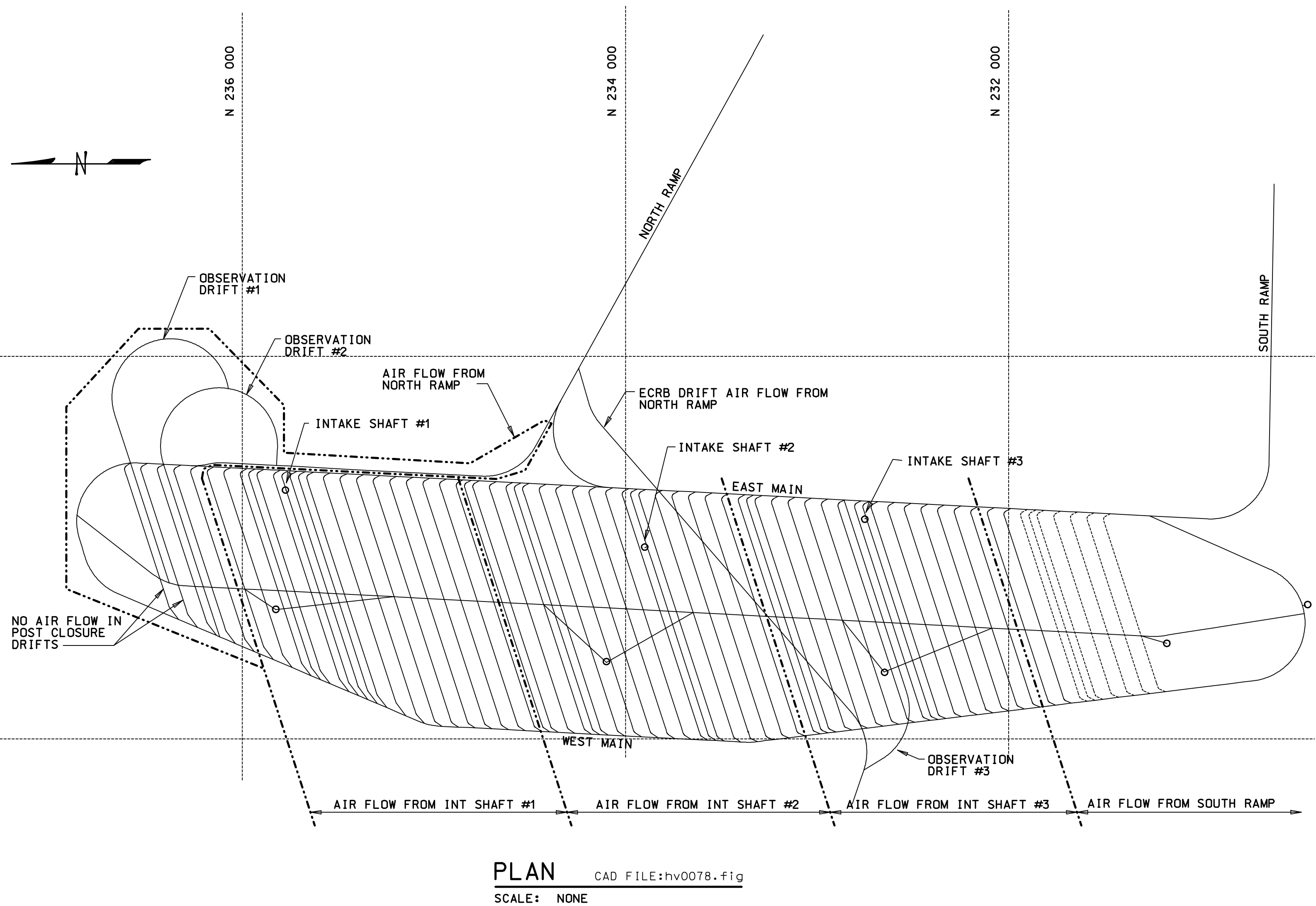

Figure 2. Intake Airflow Volume Allocations - 70,000 MTU Case

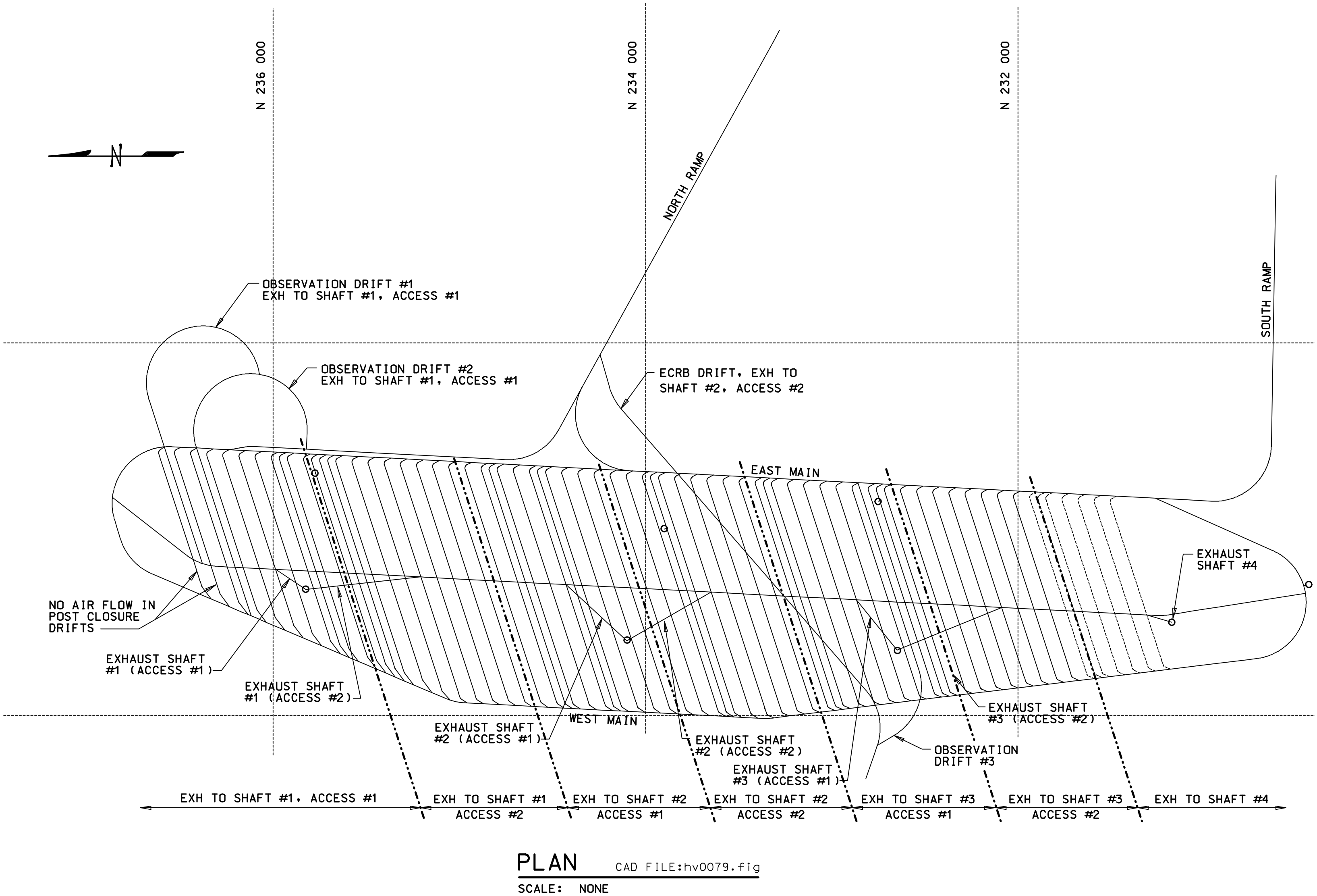

Figure 3. Exhaust Airflow Volume Allocations - 70,000 MTU Case

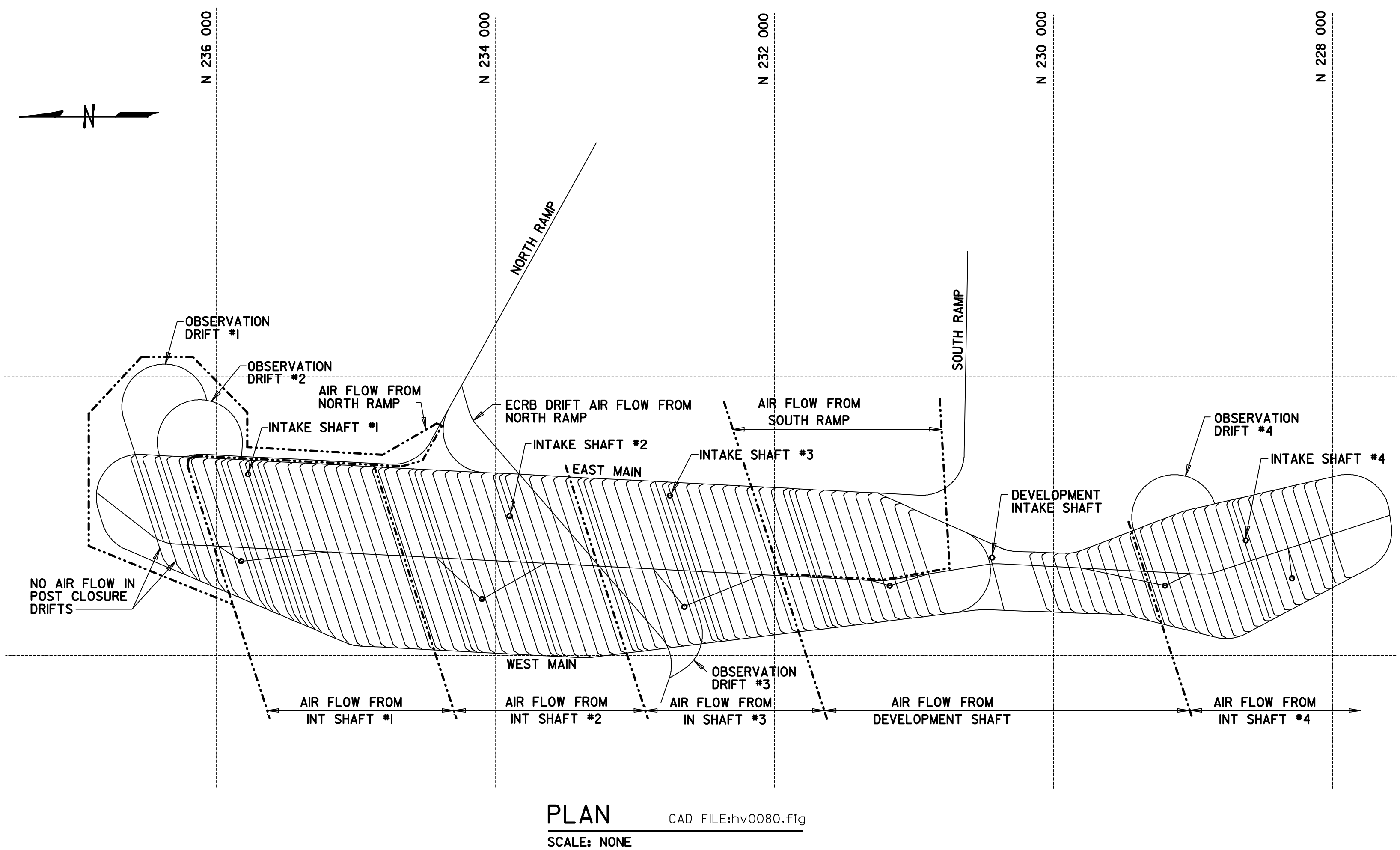

Figure 4. Intake Airflow Volume Allocations – 97,000 MTU Case

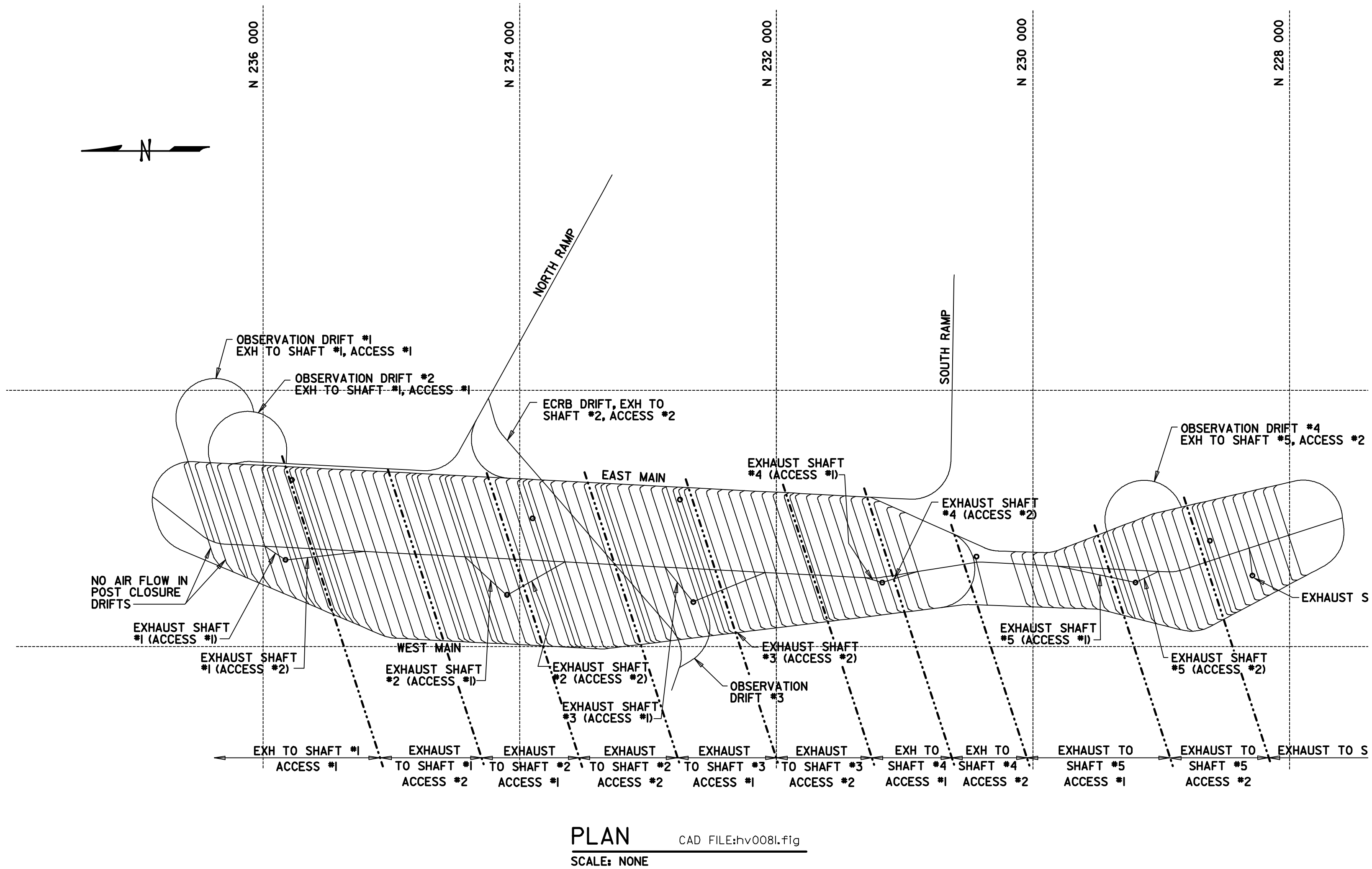

Figure 5. Exhaust Airflow Volume Allocations – 97,000 MTU Case

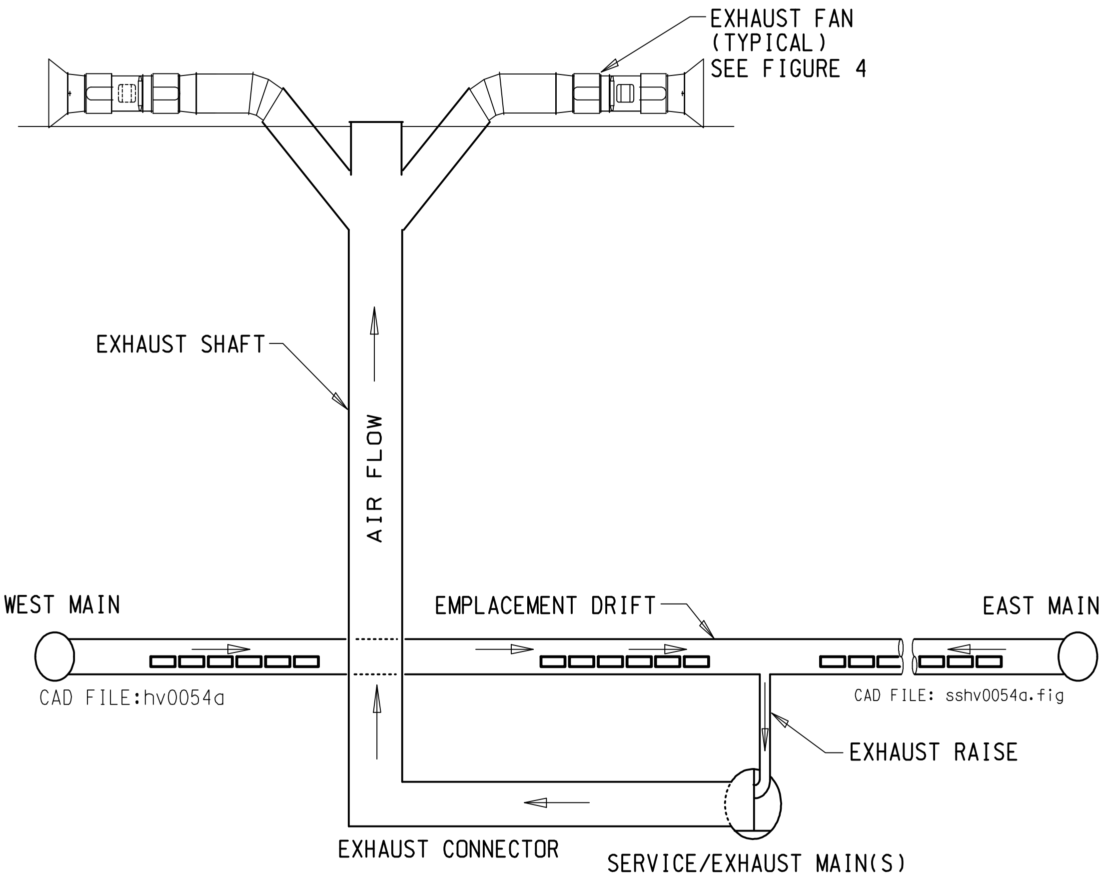

Figure 6. Emplacement Drift Conceptual Airflow

In the "Emplacement Drift Air Control System" (p. 44), air control was provided by a single air door at the emplacement drift entry in combination with valves on the exhaust raise. As an option, the current design may use an air lock (dual doors) to provide the primary ventilation control at the emplacement drift entry. As discussed in the "Emplacement Ventilation System," Section 6.3.2, air regulators would be contained at each airlock door and airflow could be regulated at the emplacement level rather than at the Exhaust Main level.

Due to the increased air volume and multiple intakes, it is envisioned the Exhaust Main will be a single drift with a center divider wall (see Section 2.2.2.4) that will provide airflow isolation as discussed below. The potential peak emplacement drift exhaust air temperature of 60 degrees C ("Overall Subsurface Ventilation System," Attachment III) is a temperature barrier restricting personnel access. Due to the heat and possible contamination, personnel will not work in this air stream. This air stream is contained in what is referred to as the exhaust side of the Exhaust Main.

The performance confirmation, empty spare emplacement, and cross-block drifts are the only air paths to provide airflow to what is referred to as the service side of the Exhaust Main where the instrumentation and personnel access is maintained (see Section 2.2.2.3). The performance confirmation, cross-block, and empty emplacement drifts will not contain waste packages and, therefore, will not be heated or exposed to the possibility of contamination. The air exiting these areas will be carried in an air stream (separate from the exhaust side air stream) that would be considered a normal work place. As an option, some or all of the cooler air contained in the service side can be redirected to the warmer airflow stream in the exhaust side to cool that air stream. This concept is discussed in the "Overall Subsurface Ventilation System," Section 6.1, and the "Emplacement Ventilation System," Section 6.2.2.

