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1. PURPOSE

The purpose of this analysis is to develop preliminary design features for the isolation barriers between the repository subsurface emplacement and development sides. The objective is to provide ventilation barrier systems that interface with and support development of an overall ventilation system design.

The scope of the analysis for the ventilation barriers between the emplacement and development sides covers:

1. Development of the configuration and arrangement of the ventilation barriers in the main access and exhaust drifts, including systems for restricting and monitoring air leakage through the barrier, provisions for rail and pedestrian traffic between the emplacement and development sides for off-normal (emergency) situations, and monitoring and control systems. Rail traffic for normal situations will also be examined.
2. Materials of construction and construction approach.

2. QUALITY ASSURANCE

The items which are the subject of this design analysis have not been classified in accordance with QAP-2-3. However, airlocks, isolation doors, and other ventilation barriers (permanent and temporary) have been placed on the *Q-List* (Reference 5.1) by direct inclusion. Therefore, for purposes of this analysis, all ventilation barriers and related structures will be considered Quality Affecting and subject to the *Quality Assurance and Requirements Description* (Reference 5.2). This design analysis activity has been evaluated (Reference 5.5) in accordance with QAP-2-0 and found to be quality affecting. As specified in NLP-3-18, this activity is subject to QA controls.

Much of the input data used in this analysis is preliminary and "unqualified" and, therefore, the outputs also are unqualified. Due to the preliminary nature of this analysis, all data must be treated as unqualified/unconfirmed and the formal TBV and TBD tracking system as described in NLP-3-15 for the To Be Verified (TBV) and To Be Determined (TBD) Monitoring System does not apply. The conclusions from this design analysis can not be used as input into documents supporting procurement, fabrication, or construction.

3. METHOD

Ventilation barriers will be evaluated on the basis of their function, performance (minimal leakage, regulated access, etc.), and structural integrity. The barrier configuration and structural

requirements will be determined by considering the construction materials, and equipment and personnel utilization. A calculation will be performed analyzing forces and identifying structural member sizes.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

4.1.1 Diameter of Underground Openings

Underground openings for the repository including ramps, access/service main, and central exhaust main will have nominal diameters of 7.62 m. (Reference 5.8).

4.1.2 Underground Layout

The current repository layout (Reference 5.8) contains long parallel emplacement drifts, a single emplacement block, two shafts and two access ramps, single perimeter/access drift and single central exhaust drift, and other features not essential to this analysis.

4.2 CRITERIA

4.2.1 Separation of Underground Ventilation Systems

The excavation and waste emplacement ventilation systems will be separated by physical barriers. (Ref 5.3; 3.7.5.B.3)

4.2.2 Ventilation Barrier Leakage

The ventilation pressure on the excavation side will exceed the pressure on the emplacement side so that leakage will occur from the excavation side to the emplacement side. (Ref 5.3; 3.7.5.B.4)

4.2.3 Robustness of Ventilation Barrier Design

Ventilation barriers will be designed to continue functioning during normal operations and under postulated accident conditions. (Ref 5.3; 3.7.5.B.2)

4.2.4 Reliability Requirement

System designs shall be developed to minimize personnel injury. The reliability of systems will be shown by analysis. These systems shall be designed and located so that they continue to perform their safety functions effectively during and after credible fire and explosion conditions. The barriers shall remain standing and sound during fire exposure. Each utility service system shall be designed to perform under both normal and accident conditions and shall include redundant systems to perform safety functions. (Ref 5.3; 3.2.5.1, 3.2.6.2.2B)

4.3 ASSUMPTIONS

4.3.1 Pressure Difference between the Development and Emplacement Ventilation Systems

The ventilation systems for the emplacement and development areas shall be designed such that there is a pressure differential from the development to emplacement sides (Criterion 4.2.2). The pressure in the development area shall be higher than the pressure in the emplacement area by a minimum pressure to be determined in subsequent analysis. An air pressure differential across the barrier system of at least 3,000 Pa (12 inches water gauge)(TBV) plus an additional pressure above 3,000 Pa is used to determine the relative size of the primary structural members. The 3,000 Pa value represents an average of a range of expected high pressure differentials which may occur across individual barriers. Pressures derived from preliminary analyses will be used for initial sizing. Pressures derived from final analyses will be used for final sizing This assumption is used in Section 7.1.2 and 7.2.5 and Attachment I.

4.3.2 Material Restrictions

Organic materials are restricted for use as rock support and other postclosure permanent materials in all openings. Concrete and steel are allowable preclosure construction material in all openings (Reference 5.4; DCSS 027, TBV). This assumption is used in Section 7.2.1.