2.3.2 Emplacement Drift Air Volume

In "ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study," Table 6-5, modeling concluded that for a ventilation flow rate of 15 m^3/s, at 1.4 kW/m and 1.6 kW/m load, 71 percent of the heat was removed after 50 years of continuous ventilation. With an upper and lower bound delineated, an emplacement drift air volume of 15 m^3/s per split was selected for use in the "Overall Subsurface Ventilation System," Section 6.1.1.

2.3.3 Blast Cooling Air Volume

In the "Overall Subsurface Ventilation System," Section 6.1.4 a blast cooling volume of 47 m^3/s is used to provide supplemental airflow to deal with operational upsets (see Section 2.2.2.2). The blast cooling airflow allows the ventilation system to be adjusted to provide cooling and allow personnel or equipment access.

2.3.4 Construction Ventilation Phase

During early repository construction the Exploratory Studies Facility (ESF) loop (North Ramp, East Main and South Ramp) provides a flow path for the ventilation air. The existing airflow pattern through ESF ventilation system will be used, i.e. fresh air intake through the North Ramp and exhaust out the South Ramp. The ESF flow-through air volume will be capable of providing airflow for multiple work faces. Local ventilation is the volume of air supplied from the Main Drift through to the working face. Global ventilation is the volume of air that is provided from surface to the main drifts. Local ventilation systems will intake fresh air from the ESF, get used at the working face, be filtered as necessary and then be discharged back to the ESF south tunnel or ducted to the surface. It is envisioned that two main drifts would be excavated to the north, off the North Ramp curve. The first main drift (North Ramp Access) will provide airflow to the first block of emplaced waste. The second main drift is required to allow the development effort to proceed after waste has been emplaced in the first block. During the construction phase this allows the two ventilation systems to be isolated by barriers satisfying. "Overall Subsurface Ventilation System," Section 6.3.1 describes the ventilation concept for this phase in more detail.

2.3.5 Construction/Emplacement Phase

The repository is developed in a series of "panels" isolated from the emplacement area by the isolation airlocks that create two independent ventilation systems. Isolation barriers will exist at all emplacement/development interfaces on both the emplacement and exhaust levels. When the development of a panel of emplacement drifts is complete, the isolation barriers are relocated and the panel is then released for emplacement. At this time, the next panel is developed. This sequence continues until all emplacement drifts in the repository are complete. The construction/development ventilation air is supplied through a blowing system installed at the development shaft and the emplacement ventilation system operates in an exhaust mode with fans placed on top of the exhaust shafts. As discussed in Section 6.3.2 of the "Overall Subsurface Ventilation System" this creates a pressure differential across the isolation barrier separating the development and emplacement ventilation systems and ensures any leakage between the two systems is from the development side toward the emplacement side.

After the development activities have been completed, only the emplacement ventilation system will be operated.

2.3.6 Monitoring

When all waste packages have been emplaced, the repository enters the monitoring phase. The design will allow for an airflow for a period of up to 300 years.

The ventilation-related monitoring requirements include pressure, humidity, temperature, flow rate, carbon monoxide, door status, fan status, and louver status for assorted locations including main intake, main exhaust drifts, and the working areas. In addition to the ventilation-related monitoring requirements select monitoring of radioactive and non-radioactive particulates (e.g., dust, silica, etc.) is necessary. The Subsurface Ventilation Monitoring System is described in the "Overall Subsurface Ventilation System," Section 6.5.

2.3.7 Closure Ventilation

Closure ventilation requirements are described in the "Overall Subsurface Ventilation System," Section 6.3.4.

2.3.7.1 Emplacement Drift Backfill Ventilation

If the repository closes after 30 years of emplacement drift ventilation, the exhaust (from the emplacement drifts) air temperature is expected to have dropped to approximately 49 degrees C ("ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study," Table III-8) if ventilated with an air volume of 15 m^3/s (assuming 1.6 kW/m). Should emplacement backfill be needed, no special airflow is required to lower the temperature further since remote equipment can operate in temperatures up to 50 degrees C. The ventilation system during emplacement backfill, as with the normal emplacement drift ventilation concept, would be capable of providing a reduced controlled air movement during and after backfill placement. After backfill placement a regulated flow can be maintained to ensure that the airflow direction does not reverse. The "Overall Subsurface Ventilation System," Section 6.3.4.1 describes this in more detail.

2.3.7.2 Main Drift Backfilling Ventilation

Fresh air from the intake shaft is directed to the backfilling work area by ducts, drawn across the face and exhausted through a cross-block drift. Dust filtration units would be used as necessary. As the backfilling continues, the duct is repositioned and maintains the airflow return exhaust ahead of the operator. The exhaust main (now devoid of any intake air) remains to be backfilled and this can be accomplished by installing rigid ducting (exhaust) down the shaft to the work area. The "Overall Subsurface Ventilation System," Section 6.3.4.2, describes this in more detail.

2.3.7.3 Shaft Backfilling Ventilation

The shaft backfilling system would be similar to other backfilling processes. Temporary ventilation can be supplied to the work area by flexible ducts and portable fans. The "Overall Subsurface Ventilation System," Section 6.3.4.3, describes this in more detail.

2.3.8 Mitigating Airborne Particulates and Radon gas in the Repository

The subsurface ventilation system must be designed to prevent, control, remove, contain, or dilute contaminants such as radon and dust (which may include free silica, cristobalite, and quartz). The "Overall Subsurface Ventilation System," Sections 6.4.1 and 6.4.2, presents strategies for controlling dust and addressing radon concerns. Air velocities higher than 3 m/s will re-entrain settled dust in the air stream ("Mine Ventilation and Air Conditioning," p.125). It is expected that that the drift air velocity on the development side will not exceed 3 m/s velocity. Radon gas is liberated in relation to the exposed rock area.

2.4 COMPONENTS DESCRIPTION

This section describes select components of the ventilation system.

2.4.1 Air Control Options

As discussed in "Emplacement Ventilation System," Section 6.3, airflow regulation is required in the emplacement drifts. The design consists of isolation doors located in both the east and west emplacement drift turnouts. Each door has louvers that serve as inlets for ventilation air. The air passes through the drift and exits down the exhaust raise. Louvers are installed in each door to control airflow to the emplacement drift. The outer emplacement door opens, allowing the transport locomotive and waste package transporter to enter. The inner emplacement door remains shut and maintains the ability to control airflow. After the transport equipment enters the airlock, the outer emplacement door shuts and the inner one opens. The dual isolation door concept is illustrated in the "Emplacement Ventilation System," Figure 5.

2.4.2 Emplacement Drift Isolation Door Construction

As discussed in the "Emplacement Ventilation System," Section 6.4.1, the emplacement drift isolation doors provide some level of radiation protection. They can be constructed of a composite of steel and concrete or completely steel. The all-steel door would be composed of two plates joined together by steel spacers. An insulating material would be placed inside the hollow area between the spacers or on the interior surface of the door facing the emplacement area.

Each door is installed in a concrete bulkhead since concrete acts as a partial shield against radiation. By forming a seal against the walls of the drifts and by filling cracks in the rock, leakage around the bulkhead can be minimized.

2.4.3 Exhaust System

In the "Site Recommendation Subsurface Layout," Section 6.2.1.1 the Exhaust Main is excavated at 7.62 m diameter and contains a 0.2 m thick partition wall (Section 5.2.7.6) to provide a barrier to separate airflows (see Section 2.2.2.4). This concept (split exhaust main) is described further in the "Emplacement

Ventilation System," Section 6.2.3. In this concept, a single Exhaust Main is separated into an exhaust side and a service side by a partition. The air from emplacement drifts containing waste packages will generally be channeled to the exhaust side of the partition, while air from the performance confirmation, cross-block, and empty drifts will go to the service side. Since the exhaust side of the main will be hotter than the service side, the partition will need to be insulated. The service side must be kept at a temperature suitable for personnel access.

The exhaust raise and outlet structure is located on the service side of the Exhaust Main to allow personnel access for maintaining the regulating valves, radiation detectors, and other instruments necessary for monitoring waste emplacement system performance. Radiation shielding on either the outlet structure or the partition itself may be necessary. The "Emplacement Ventilation System," Section 6.4.3, provides additional description of the split Exhaust Main.

2.5 CRITERIA COMPLIANCE

Table 6 summarizes the criteria governing design of the system and explanations of how the design complies with the criteria.

Table 6. Criteria Summation

Criterion	Adherence to Criteria
1.2.1.1	This criterion will be met once the design has been finalized.
1.2.1.2	Criterion has been met in the “Emplacement Ventilation System” Sections 6.1, 6.3.1, 6.3.2). Airflow can be regulated by options that include: 1) louvers on emplacement drift isolation doors located in the east and west turnout with exhaust regulators installed at the bottom of the exhaust raise. 2) Dual isolation doors in each emplacement drift turnout to form an air lock with louvers installed in each door to regulate the airflow. This arrangement doesn't rely on regulators at the bottom of the exhaust raises.
1.2.1.3	The potential peak emplacement drift exhaust air temperature is 60EC (“Overall Subsurface Ventilation System,” Section 6.1). Human access will not be permitted in air streams with this temperature (“Overall Subsurface Ventilation System,” Section 6.1). The criterion has been met in the “Emplacement Ventilation System,” Section 6.2.3, by channeling the hotter air to the exhaust side of a split exhaust main, separated from the service side by an insulated partition. The “Site recommendation Subsurface Layout,” Section 5.2.7.6, uses a single exhaust drift with a partition. In the “Overall Subsurface Ventilation System,” Sections 5.7 and 6.1.4, a blast cooling airflow is available to cool areas where access is needed and temperatures exceed 48EC.
1.2.1.4	The criterion has been met in the “Overall Subsurface Ventilation System,” Sections 5.7, 6.1, and 6.1.4. It is assumed that blast cooling air volume of 47 m3/s will be provided to lower the temperature of the drift to below 50EC for remote equipment access to emplacement areas.
1.2.1.5	This criterion will be met once the design is finalized.
1.2.1.6	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.1, 6.3.1, and 6.3.2. Construction/development ventilation air is supplied through a blowing system installed at the development shaft. The emplacement ventilation system operates in an exhaust mode. This system maintains a pressure differential across the isolation barrier separating the development and emplacement ventilation systems and ensures any leakage between the two systems is from the development side toward the emplacement side.
1.2.1.7	This criterion will be met when the design is finalized.
1.2.1.8	The “ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study,” Table 6-2, indicates that an air volume of 15 m3/s and a thermal load of 1.6 kW/m the peak drift wall temperature will be 87°C for a drift that is ventilated for 30 years. Used in the “Site Recommendation Subsurface Layout,” Section 6.2.3.5.
1.2.1.10	This criterion will be met when the design is finalized.
1.2.1.11	Criterion has been met in the “Overall Subsurface Ventilation System,” Section 6.3.3. When all waste packages have been emplaced, the repository enters the monitoring phase. Ventilation System components would require rebuild/refurbishing for extended operations.
1.2.1.12	Criterion has been met in the “Overall Subsurface Ventilation System,” Section 6.3.3. The Main fans will require routine maintenance such as rebuild/refurbishing during the preclosure period and during any extended period of operation.
1.2.2.2.1	This criterion will be met when the design is finalized.
1.2.2.2.2	This criterion will be met when the design is finalized.