4.3.3 Seismic Design of the Barriers

The seismic design of repository systems, structures, and components shall be based upon the methodology in *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (Reference 5.9). (Reference 5.4, Key 064, TBV)

For the ventilation barriers, seismic design parameters in *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain* (Reference 5.10) are assumed to correspond to Frequency-Category I (Reference 5.9). The mean peak horizontal acceleration of 0.27 g is obtained based on an assumed performance category of 2. This value is further assumed to be applicable to both vertical and horizontal ground motions (Ref 5.10, p.6, Tbl 1). As a conservative consideration, factors for reduction of ground motion with depth are not used in this analysis. Thus, it is assumed that a mean peak horizontal and vertical acceleration of 0.27 g will impact the typical ventilation barrier during a seismic event (TBV).

Seismic analysis will consist of a quasi-static analysis applying a horizontal and vertical acceleration to the barrier structure. The seismic force will be the product of the horizontal and vertical accelerations times the weight of the item being analyzed. This assumption is used in Section 7.1.5.8 and Attachment I.

4.4 CODES AND STANDARDS

4.4.1 American Institute of Steel Construction (AISC)

AISC-MO16-89 AISC Manual of Steel Construction, Allowable Stress Design, Ninth Edition, 1989.

4.4.2 American Society of Civil Engineers (ASCE)

ASCE 7-95 Minimum Design Loads for Buildings and Other Structures (Approved June 1966)

4.4.3 American Society for Testing and Materials (ASTM)

ASTM A36/A36M-94 Standard Specification for Carbon Structural Steel

4.4.4 Code of Federal Regulation (CFR), Title 10, Energy, Part 60--*Disposal of High-Level Radioactive Wastes in Geologic Repositories*

§60.113(a)(1) Engineered barrier system.

- (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; ...

§60.131(j) Compliance with mining regulations.

To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, chapter I, subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

Subpart H--Training and Certification of Personnel

§60.160 General Requirements

Operations of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety must also be certified in such operations.

4.4.5 Code of Federal Regulations, Title 29, Part 1926--Safety and Health Regulations for Construction

Subpart C--General Safety & Health Provisions

§1926.21(6) Safety Training and Education

All employees required to enter into confined or enclosed spaces shall be instructed as to the nature of the hazards involved, the necessary precautions to be taken, and in the use of protective and emergency equipment required.

Subpart S--Underground Construction, Caissons, Cofferdams, and Compressed Air.

§1926.800(b)(1) Underground Construction Access and Egress.

The employer shall provide and maintain a safe means of access and egress to all work stations.

4.4.6 Code of Federal Regulations, Title 30, Part 57--Safety and Health Standards--Underground Metal and Non Metal Mines.

Subpart G--Ventilation.

§57.8531 Construction and maintenance of ventilation doors.

(d) [Ventilation doors shall be--] Self-closing, if manually operated...

(e) [Ventilation doors shall be--] Equipped with audible or visual warning devices, if mechanically operated.

§57.8535 Seals.

Seals shall be provided with a means for checking the quality of air behind the seal...

Subpart J--Travelways and Escapeways.

§57.11050 Escapeways and refuges.

(a) Every mine shall have two or more separate, properly maintained escapeways to the surface from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others....

§57.11051 Escape routes.

(b) [Escape routes shall be--] Marked with conspicuous and easily read direction signs that clearly indicate the ways of escape.

5. REFERENCES

5.1 *Q-List, YMP/90-55Q Rev. 4.*

5.2 *Quality Assurance Requirements and Description (QARD) for the Civilian Radioactive Waste Management Program, DOE/RW0333P Rev. 7.*

- 5.3** *Repository Design Requirements Document (RDRD)*, YMP/CM-0023, Rev. 0, ICN 01.
- 5.4** *Controlled Design Assumptions Document (CDA)*, D.I. No. B00000000-01717-4600-00032 Rev. 04, ICN 2.
- 5.5** Activity Evaluation for *Subsurface Ventilation Isolation Barriers* (TR47FB9), August 7, 1997.
- 5.6** Not Used
- 5.7** Not Used
- 5.8** *Repository Subsurface Layout Configuration Analysis*, D.I. No. BCA000000-01717-0200-00008 Rev. 00.
- 5.9** *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain*, Topical Report YMP/TR-003-NP, Rev. 1, Draft A, August 1996.
- 5.10** *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain*, D.I. No. BAB000000-01717-5705-00001 Rev. 02.
- 5.11** *Waste Package Design Basis Events*, D.I. No. BBA000000-01717-0200-00037 Rev. 00.
- 5.12** *Preliminary MGDS Hazards Analysis*, D.I. No. B00000000-01717-0200-00130 Rev. 00.
- 5.13** *Waste Package Off-Normal and Accident Scenario Report*, D.I. No. BBA000000-01717-5705-00008 Rev. 00.

6. USE OF COMPUTER SOFTWARE

Not applicable. Computational Software was not used.