Table 6. Criteria Summation (continued)

Criterion	Adherence to Criteria
1.2.2.2.3	Criterion has been met in the “Emplacement Ventilation System,” Sections 6.4.1. The isolation doors control human access to the emplacement drifts and provide some level of radiation protection.
1.2.2.2.4	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.1 and 6.3.4.1. The surface emplacement fan installations, operating in an exhaust mode at each exhaust shaft, create a negative air pressure on the Exhaust Main level that is a higher negative air pressure than on the emplacement level, therefore, preventing recirculation from inside the emplacement drifts out to the main drifts.
1.2.2.2.5	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.4 and 6.4.2.1) the design of the drift length for a dead-end heading that would ensure the exposure limits for radon are not exceeded; 2) employing dust filtration units during construction and development phases so that the occupational doses are ALARA (from radon); 3) employing mobile filtration units to treat emplacement drift exhaust air during off-normal events
1.2.2.2.6	Design methods intended to satisfy this criterion are described in the “Overall Subsurface Ventilation System,” Sections 6.4 and 6.4.2.
1.2.3.1	This criterion will be met when the design is finalized.
1.2.3.2	This criterion will be met when the design is finalized.
1.2.3.3	This criterion will be met when the design is finalized.
1.2.3.4	This criterion will be met when the design is finalized.
1.2.3.5	This criterion will be met when the design is finalized.
1.2.3.6	This criterion will be met when the design is finalized.
1.2.3.7	This criterion will be met when the design is finalized.
1.2.3.8	This criterion will be met when the design is finalized and the system components have been tested to ensure their operation under temperatures of up to 96EC.
1.2.3.9	This criterion will be met when the design and the waste package stream have been finalized.
1.2.4.1	This criterion has been met in the “Overall Subsurface Ventilation System,” Section 6.5. The ventilation-related monitoring requirements include pressure, humidity, temperature, flow rate, carbon monoxide, door status, fan status, and louver status for various locations including main intake, main exhaust drifts, and the working areas. Select monitoring of radioactive and non-radioactive particulates (e.g., dust, silica) is also required.
1.2.4.2	This criterion will be met when the design is finalized.
1.2.4.3	This criterion will be met when the design is finalized.
1.2.4.4	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.2.2 and 6.2.4. The Subsurface Facility and Excavation Systems interface with the total repository air volume, or components of, to ensure the repository is capable of supporting the ventilation needs. The number of ventilation shafts must be estimated to provide an interface with the Subsurface Facility and Excavation Systems to ensure that the repository is capable of supporting the ventilation needs.
1.2.4.5	Criterion has been met in the “Overall Subsurface Ventilation System,” Section 6.1. The emplacement drift airflow can be adjusted for drip shield installation, backfill placement, or to react to off-normal events that may occur. This ability to regulate airflow demonstrates the ventilation system’s capability to interface with the emplacement drift system and satisfy the temperature requirement for remote access.
1.2.4.6	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.2.2 and 6.2.4. (See criterion 1.2.4.4)
1.2.4.7	Criterion has been met in the “Overall Subsurface Ventilation System,” Sections 6.3.4, and 6.3.4.1. Currently emplacement drift backfilling is not part of the design. However, it is not being excluded from consideration in the future. The ventilation system during emplacement backfill would be capable of reducing the air movement during and after backfill placement and removing dust. The contaminated air can be filtered with equipment.
1.2.4.8	Criterion will be met when the design is finalized.
1.2.4.9	Criterion has been met in the “Overall Subsurface Ventilation System,” Section 6.5. Monitoring for radioactive and non-radioactive particulates is required. Figures 9 and 10 describe the ventilation and radiation monitoring flowsheet.
1.2.5.1	Criterion will be met when the design is finalized.

Table 6. Criteria Summation (continued)

Criterion	Adherence to Criteria
1.2.6.1	Criterion will be met when the design is finalized.
1.2.6.2	Criterion will be met when the design is finalized.
1.2.6.3	The methods to satisfy this criterion are described in the “Overall Subsurface Ventilation System,” Sections 6.4 and 6.4.2. The subsurface ventilation system must be designed to control the concentration of radon daughters in the potentially occupied areas of the repository. This criterion will be met when the design is finalized.
s 1.2.6.4 - 1.2.6.13 (except 1.2.6.8 & 1.2.6.10)	Criteria will be met when the design has been finalized.
1.2.6.10	This criterion has been met by addressing applicable assumptions and requirements in the ” Monitored Geologic Repository Project Description Document.”.

3. SYSTEM OPERATIONS

This section will be completed in a later revision.

4. SYSTEM MAINTENANCE

This section will be completed in a later revision.

APPENDIX A CRITERION BASIS STATEMENT

This section presents the criterion basis statements for criteria in Section 1.2. Descriptions of the traces to "Monitored Geologic Repository Requirements Document" (MGR RD) and "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" are shown as applicable. In anticipation of the interim guidance being promulgated as a Code of Federal Regulations, it will be referred to as "10 CFR 63" in this system description document.

1.2.1.1 Criterion Basis Statement

I. Criterion Need Basis

The MGR RD invokes "Safety and Health Regulations for Construction" (29 CFR 1926). Section 1926.800.k (2) requires a minimum of 200 cubic feet of fresh air per minute for each employee underground. For this requirement to be satisfied, the maximum number of persons expected underground must be established to ensure the system can provide adequate fresh air for maximum number of people expected in the development and emplacement sides. The analysis below establishes the basis for the number of personnel. This criterion meets MGR RD 3.1.F.

II. Criterion Performance Parameter Basis

Title: Criteria Basis Statement for the Number of Subsurface Personnel

Purpose

The purpose of this analysis is to determine the maximum number of personnel that will be underground at any one time. This analysis will limit itself to establishing the number of personnel for a 50 year period after start of emplacement. There is no clear indication at the present time as to when the repository will close or if emplacement drift backfill will be used. These factors will affect the number of underground personnel required and it is left to a future analysis to determine these values.

Assumptions

1. Three shifts will be worked per day. The first shift will have 50 percent of the total number of personnel, the second shift will have 35 percent, and the third shift will have 15 percent. This is a general shift breakdown allowance similar to operating facilities that base their work day on having the major portion of the maintenance done on day shift, a moderate amount on evening shift, and only breakdown maintenance on graveyard shift. This schedule also allows for the major portion of miscellaneous, small construction projects to be carried out on day shift. This type of shift breakdown provides a conservative approach that is generally followed in underground development projects including the Exploratory Studies Facility.

2. The maximum number of visitors will not exceed 50 at any one time. This is a policy call by the operations manager. The actual number should be less than or equal to 50.

The policy at the Exploratory Studies Facility currently limits the number of subsurface visitors to 50.

3. The "Engineering File-Subsurface Repository," Section 6, page 35, assumes the information available for staffing; it makes conservative estimates for the current repository scope of work. As used in the criterion, data from this source does not affect the system's critical characteristics and will not be directly relied upon to address safety or waste isolation issues. The file does not provide a split between underground and surface workers. This split is set at 85 percent underground and 15 percent surface from "Mining Engineering Analysis" (p.15).

Criteria Analysis

The number of subsurface personnel is based upon estimated information (Assumption 3). This estimate developed quantities for major development and emplacement activities and estimated management and craft manpower to complete these activities. These figures reveal that the maximum number of workers for the development and emplacement areas do not occur at the same time. The maximum (or peak) number of personnel is shown below for development, emplacement, and monitoring phases. The peak number of personnel are 712 (2004-2009) and 466 (2010-2031) for the development areas and 90 (2010-2033) and 82 (2034-2059) for the emplacement areas.

The maximum number of people underground for the development side (712) will occur during the first construction period, from 2004 to 2009. The first shift will have 60 percent of the total for management and craft (Assumption 1), or 356. Eighty-five percent of this figure will be underground (Assumption 3), or 356 x 85 percent = 303. When the total number of visitors is taken into account (Assumption 2), the total is: 303 + 50 = 353 personnel underground.

The maximum number of people underground for the emplacement side will occur during the period 2010 to 2033, and is 90 personnel. The first shift will have 50 percent of the total (Assumption 1), or 45 personnel. Eighty-five percent of this figure will be underground (Assumption 3), or 45 x 85 percent = 39. When the total number of visitors is taken into account (Assumption 2), the total is: 39 + 50 = 89 personnel underground.

In "MGDS Consulting Board Report No. 6," p. 35, the Consulting Board recommended that shift change occur at the face for workers involved with the Tunnel Boring Machine operations. This would raise the number of personnel underground for the development side of the repository. However, it is unlikely that all personnel, including staff and visitors, will be underground at the same time during the shift change. For example, many office/management personnel would not be underground at shift change. Therefore, the numbers developed above are conservative.

Conclusion

The maximum number of personnel on the development side should be 353 and on the emplacement side should be 89. The number of subsurface personnel is TBV.

1.2.1.2 Criterion Basis Statement

I. Criterion Need Basis

Controlling airflow to emplacement drifts provides needed flexibility for repository operation and testing. For example, the subsurface testing programs will include thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted. This criterion is also necessary to ensure blast cooling of an individual drift. Blast cooling would be necessary if the air temperature in an emplacement drift had to be reduced temporarily. Remote equipment access and waste package retrieval are examples where blast cooling would be necessary.

II. Criterion Performance Parameter Basis

N/A

1.2.1.3 Criterion Basis Statement

I. Criterion Need Basis

The purpose of this criterion is to establish the maximum ambient dry bulb temperature for areas requiring human access. This criterion also provides the maximum heat exposure for normal eight-hour work areas. The criterion does not establish heat exposure limits for the operating facility, but is provided to ensure the subsurface ventilation design supports established heat exposure limits for unprotected workers in subsurface work areas.

II. Criterion Performance Parameter Basis

"Worker Protection Management for DOE Federal and Contractor Employees," section 4.l.1, invokes "Threshold Limit Values and Chemical Substances and Physical Agents and Biological Exposures Indices." "Threshold Limit Values and Chemical Substances and Physical Agents Biological Exposures Indices, " Table 1, states that the threshold limit for continuous heavy work conditions is 25 degrees C wet-bulb-globe temperature (WBGT). WBGT is a heat stress assessment of actual work locations. This criterion is provided to ensure that the design of Subsurface Ventilation System controls air parameters necessary to help meet "Threshold Limit Values and Chemical Substances and Physical Agents and Biological Exposures Indices" threshold temperature limits for actual work locations.

WBGT is an empirical heat-stress index and not something that can be calculated for all subsurface areas. The radiant heat is assessed using a globe thermometer in actual work conditions. Radiant heat (except for rock mass close to the loaded emplacement drifts where frequent human excess is not expected) is not a significant heat source in the subsurface facility. Areas where radiant heat may be significant (e.g., turnouts) are not considered normal eight-hour shift work locations and thus, are not subject to the heat exposure limit per this criterion.

Since radiant heat is not significant, effective temperature heat index will be comparable to WBGT. Effective temperature heat index can be used in design calculations, because effective temperature can be determined from the three determining psychrometric parameters (dry-bulb, wet-bulb, air velocity). This makes it possible to verify this criterion via design analyses while ensuring compliance with the American Conference of Government Industrial Hygienists' heat stress limits. "Threshold Limit Values and Chemical Substances and Physical Agents and Biological Exposures Indices" section 11.4.3, indicates a good standard is to maintain effective temperature between 21 and 26.5 degrees C. Thus, a 25 degrees C effective temperature is chosen.

An increase of dry-bulb temperature higher than 48.9 degrees C will exceed the heat stress index of 25 degrees C effective temperature regardless of air velocity effects. By this correlation and for ventilation design purposes, an arbitrary maximum dry bulb temperature of 48 degrees C is established as the safe maximum allowable temperature for subsurface employees that will be the basis for design criteria.

The maximum dry bulb temperature is an unqualified value and is labeled TBV. The maximum effective temperature and the maximum dry-bulb temperature represent the design capability of the system and not actual temperature limits allowed without human access.

1.2.1.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires all Monitored Geologic Repository (MGR) structures, systems, and components (SSCs) be designed for availability, maintainability, and habitability standards. The system is required to be capable of controlling the subsurface air temperature limits for remote access operations based on system functional requirement to control air temperature. This criterion states that the system shall be capable of limiting the maximum temperatures for the Emplacement Drifts, Access Mains/Ramps/Alcoves, Performance Confirmation Drifts, Exhaust Main, and Turnouts. This temperature is for equipment (e.g., waste emplacement gantry) used during remote operations. The system controls the maximum air temperatures in these areas only for remote access conditions. During normal operating conditions (e.g., caretaker mode) the maximum temperatures are determined primarily by thermal loading conditions.

The following analysis establishes 50 degrees C for the dry bulb temperature. This temperature limit applies to the temperature control capability of the system and not the maximum allowed temperature in these areas during other operating modes. The system does not control the minimum air temperature for remote equipment operations. The outside air will be warmed by the rock formation as it travels through the facility. In addition, the SSCs important to safety will be qualified to the outside air temperature range per the system description document (SDD) criterion for natural environments.

II. Criterion Performance Parameter Basis

Title: Criterion Performance Parameter Basis for Maximum Ambient Temperature in Remote Access Areas

Purpose

The purpose of this analysis is to establish the maximum dry bulb temperature as a threshold limit for repository environment that will allow commercial grade equipment to operate in remote repository access areas. This will include drift temperature for remote control operation of equipment during loading and unloading of waste packages in each emplacement drift.

Assumptions

Remote operated vehicles and equipment are using commercially available on-board electronics and actuators. It is good engineering practice to use commercial grade electronic units to take advantage of common technology and cost effective components.

Criteria Analysis

Design strategies and existing technologies are available to use remote operated vehicles within extreme thermal environments expected inside emplacement drifts. A key area of concern, however, is the use of on-board electronics and actuators that are sensitive to extreme temperatures. It is common for commercial grade electronics and components to have design operating temperatures in the range of 50 to 85 degrees C ("The Electrical Engineering Handbook"). Electronic components designed for temperature environments over 85 degrees C are available. This specialized equipment will be costly to operate in the repository and is not recommended.

Except for special high temperature equipment used to acquire performance confirmation data in the emplacement drifts, the elevated temperature limit for remote controlled access areas will be conservative in that the lower limit in the "The Electrical Engineering Handbook" is used for repository operations. The temperature limit should allow use of a wide range of commercially available cost effective electronics and components. The repository design should be able to maintain a maximum recommended dry-bulb temperature of 50 degrees C for remote access areas.

Conclusion

The maximum ambient dry-bulb temperature for repository equipment and electronic components operated remotely is 50 degrees C. The subsurface ventilation shall have the capability to provide ambient air below this maximum limit to allow commercial grade equipment to operate in repository remote access areas.

1.2.1.5 Criterion Basis Statement

I. Criterion Need Basis

Conductive and radiant heat transfer from the waste packages to the surrounding rock will cause a large-scale increase in the wall rock temperatures. This criterion is included because of the potential impacts that temperature change may have on other SSCs in the emplacement drifts. Inclusion of this criterion helps to protect SSCs and minimizes the need for maintenance in the emplacement drifts over the preclosure life. If access to an emplacement drift is needed for waste retrieval or other operations, blast cooling of the emplacement drift is needed to bring the temperature down to allow remote operations.

This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

The "Evaluation of Ground Support Heating and Cooling Cycles" evaluates and bounds the effects of a rapid air temperature change on ground support. It did consider the maximum expected airflow rate for emplacement drifts. It does not use the most conservative outside temperature. The computed stresses are within design limits based on these constraints. The analysis does not establish the maximum air temperature change that would be acceptable to Ground Control System. Therefore, the maximum rate of temperature change for the emplacement drifts is TBD.

1.2.1.6 Criterion Basis Statement

I. Criterion Need Basis

Maintaining separate ventilation for the emplacement and development areas is provided as a design criterion because it offers operational and engineering advantages. This criterion ensures separation of SSCs that support construction activities from those that support repository operations that are under NRC regulations and radiation protection programs. The development area will generate dusty air due to excavation activities. It is desirable to isolate dusty air from the emplacement area and potentially radioactive air from the development areas. Otherwise, the development areas, all the way to the muck piles, would be subject to potential contamination from radioactive dust.

The primary ventilation need for the development area (air quality) and repository operation area (heat removal) are different. Ventilation for the development area will have to accommodate the changing and moving of work areas as excavation progresses. Therefore, development operations should be independent of repository operations and vice versa. This criterion ensures that planned or unplanned ventilation shutdowns in one area will not affect ventilation in the other area.

II. Criterion Performance Parameter Basis

N/A

1.2.1.7 Criterion Basis Statement

I. Criterion Need Basis

This criterion establishes the minimum pressure differential across the isolation barrier(s) for the development and emplacement areas. The ventilation for the development and the emplacement sides must be separate. The leakage will be from the development side to the emplacement side. The analysis below establishes the minimum pressure differential.

II. Criterion Performance Parameter Basis

Title: Air Pressure Differential Across Isolation Barriers

Purpose

The purpose of this analysis is to develop a basis for the air pressure differential across the isolation barriers.

Assumption

1. The barrier will be constructed to withstand a wide range of differential pressures.

Rationale: Pressure fluctuations will occur between the development and the emplacement sides. This criterion establishes the nominal pressure differential.

2. Backup power will be provided to the emplacement exhaust fans to maintain control of the airflow during a power outage. This level of flow may be below full operational levels.

Rationale: The pressure differential is maintained by the airflow in the development and emplacement sides.

Criteria Analysis

U.S. Department of Energy (DOE) nuclear facilities are required to maintain a negative ventilation pressure in the innermost area of nuclear materials handling and storage facilities ("Nuclear Air Cleaning Handbook, Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application"). The " Nuclear Air Cleaning Handbook, Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application" designates four isolation zones, beginning with the outside environment and becoming progressively more negative from each interzone to the next. "Nuclear Air Cleaning Handbook, Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application" requires a minimum of 62.5 Pa (.25 in wg).

The minimum pressure differential can be reasonably set at 125 Pa (0.50 in wg) in conformance with Section 6.5.1 of "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)." An allowance for the pressure fluctuations developed by moving traffic should be added to this by the designers (Assumption 1). Engineering judgement and "Nuclear Air Cleaning Handbook, Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application" indicates that a minimum pressure allowance of 62.5 Pa (0.25 in wg) is reasonable and will not impact the design excessively.

There are no pressure regulators planned for either the North or South Portal entry areas. Therefore, the magnitude of the pressure differential is the result of pressure drops resulting from friction losses between the isolation door area and the outside air pressure at the portals. If there is no airflow in those areas, there will be no pressure differential across the isolation barrier. This scenario is not a probable consideration since backup power will be available to operate the fans during an outage of the main power system (Assumption 2). Natural ventilation pressure due to the heating of the air in the emplacement side exhaust shaft will assist the airflow during power outages.

Conclusion

The overall effect of the negative pressure is that leakage will progress from the development side of the repository to the emplacement side. In the case of a possible nuclear release, the contaminants will stay on the emplacement side and not migrate to the development side. A negative pressure differential of 62.5 Pa (0.25 in wg) should be provided to ensure that leakage will move from the development side to the emplacement side.

1.2.1.8 Criterion Basis Statement

I. Criterion Need Basis

A functional requirement for this system is to limit the maximum air temperature in the emplacement drift. This criterion is provided based on management's direction to utilize ventilation to limit the maximum temperature in the surrounding rock mass.

II. Criterion Performance Parameter Basis

The maximum air temperature allowed in the emplacement drifts is 96 degrees C as provided in Section 5.2.24 of the "Monitored Geologic Repository Project Description Document."

1.2.1.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support the requirement that the maximum emplacement drift wall temperature, during post closure shall not exceed 200 degrees C if a higher thermal mode is selected. To allow for flexibility of operations within a range of thermal modes during preclosure and postclosure, a low end of range of maintaining WP surface temperature below 85 degrees C has been selected.

II. Criterion Performance Parameter Basis

The maximum emplacement drift wall temperature of 200 degrees C is provided in Section 5.2.24 of the “Monitored Geologic Repository Project Description Document.” Section 5.1.1.3 of the “Monitored Geologic Repository Project Description Document” provides for the low end of the thermal operating range.

1.2.1.10 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support MGR RD 3.3.A, which requires compliance with applicable industry codes and standards. The criterion establishes the outside design requirements for the heating and cooling load calculations. Use of applicable and accurate environmental data (and other parameters) is essential in calculation of heating and cooling loads. The data provided in Table 2 of this document is not intended to be all-inclusive (the design organization may obtain additional data from qualified sources as required). However, deviations from the specific parameters that are provided in Table 2 must be documented.

II. Criterion Performance Parameter Basis

The outside design conditions are obtained from Tables 1A and 1B of the ASHRAE "Fundamentals" handbook Chapter 26. Selection of Mercury, Nevada as the representative site is appropriate because it is close to and representative of the conditions in the North Portal area.

1.2.1.11 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support Section 5.1.1.1 of the “Monitored Geologic Repository Project Description.

II. Criterion Performance Parameter Basis

The value of 30 years is taken from Section 5.1.1.1 of the “Monitored Geologic Repository Project Description Document.”

1.2.1.12 Criterion Basis Statement

I. Criterion Need Basis

This criterion establishes the additional length of time the system may be asked to operate to allow future generations to continue monitoring the repository. This criterion supports

Section 5.1.1.1 of the “Monitored Geologic Repository Project Description Document.” This criterion also supports 10 CFR 63.111(e)(2) and 10 CFR 63.111(e)(3).

II. Criterion Performance Parameter Basis

The 300 years is provided in section 5.1.1.1 of the “Monitored Geologic Repository Project Description Document.”

1.2.1.13 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support Section 5.3.6 of the “Monitored Geologic Repository Project Description.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices with particular attention to those that incorporate system safety. This criterion is provided to ensure that the subsurface ventilation main intake airways are located to minimize the potential for subsurface air containing exhaust airflow from a surface facility. This will minimize subsurface intake air containing noxious, toxic, or corrosive gases and vapors.

II. Criterion Performance Parameter Basis

The 100 m is provided in "Accident Analysis for a Nonmechanistic Waste Package Failure (Subsurface)" in Section 7.9. This value is TBV.

1.2.2.2.2 Criterion Basis Statement

I. Criterion Need Basis

This criterion is based on MGR RD 3.1.E which states that the MGR shall comply with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910.1000). Table Z-1 of this standard provides indoor air quality limits. As mandated by "Worker Protection Management for U.S. Department of Energy (DOE) Federal and Contractor Employees," Section 4.1.1 (DOE Order 440.1A), per "Occupational Exposure Assessment" (Implementation Guide DOE G 440.1-3), the "Values for Chemical Substances and Physical Agents and Biological Exposure Indices" will be used when the limits are more protective than the Occupational Safety and Health Administration permissible exposure limits.

MGR RD 3.1.G requires compliance with the applicable laws, codes, CFRs, NUREGs, DOE Orders, and other directives.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.3 Criterion Basis Statement

I. Criterion Need Basis

10 CFR 63.112(e)(5) requires this system to control access to high radiation areas. This criterion also met “Standards for Protection Against Radiation (10 CFR 20.1602) which requires control of access to high radiation areas. The emplacement drift entrances are considered ventilation dampers and are part of this system. The emplacement entrances will also control access to the emplacement drifts.

This criterion meets MGR RD 3.1.B and 3.1.C.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. The air in the emplacement drifts during the caretaker mode will be at high temperatures and, therefore, must be prevented from back-flowing into the turnouts and access mains that may be occupied by people. This criterion is provided for personnel safety reasons.