7. DESIGN ANALYSIS

7.1 VENTILATION BARRIER DESIGN CONSIDERATIONS

7.1.1 Separation of Ventilation Systems

Ventilation will be a critical support function in the subsurface repository for conducting development of the underground repository and emplacement of the waste packages. Repository development and emplacement will involve distinct and separate operations; each requiring separate ventilation systems (Criterion 4.2.1). A system of barriers will be erected in the main drifts and performance confirmation drifts to separate the two ventilation systems. The barriers may be erected at several locations and be relocated periodically until repository development is completed. The components of each barrier may be dismantled and reused or discarded as is determined in subsequent analysis. The barriers must be substantial enough (Criterion 4.2.3) to function safely (Criterion 4.2.4) as long as they are in place. General design alternatives for the ventilation barriers are evaluated in this analysis for their application and success in meeting the design criteria.

7.1.2 Personnel Access and Egress

Guidance to personnel safety is provided by federal statutes in both the Occupational Health and Safety Act (OSHA) of 1970 and Mine Safety and Health Amendments Act (MSHA) of 1977. Pertaining to OSHA, a safe means of access and egress is mandated for personnel while performing underground construction (29 CFR §1926.800) (Standard 4.4.5). MSHA (30 CFR §57.11050) (Standard 4.4.6) states that at least two means of egress must be provided. While both statutes are complementary, the requirement to use either is also set forth in federal statute (10 CFR §60.131; Standard 4.4.4).

Normal personnel access to the subsurface repository will be restricted to the development side access and the emplacement side access for personnel working on those respective sides. Personnel on the emplacement side will be trained and certified in disposal of high level radioactive wastes in a geologic repository in accordance with 10 CFR 60 (§60.160) (Standard 4.4.4) while the personnel on the development side will be trained in safety related matters as per 29 CFR 1926 (Standard 4.4.5) only. Access to the emplacement side by development personnel can be interpreted as being prohibited by 10 CFR 60 (Standard 4.4.4) unless appropriate supervision (trained and certified in proper procedures) oversees the activities being performed by these personnel. The development and emplacement personnel will not be mixed during normal operations and will conduct their respective activities separately. The presence of untrained and uncertified underground personnel on the emplacement side who may come from the development side during off-normal conditions which are catastrophic in nature cannot be precluded at this time however. To discourage unauthorized access into the emplacement side of the underground repository, physical barriers and administrative controls will likely be imposed. However, emergency egress must also be provided

through the ventilation isolation barriers from either side to the other for personnel who are endangered by an off-normal situation such as a fire and be provided only for personnel access and not for equipment access.

The first means of egress is through the primary accesses on the emplacement side and the development side as previously stated. A second means of egress for the development side may be through any ventilation opening. The emplacement side does not have a second means of egress unless through the development side. To meet the second-means-of-egress guideline, only a small doorway is required for passage through the ventilation barriers in the main drifts. A single barrier makes emergency egress difficult with approximate 3,000 Pa air pressure differential from one side to the other (Assumption 4.3.1). An airlock provides a more attainable means of egress for personnel.

7.1.3 Utilities Access

Each side of the ventilation barriers will have utilities for specific functions. These utilities may include supply and waste water pipelines, a compressed air pipeline, electrical cable(s), and monitoring/control cables. Comparable utility features, numbers, and sizes will be determined in subsequent analyses. Only the development side is likely to have ventilation ducting.

No current requirement exists for extending electrical cables, pipelines, and ventilation ducting through the isolation barriers. Utilities may terminate at or near the isolation barriers on either side unless otherwise determined in subsequent analyses. Should any utilities be passed through the barriers, transition connections will be provided in the barrier covering panels or cast in concrete barriers as discussed in Section 7.2.3.

7.1.4 Equipment Access

A large doorway has not been included in the barriers as there are currently no requirements for passing equipment from one side of a ventilation barrier to another under normal conditions. However, operational considerations may allow equipment to pass through a barrier system to recover from an off-normal situation. One such off-normal event has been identified in the *Waste Package Design Basis Events* (Reference 5.11) for derailment of a waste package transporter as is discussed in Section 7.1.5.9. A removable panel or set of panels has been included in the barrier structure instead of a door. While a door however secured may be readily opened, a removable panel or set of panels requires extra effort and resolve to be opened.

A rail-mounted conveyance may at some time be needed to pass from the development side of the isolation barrier(s) to the emplacement side. A potential opening to accommodate a locomotive or other conveyance is blocked-out in the framing plan for each isolation barrier and covered with a

panel as discussed in Section 7.2.4.