II. Criterion Performance Parameter Basis

N/A

1.2.2.2.5 Criterion Basis Statement

I. Criterion Need Basis

This criterion implements the requirements from MGR RD 3.1.B, (compliance with "Standards for Protection Against Radiation" (10 CFR 20)), and 10 CFR 63.111(a)(1). The primary requirement for ALARA is contained in “Standards for Protection Against Radiation” (10 CFR 20.1101(b)), which states: "The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to the members of the public that are as low as is reasonably achievable (ALARA)." The referenced sections of 10 CFR 63 reference the radiation protection limits of 10 CFR 20 and ALARA design features.

MGR RD 3.1.G requires compliance with the applicable laws, codes, CFRs, NUREGs, DOE Orders, and other directives.

Compliance with "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable" (Regulatory Guide 8.8), is invoked because this regulatory guide is one of the primary regulatory documents that addresses ALARA and is acceptable to the U.S. Nuclear Regulatory Commission. This regulatory guide provides guidelines on achieving the occupational ALARA goals during the planning, design, and operations phases of a nuclear facility. According to Section B of this guide: "Effective design of facilities and selection of equipment for systems that contain, collect, store, process, or transport radioactive material in any form will contribute to the effort to maintain radiation doses to station personnel ALARA." Section C.2 addresses facility and equipment design features. The design process of each system must include an evaluation of the applicable requirements in Section C.2 of Regulatory Guide 8.8.

In addition to following the guidelines in Regulatory Guide 8.8, the design of the system must meet the project ALARA program goals. The project ALARA program will include both qualitative and quantitative goals. Regarding the ALARA program of a licensee, Section C.1.a.(2) of Regulatory Guide 8.8 states: "The policy and commitment should be reflected in written administrative procedures and instructions for operations involving potential exposures of personnel to radiation and should be reflected in station design features. Instructions to designers, constructors, vendors, and station personnel specifying or reviewing station features, systems, or equipment should reflect the goals and objectives to maintain occupational radiation exposures ALARA."

II. Criterion Performance Parameter Basis

The project ALARA program goals are TBD.

1.2.2.2.6 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices with particular attention to system safety. Protection of workers in the repository from excessive exposure to radon daughter products is adopted based on the provisions of "Safety And Health Standards--Underground Metal And Nonmetal Mines" (30 CFR 57). Radon exposures are governed by "Occupational Safety and Health Standards" (29 CFR 1910).

This criterion meets MGR RD 3.1.E.

II. Criterion Performance Parameter Basis

The radon exposure limits are cited in 29 CFR 1910.1096.

1.2.3.1 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to support MGR RD 3.3.A, which requires compliance with applicable codes and standards. Wind is one of the primary external environmental parameters that can affect buildings and structures located outside. Proper consideration of wind is required to ensure that buildings and structures can withstand the wind forces, and that system components are adequately protected from the wind.

According to Section 6.5.2 of the standard for “Minimum Design Loads for Buildings and Other Structures” (ANSI/ASCE 7-95), the basic wind speed is to be used in the determination of the design wind loads for all buildings and structures. A similar discussion is provided in Sections 1615, 1616, and 1618 of the “1997 Uniform Building Code” (Volume 2, “Structural Engineering Design Provisions”).

II. Criterion Performance Parameter Basis

The maximum wind speed is obtained from "MGR Design Basis Extreme Wind/Tornado Analysis" (Section 7).

1.2.3.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. Snowfall is a design parameter needed for exposed structures to account for external loadings.

II. Criterion Performance Parameter Basis

The snowfall environment for the Yucca Mountain site was determined from the following information. The nine meteorological monitoring sites operated by the Radiological and Environmental Field Programs Department, as defined in "Meteorological Monitoring Program 1996 Summary Report," pp. 1-1 to 1-5, do not monitor snowfall because it is an infrequent occurrence. "Engineering Design Climatology and Regional Meteorological Conditions Report" includes snowfall information for some other sites in the general area that were examined to bound the snowfall environment that could occur at the Yucca Mountain site. As used in the criterion, data from this source does not affect the system's critical characteristics and will not be directly relied upon to address safety or waste isolation issues. The closest of these sites is Desert Rock Airport south of Mercury, about 45 km east-southeast of Yucca Mountain. Snowfall data were also included for Tonopah, which is about 150 km north-northwest of the repository and at a higher elevation. Tables A-12 and A-14 of "Engineering Design Climatology and Regional Meteorological Conditions Report" provide climatological summaries for those locations that include daily maximum, monthly maximum, and annual totals for snowfall. The snowfall data for Tonopah is considered to provide a conservative estimate of snowfall at the repository site for the following reasons: The elevation at Site 1 (which is closest to the proposed repository surface facilities) is 1,143 m (from the "Engineering Design Climatology and Regional Meteorological Conditions Report," Table A-17), Desert Rock is 1006.1 m, and Tonopah is 1655.1 m (from Table 2.2 of "Regional and Local Wind Patterns Near Yucca Mountain"). Average yearly total precipitation for Site 1, Desert Rock, and Tonopah are 4.97, 5.5, and 5.53 in., respectively (from the "Engineering Design Climatology and Regional Meteorological Conditions Report," Tables A-1, A-12 and A-14). Annual average snowfall depths are 2.86 in. at Desert Rock and 13.53 in. at Tonopah. Tonopah is further north, receives slightly more total precipitation, and is at a higher altitude; therefore, use of snow data from Tonopah is considered to be the conservative bounding area for Yucca Mountain. The maximum daily snowfall for Tonopah is 10 in. (rounded up from 9.7 in.) and occurs in the month of February (from Table A-14).

The monthly snowfall is used to establish and bound the maximum snowfall accumulation. This is based on the conservative nature of the maximum monthly snowfall and the consideration that all of the monthly snowfall occurs in a short period of time with no reduction for melting. The maximum monthly snowfall for Tonopah is 17 in. and occurs in the month of December (from Table A-14).

The snowfall data for Tonopah were not collected under an Office of Civilian Radioactive Waste Management approved quality assurance program. The data were collected by the National Weather Service at its Tonopah station and are accepted by the scientific community as an accurate measurement of the actual snowfall at the station. The data are suitable for use in the analysis, as discussed above, to provide conservative estimates of the possible maximum snowfall at the Yucca Mountain site for use in design criteria.

1.2.3.3 Criterion Basis Statement

I. Criterion Need Basis

Temperature is considered to be one of the primary environmental parameters that can affect component performance or result in advanced degradation. To ensure proper performance, many manufacturers specify the temperature environment in which the component must operate. This criterion establishes the outdoor temperature environment in which SSCs are expected to operate.

This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

The extreme outside temperature range of 5 degrees F to 117 degrees F is based on the annual extreme minimum and maximum temperatures for the nine meteorological monitoring sites located in the Yucca Mountain area. Locations of the nine sites are shown in Figure 2-1 of the "Engineering Design Climatology and Regional Meteorological Conditions Report." Extreme temperatures (and other data) are in Tables A-1 through A-9 of the report.

1.2.3.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. The humidity is a primary environmental parameter that can affect component performance and anticipated life expectancy. This criterion establishes the external humidity environment to be used for design.

II. Criterion Performance Parameter Basis

The humidity values are taken from the "Engineering Design Climatology and Regional Meteorological Conditions Report," Table A-1, Site 1 (NTS-60). Using Site 1 data is appropriate because the site is the closest and most representative of the North Portal, South Portal, and ventilation shafts. The annual mean humidity for Site 1 is 28 percent, which is the average of the yearly averages for each of the time periods (Hour 0400, 1000, 1600, 2200) (from Table A-1). The minimum summer mean humidity for Site 1 is 13 percent, which occurred in the month of June at hour 1600 (from Table A-1). The maximum winter mean humidity for Site 1 is 46 percent (rounded up from 45.9) which occurred in the month of December at hour 0400 (from Table A-1).

1.2.3.5 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. Airborne particulates are required to be considered to ensure airborne particulate matter (10 µm or less) limitations are met for subsurface personnel. This criterion is needed to establish the design basis dust levels for surface intake air. This criterion will primarily be used by Design Organization to determine if filtration is necessary and, if so, what type. The annual average dust levels are used in this criterion as they are more representative of site dust levels for the surface. The 24-hour peak levels provided in "Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996," Table 9, are not used because their occurrence is relatively infrequent, as indicated in Figure 4 and Figure 5 of the same report. "Protection of Environment: National Primary and Secondary Ambient Air Quality Standards," Section 50.6, requires measurement of 10 µm or less of respirable particulate matter.

II. Criterion Performance Parameter Basis

The air particulate data is provided from "Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996," Table 9. The values are the average values provided for years 1989 to 1995. The sampling techniques followed project conventional quality assurance requirements (see Section 1.3 “Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996"). The highest annual average particulate matter concentration (10 µm or less) is 12 µg/m3 for the years recorded in " Meteorological

Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report," Table 9.

1.2.3.6 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. This criterion is needed to establish the design basis dust levels for surface intake air. The total suspended particulate matter (50 µm or less, Table 9 of " Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996") is provided to help Design in establishing filtration needs for intake air.

II. Criterion Performance Parameter Basis

The air particulate data is provided from "Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996," Table 9. The values are the average values provided for years 1989 to 1995. The sampling techniques followed project conventional quality assurance requirements (see Section 1.3 of "Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996"). The highest annual average total suspended particulate matter concentration (50 µm or less) is 30 µg/m3 for the years recorded in "Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996," Table 9.

1.2.3.7 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. The in situ rock temperature influences the heat conduction to the surrounding rock and, thus, the subsurface air temperature.

II. Criterion Performance Parameter Basis

The in situ rock temperature is TBD.

1.2.3.8 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. The maximum air temperature in the emplacement drifts is needed to define the temperature conditions for this system design.

II. Criterion Performance Parameter Basis

The maximum air temperature in the emplacement drifts is based on the maximum rock temperature from MGR RD 3.2.M.

1.2.3.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed for the design of this system. This criterion establishes the maximum linear heat load in the emplacement drifts.

This criterion supports MGR RD 3.2.M.

II. Criterion Performance Parameter Basis

The line loading parameters are taken from the "Monitored Geologic Repository Project Description Document," Section 5.2.10.

1.2.4.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. This criterion ensures the system interfaces with the Monitored Geologic Repository Operations Monitoring and Control System. Other parameters could be added if additional airborne hazards are identified in future analyses. The type of monitoring is dependent on the design basis environmental conditions to be developed after this revision and will be provided by the final design.

Airflow Rate (or Velocity)

Minimum airflow rates and velocities in all working areas are required by "Safety and Health Regulations for Construction" (29 CFR 1926.800 (k)(2) and (3)). Monitoring the airflow rates or velocities is needed to ensure the compliance with applicable airflow requirements. Monitoring of the airflow rates at dust filters will provide data useful for the maintenance of dust filtration system and enhancement of air quality.

Air Pressure Differential

The development and emplacement operations will be physically separated from each other by use of isolation air locks. The development side will be designed to operate at a ventilation pressure higher than that of emplacement side. The air pressure differential at the air locks and fans must be monitored to ensure airflow is from the area of the lowest potential for radioactivity to the area of highest.

Air Temperature

Monitoring of air temperatures in the subsurface working areas is needed because it is a part of the control processes of the ventilation air quality. Monitoring of air temperatures in the exhaust airways (including ventilation ducts) can provide data that can be used to anticipate the thermal conditions in the emplacement drifts and the amount of convective heat transferred into the ventilation airflow.

Relative Humidity

Monitoring of the humidity of the ventilation airflow in the subsurface working areas is needed because it is a part of the control processes of the ventilation air quality. Monitoring of air humidity in the exhaust airways (including ventilation ducts) can provide data that can be used to anticipate the humidities in the emplacement drifts and the amount of water moisture transferred into the ventilation airflow.

Airborne Particulate

To keep the exposure of employees to airborne contaminants within the Threshold Limit Values (cited by "Protection of Environment: National Primary and Secondary Ambient Air Quality Standards" (40 CFR 50.6)), concentration of airborne particulate needs to be monitored.

Concentration of Carbon Monoxide (CO)

Monitoring of CO concentration is needed for monitoring air quality as indicated in "Protection of Environment: National Primary and Secondary Ambient Air Quality Standards" (40 CFR 50.8) for surface facilities. This safety measure is applied to the subsurface as a conservative feature for added fire protection and air quality. It also assists the efforts to achieve compliance with the requirements on airborne contaminant exposure.

One system function is to provide a means of monitoring the operational status of critical equipment. This criterion identifies the equipment that is crucial to the system's operations. The position of the air dampers indicates airflow conditions. The fan's RPM, voltage, current, and on-off readings are necessary to assess operating conditions. The position of the emplacement doors and the airlocks provide immediate indication of potentially unsafe work conditions. This criterion may not apply to all dampers and fans. Once the design is complete, this criterion will be revised to identify the specific equipment (i.e., equipment number) that will be monitored.

This criterion meets MGR RD 3.1.F and 3.1.G.

II. Criterion Performance Parameter Basis

N/A

1.2.4.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. This criterion ensures the system provides the capability to interface with the Subsurface Fire Protection System. The specific criteria for this requirement have not been determined, but the Subsurface Fire Hazard analysis, once performed, will be used to identify the necessary criteria for fire protection.

II. Criterion Performance Parameter Basis

N/A

1.2.4.3 Criterion Basis Statement

I. Criterion Need Basis

This criterion is provided to ensure that this system interfaces with the Subsurface Electrical Distribution System for power demands that are needed for ventilation operations. This criterion is provided as a functional criterion because the specific mechanical/electrical interfaces are design solution dependent.

II. Criterion Performance Parameter Basis

N/A

1.2.4.4 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs be designed and fabricated in accordance with engineering principles and practices. The Subsurface Facility System provides the subsurface layout, arrangement, and opening sizes. This interface is required to ensure the layout supports Subsurface Ventilation operations.

II. Criterion Performance Parameter Basis

N/A

1.2.4.5 Criterion Basis Statement

I. Criterion Need Basis

The purpose of this interface is to ensure the performance goals of the Emplacement Drift System are considered during Subsurface Ventilation design. The temperature constraints for the repository have to be considered as part of the design of this system.

This interface is necessary to meet MGR 3.2.M.

II. Criterion Performance Parameter Basis

N/A

1.2.4.6 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to ensure the interfaces between this system and the Subsurface Excavation System are addressed during the design. The purpose of this interface is to ensure appropriate ventilation is provided to support excavation operations. This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.4.7 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to ensure the interfaces between this system and the Backfill Emplacement System are addressed during the design. The purpose of this interface is to ensure appropriate ventilation is provided to support backfill operations. This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.4.8 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to ensure the interfaces between this system and the Safeguards and Security System are addressed during the design. The purpose of this interface is to ensure appropriate controls and alarms for access to the high radiation areas in the emplacement drifts. This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.4.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion is needed to ensure the interfaces between this system and the Site Radiological Monitoring System are addressed during the design. The purpose of this interface is to ensure appropriate accommodation of radiation monitoring for subsurface and surface exhaust airflows. This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.4.10 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the Uncanistered SNF Disposal Container System to ensure ventilation supports the preclosure temperature constraints on the Uncanistered SNF Disposal Containers. This criterion supports MGR RD 3.2.L by helping to maintain long-term temperature conditions that will not accelerate the degradation of the cladding. The short-term availability of this system is not critical, however, because long periods (months) of no ventilation are required for significant increases in the cladding temperatures.

II. Criterion Performance Parameter Basis

N/A

1.2.4.11 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the Defense High Level Waste Disposal Container System to ensure ventilation supports the preclosure temperature constraints on the Defense High Level Waste Disposal Containers. This criterion supports the long-term temperature conditions and minimizes degradation of the cladding. The short-term availability of this system is not critical, however, because long periods (months) of no ventilation are required for significant increases in the cladding temperatures.

II. Criterion Performance Parameter Basis

N/A

1.2.4.12 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the Naval Spent Nuclear Fuel Disposal Container System to ensure ventilation supports the preclosure temperature constraints on the Naval Spent Nuclear Fuel Disposal Containers. This criterion supports the long-term temperature conditions and minimizes degradation of the cladding. The short-term availability of this system is not critical, however, because long periods (months) of no ventilation are required for significant increases in the cladding temperatures.

II. Criterion Performance Parameter Basis

N/A

1.2.4.13 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the DOE Spent Nuclear Fuel Disposal Container System to ensure ventilation supports the preclosure temperature constraints on the DOE Spent Nuclear Fuel Disposal Containers. This criterion supports the long-term temperature conditions and minimizes degradation of the cladding. The short-term availability of this system is not critical, however, because long periods (months) of no ventilation are required for significant increases in the cladding temperatures.

II. Criterion Performance Parameter Basis

N/A

1.2.4.14 Criterion Basis Statement

I. Criterion Need Basis

The system interfaces with the Canistered Spent Nuclear Fuel Disposal Container System to ensure ventilation supports the preclosure temperature constraints on the Canistered Spent Nuclear Fuel Disposal Containers. This criterion supports MGR RD 3.2.L by helping to maintain long-term temperature conditions that will not accelerate the degradation of the cladding. The short-term availability of this system is not critical, however, because long periods (months) of no ventilation are required for significant increases in the cladding temperatures.

II. Criterion Performance Parameter Basis

N/A

1.2.5.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires MGR SSCs to be designed and fabricated in accordance with applicable industry codes, standards, and engineering principles and practices with particular attention to those that incorporate system safety, human factors, reliability, availability, maintainability, and habitability standards. A requirement for a reasonably bounded availability meets the intent of this criterion.

II. Criterion Performance Parameter Basis

The inherent availability of .9825 is provided in "Bounded Minimum Inherent Availability Requirements for the SDDs." This value is TBV.

1.2.6.1 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.E requires compliance with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910). This criterion invokes applicable requirements on this system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.2 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.1.F requires compliance with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926). This SDD covers both development and emplacement ventilation. This criterion invokes the applicable section of 29 CFR 1926 to the design of the development side ventilation system.

II. Criterion Performance Parameter Basis

N/A

1.2.6.3 Criterion Basis Statement

I. Criterion Need Basis

"Radiation Protection in Uranium Mines" (ANSI N13.8-1973) is invoked to address the potential problem with radon in dead-end areas of the repository. This standard is primarily applicable to uranium mines; however, the design guidelines and features presented in Section 14.5 of the standard would help limit concentrations of radon daughters in the repository. This requirement applies only to areas where there is a potential for employee exposure to radon daughters. The extent of applicability will be based on the final design.

This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.6.4 Criterion Basis Statement

I. Criterion Need Basis

The handbooks from the ASHRAE provide industry-wide accepted guidelines and design information for all ventilation system applications, and are deemed applicable to the Subsurface Ventilation System.

This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.6.5 Criterion Basis Statement

I. Criterion Need Basis

"Standard for the Installation of Air Conditioning and Ventilation Systems" (NFPA 90A) provides minimum standards for fire protection of air duct systems. Protection of the subsurface air duct(s) is essential to personnel safety. This criterion is provided to ensure the applicable provisions of NFPA 90A are incorporated in the design of this system.

This criterion supports MGR RD 3.3.A.

II. Criterion Performance Parameter Basis

N/A

1.2.6.6 Criterion Basis Statement

I. Criterion Need Basis

Design, selection, arrangement, configuration, and integration of SSCs involve many elements. To accomplish an effective and safe work environment, the human-system interface must incorporate human factors engineering (HFE) criteria. Use of the “Department of Defense Design Criteria Standard, Human Engineering” (MIL-STD-1472E), in conjunction with the other HFE standards and guidelines cited in this SDD, will provide a human-system interface that maximizes performance and minimizes risk to personnel.

In support of MGR RD 3.3.A, this criterion ensures that the system will be designed to be safely and effectively used by all expected users. The DOE Good Practices Guide "Human Factors Engineering" (GPG-FM-027, paragraph 2.3.1) endorses the use of MIL-STD-1472E (GPG-FM-027 references the earlier version of MIL-STD-1472).

II. Criterion Performance Parameter Basis

N/A

1.2.6.7 Criterion Basis Statement

I. Criterion Need Basis

Maintainability of system equipment involves many factors, including the human-machine interface. This interface must address the design for maintainability through the incorporation of HFE criteria. In support of MGR RD 3.3.A, this criterion ensures that the system will be designed to be safely and effectively maintained through compliance with applicable industry standards. The DOE Good Practices Guide "Human Factors Engineering" (GPG-FM-027, paragraph 2.3.1) endorses the use of "Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities" (UCRL-15673) for addressing HFE maintainability design criteria.

II. Criterion Performance Parameter Basis

N/A

1.2.6.9 Criterion Basis Statement

I. Criterion Need Basis

This criterion is derived from regulatory precedence cited in MGR RD 3.1.B, which invokes "Standards for Protection Against Radiation" (10 CFR 20).

II. Criterion Performance Parameter Basis

N/A

1.2.6.10 Criterion Basis Statement

I. The “Monitored Geologic Repository Project Description Document” allocates technical requirements and controlled project assumptions to systems. This criterion identifies the need to comply with the applicable technical requirements and assumptions identified in the subject document.

II. Criterion Performance Parameter Basis

N/A

1.2.6.11 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires compliance with applicable industry codes and standards. This criterion identifies “Administrative, Fire- and Life-Safety, and Field Inspection Provisions” Volume 1 of "1997 Uniform Building Code,” as applicable to the design of the system. This criterion supports MGR RD 3.1.G.

II. Criterion Performance Parameter Basis

N/A

1.2.6.12 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires compliance with applicable industry codes and standards. This criterion identifies "1997 Uniform Building Code” (Volume 2, “Structural Engineering Design Provisions”) as applicable to the design of the system. This criterion supports MGR RD 3.1.G.

II. Criterion Performance Parameter Basis

N/A

1.2.6.13 Criterion Basis Statement

I. Criterion Need Basis

MGR RD 3.3.A requires compliance with applicable industry codes and standards. This criterion identifies “1997 Uniform Building Code” (Volume 3, “Material, Testing and Installation Standards”) as applicable to the design of the system. This criterion supports MGR RD 3.1.G.

II. Criterion Performance Parameter Basis

N/A

APPENDIX B ARCHITECTURE AND CLASSIFICATION

The system architecture and QA classification are identified in Table 7. The QA classifications are established in "Classification of the MGR Subsurface Ventilation System."

Table 7. System Architecture and QA Classification

Subsurface Ventilation System	QL-1	QL-2	QL-3	CQ
Development Area Ventilation System				X
Emplacement Area Ventilation System				X

APPENDIX C ACRONYMS, SYMBOLS, AND UNITS

C.1 ACRONYMS

ALARA	As Low As Reasonably Achievable
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CFR	Code of Federal Regulations
CO	carbon monoxide
CQ	Conventional Quality
DOE	U. S. Department of Energy
F	function
HFE	Human Factors Engineering
N	north
M&O	Management and Operator
MGR	Monitored Geologic Repository
MGR RD	Monitored Geologic Repository Requirements Document
N/A	Not Applicable
NRC	U. S. Nuclear Regulatory Commission
NUREG	NRC Regulation (or position preface)
QA	quality assurance
QL	Quality Level
RPM	revolutions per minute
S	South
SSCs	structures, systems, and components
SDD	System Description Document
TBD	to be determined
TBV	to be verified
W	west
WBGT	wet-bulb globe temperature

C.2 SYMBOLS AND UNITS

°	degrees
%	percent
‘	minutes of arc
“	seconds of arc
C	Celsius
F	Fahrenheit
ft	feet
ft/s	feet/second
in.	inches
m	meters
µg	micrograms
µm	microns
Pa	Pascals
s	seconds

wg	water gauge
m^3	cubic meters
kW	kilowatts

APPENDIX D FUTURE REVISION RECOMMENDATIONS AND ISSUES

This appendix identifies issues and actions that require further evaluation. The disposition of these issues and actions could alter the functions and design criteria that are allocated to this system in future revisions to this document. However, the issues and actions identified in this appendix do not require TBDs or TBVs beyond those already identified

Issue 1 - Resolve outstanding TBDs and TBVs.

Issue 2 - Improve consistency within units of measurement.

Issue 3 - Resolve problems between meeting the OSHA air quality requirement for personnel working underground and the quality of surface ambient air.

Issue 4 - How will Radon and its daughter products be controlled by the design?

Issue 5 - Address the issue of dust suppression on the development side of the underground facility in the design.

Issue 5 - The logic and analysis used to support the minimum separation distance between intake and exhaust airways needs to be re-evaluated during the next revision of this document.

APPENDIX E REFERENCES

This section provides a listing of references used in this SDD. References list the Accession number or Technical Information Catalog number at the end of the reference, where applicable. References that have neither an Accession number nor a Technical Information Catalog number at the end of the reference are considered "Readily Available."

"1997 Uniform Building Code." Volume 1, "Administrative, Fire- and Life-Safety, and Field Inspection Provisions." International Conference of Building Officials. April 1997. Whittier, California: International Conference of Building Officials. TIC: 233817.

"1997 Uniform Building Code." Volume 2, "Structural Engineering Design Provisions." International Conference of Building Officials. April 1997. Whittier, California: International Conference of Building Officials. TIC: 233818.

"1997 Uniform Building Code." Volume 3, "Material, Testing and Installation Standards." International Conference of Building Officials. April 1997. Whittier, California: International Conference of Building Officials. TIC: 233816.

"Accident Analysis for a Nonmechanistic Waste Package Failure (Subsurface)." CRWMS M&O. BCA000000-01717-0200-00001, Rev. 00. 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971007.0547.

"ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study." CRWMS M&O. CAL-EBS-MG-000001, Rev. 00. December 9, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000119.0134.

"Bounded Minimum Inherent Availability Requirements for the System Description Documents." CRWMS M&O. B00000000-01717-0200-00147, Rev. 00. March 13,1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980416.0791.

"Classification of the MGR Subsurface Ventilation System." CRWMS M&O. ANL-SVS-SE-000001, Rev. 00. August 31, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0219.

"Department of Defense Design Criteria Standard, Human Engineering." U.S. Department of Defense. MIL-STD-1472E. October 31, 1996. Washington, D.C.: U.S. Department of Defense. TIC: 235204.

"Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)." American Nuclear Society. ANSI/ANS-57.9-1992. 1992. La Grange Park, Illinois: American Nuclear Society. TIC: 3043.

"Emplacement Drift Air Control System." CRWMS M&O. BCAD00000-01717-0200-00005, Rev. 00. 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980102.0034.

"Emplacement Ventilation System." CRWMS M&O. ANL-SVS-HV-000003, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0688.

"Engineering Design Climatology and Regional Meteorological Conditions Report." CRWMS M&O. B00000000-01717-5707-00066, Rev. 00. October 2, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980304.0028. DTN: MO9811DEDCRMCR.00 (U).

"Engineering File - Subsurface Repository." CRWMS M&O. BCA000000-01717-5705-00005, Rev. 01. March 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990310.0078.

"Evaluation of Ground Support Heating and Cooling Cycles." CRWMS M&O. BCAA00000-01717-0200-00010, Rev. 00. September 30, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981006.0019.

"Fundamentals." American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1997 ASHRAE Handbook, Inch-Pound Edition. 1997. Atlanta, Georgia: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. TIC: 240756.

"Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities." Bongarra, Jr., James P.; VanCott, Harold P.; Pain, Richard F.; Peterson, L. Rolf; Wallace, Ronald I. UCRL-15673. June 18, 1985. Livermore, California: Lawrence Livermore National Laboratory. TIC: 206097.

"Human Factors Engineering." Office of Project and Fixed Asset Management. GPG-FM-027. March 1996. Washington, D.C.: U.S. Department of Energy, Office of Project and Fixed Asset Management. TIC: 240421.

"Implementation Guide for Use With DOE Order 440.1 - Occupational Exposure Assessment." U.S. Department of Energy. DOE Order G 440.1-3. March 30, 1998. Washington, D.C.: U.S. Department of Energy. TIC: 240305.

"Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be as Low as is Reasonably Achievable." U.S. Nuclear Regulatory Commission. Regulatory Guide 8.8, Rev. 3. June 1978. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Standards Development. Readily Available.

"Meteorological Monitoring Program 1996 Summary Report." CRWMS M&O. B00000000-01717-5705-00072, Rev. 00. October 28, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980210.0202.

"Meteorological Monitoring Program Particulate Matter Ambient Air Quality Monitoring Report January through December 1996." CRWMS M&O. BA0000000-01717-5705-00001, Rev. 00. April 16, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980416.0733.

"MGDS Consulting Board Report No. 6." Letter: S. H. Bartholomew to J. R. Dyer. December 10, 1997. Chico, California: S. H. Bartholomew, Inc Construction Consulting Services. ACC: MOL.19981030.0187.

"MGR Design Basis Extreme Wind/Tornado Analysis." CRWMS M&O. ANL-MGR-SE-000001, Rev. 00. October 28, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991215.0461.

"Mine Ventilation and Air Conditioning." Hartman, H.L.; Ramani, R.V.; Mutmansky, J.M.; and Wang, Y.J. 3rd Edition. 1997. New York, New York: Johnn Wiley & Sons. TIC: 236391.

"Minimum Design Loads for Buildings and Other Structures." American Society of Civil Engineers. ASCE 7-98. 2000. Reston, Virginia: American Society of Civil Engineers. TIC: 247427.

"Mining Engineering Analysis." Bise, Christopher J. 1986. Littleton, Colorado: Society of Mining Engineers, Inc. TIC: 243704.

"Monitored Geologic Repository Project Description Document." Bechtel SAIC Company. TDR-MGR-SE-000004, Rev. 02 ICN 02. June 2001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010628.0224.

"Monitored Geologic Repository Requirements Document." U.S. Department of Energy. YMP/CM-0025, Rev. 3, DCN 02. May 2000. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office. ACC: URN-0376.

"Nuclear Air Cleaning Handbook, Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application." Burchsted, C. A.; Fuller, A. B.; and Kahn, J. E. ERDA 76-21. March 31, 1979. Oak Ridge, Tennessee: Oak Ridge National Laboratory. TIC: 240766.

"Occupational Safety and Health Standards." Occupational Safety and Health Administration, Department of Labor. 29 CFR 1910. July 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Overall Subsurface Ventilation System." CRWMS M&O. ANL-SVS-HV-000002, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0689.

"Protection of Enviroment: National Primary and Secondary Ambient Air Quality Standards." U.S. Enviromental Protection Agency. 40 CFR 50. 1999. Washington, D.C.: U.S. Enviromental Protection Agency. Readily Available.

"Quality Assurance Requirements and Description." U.S. Department of Energy. DOE/RW-0333P, Rev. 10. April 2000. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

"Radiation Protection in Uranium Mines." American National Standards Institute, Inc. ANSI N13.8-1973. 1973. New York, New York: American National Standards Institute, Inc. TIC: 208902.

"Regional and Local Wind Patterns Near Yucca Mountain." CRWMS M&O. B00000000-01717-5705-00081, Rev. 00. November 20, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980204.0319.

"Retrievability Strategy Report." CRWMS M&O. B00000000-01717-5705-00061, Rev. 01 DCN 1. August 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990201.0011.

"Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." U.S. Department of Energy. OL&RC:SB-1714. September 3, 1999. North Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office. ACC: MOL.19990910.0079.

"Revised Waste Package Lengths." CRWMS M&O. 00309.T. June 26, 2000. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000626.0298.

"Safety and Health Regulations for Construction." Occupational Safety and Health Administration, Department of Labor. 29 CFR 1926. July 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Safety and Health Standards. Underground Metal and Non-metal Mines." Mine Safety and Health Administration, Department of Labor. 30 CFR 57. 1997. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Site Recommendation Subsurface Layout." CRWMS M&O. ANL-SFS-MG-000001, Rev. 00. 2000. Las Vegas, Nevada: CRWMS M&O. ACC: URN-0220.

"Standard for the Installation of Air Conditioning and Ventilating Systems." National Fire Protection Association. NFPA 90A, 1996 Edition. August 9, 1996. Quincy, Massachusetts: National Fire Protection Association. TIC: 240301.

"Standards for Protection Against Radiation." U.S. Nuclear Regulatory Commission. 10 CFR 20. January 1, 1999. Washington, D.C.: U.S. Government Printing Office. Readily Available.

"Technical Reports." U.S. Department of Energy, Office of Civilian Radioactive Waste Management. AP-3.11Q, Rev. 2, ICN 0. April 3, 2001. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010405.0010.

"Technical Work Plan For Subsurface Design Section FY 01 Work Activities." CRWMS M&O. TWP-MGR-MG-000001. Rev. 01. January 25, 2001. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010405.0014.

"The Electrical Engineering Handbook." Dorf, R.C. 1993. Boca Raton, Florida: CRC Press, Inc. TIC: 209253.

"Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices." American Conference of Governmental Industrial Hygienists. 1997. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists. TIC: 235871.

"Worker Protection Management for DOE Federal and Contractor Employees." U. S. Department of Energy, Office of Environment, Safety and Health. DOE O 440.1A. March 27, 1998. Washington, D.C.: U.S. Department of Energy. TIC: 242151.