7.1.5 Off-Normal Conditions

The isolation barriers are designed for performance under normal conditions. The occurrence of certain unexpected or improbable events which might impact the reliability of these barriers must also be examined to determine the limits of structural integrity and the extent of damage to the airlocks. The specific off-normal events which may be considered are fewer than were evaluated in the *Preliminary MGDS Hazards Analysis* (Reference 5.12), *Waste Package Off-Normal and Accident Scenario Report* (Reference 5.13), and the *Waste Package Design Basis Events Report* (Reference 5.11). This premise is based upon the limited effect that some events might have on the ventilation barriers. Off-normal conditions which are identified include: Collision--Locomotive & Waste Package Transporter, Explosion, Fire, Flooding, Human Factors, Loss of On-Site Power, Mechanical Failure--jamming or non-functional mechanisms, Rockfall, Seismic Activity, and Blockage of North Ramp.

7.1.5.1 Collision

Collision by the waste package transporter or a locomotive will only occur due to a runaway condition or to human factors, inadvertent or intentional. For either situation, rail-mounted equipment can be prevented from colliding with the barrier structure due to precise location and control and mechanical devices.

Precise locating and control of transporters will provide a safeguard against inadvertent head-on impact with an airlock. As waste emplacement will follow development of several excavated drifts, a transporter will not typically approach the immediate vicinity of an isolation airlock but will be directed to an emplacement drift which may be typically two or more waste emplacement drifts away from a typical barrier.

Mechanical stopping devices may be employed to prevent runaways or collision due to a combined failure of communications equipment and moving the transporter and/or locomotive past the active emplacement drift to the barrier. Initially, a set of derailleurs are being considered as stopping devices in conjunction with possibly placing the switches on a turn-in setting to emplacement drifts adjacent to the emplacement side ventilation barrier. While the derailleurs are easy to install and move and do not require elaborate or extensive accompanying facilities, they need to be placed far enough from the airlock barrier so that the forward momentum of a derailed conveyance will not carry to the barrier.

7.1.5.2 Explosion

The ventilation barrier structures are not designed to be blast proof.

7.1.5.3 Fire

Ventilation barriers will be constructed of non-flammable materials. The only potential ignition sources are from the overhead trolley wire on the emplacement side and any inadvertently stacked flammable material on the development side. The main drifts will be designed and administrative controls will be imposed to prevent both conditions. The trolley wire on the emplacement side can be terminated so that it does not contact the airlock structure. While careful maintenance inspections will greatly reduce the potential for an electrical fire from this source, fire suppression systems and the lack of flammable material will halt propagation of a potential fire in the direction of the barrier. Should an electrical fire be initiated on or near a barrier which causes a failure of the emplacement side barrier in spite of all precautions, then a new structure will be installed. The only overall effect to the repository may be the postponement of emplacing waste packages while this barrier is rebuilt. The development side barrier of the airlock will still be in place and the two ventilation systems will still be isolated.

7.1.5.4 Flooding

Ventilation barriers will not be designed to withstand hydrostatic loads. Potential flooding will disrupt the overall operation of the repository and negate the purpose of the isolation barriers.

7.1.5.5 Human Factors

Human factors can affect the ventilation barriers in three ways. The barriers can be accidentally or deliberately damaged, the barrier seal can be broken with the passage of personnel through the manway, and injured personnel may need to be evacuated through any particular barrier. A single ventilation barrier will not meet its requirements if personnel must pass through for whatever reason; thus, a dual barrier system with airlock will be needed to allow passage between the development and emplacement side.

Operational control and design will be required to prevent misuse of isolation barriers forming airlocks. Damage to the barriers by personnel will be largely minimized by including only trained and certified workers in the repository, providing adequate supervision, restricting access within the vicinity of the airlocks, and including a robust design in the components. The manway opening in each barrier will contain a self-closing door. By placing the doors so that one swings outward from the airlock on the development side and the other swings inward from the emplacement side, the

doors will tend to be self-closing due to negative air pressure. The ventilation barriers forming the airlock may be framed to permit passage of transport equipment as described in Section 7.1.5.9.

7.1.5.6 Loss of Electrical Power

The ventilation barriers are designed as passive barriers with no requirement for electrical power to operate mechanical systems. Loss of electrical power will not affect performance of these barriers. Loss of electrical power may disrupt the ventilation systems however. A loss of one or both ventilation systems should not have any adverse effect upon the ventilation barriers as the pressure differential across the barriers, either single or dual, will be less than during normal operations. The only adverse effect of power loss will be to prevent monitoring of the barriers.

7.1.5.7 Rockfall

The effect of rockfalls on the barrier system will be minimized by supplementary rock support and separation of dual barriers. Fully-lined concrete-supported main access and exhaust drifts will be installed before the barriers are installed. Dual barriers forming the seal will allow the failure of one barrier while the other continues to maintain a separation of the two ventilation systems.

7.1.5.8 Seismic Activity

Ventilation barriers are designed to withstand seismic activity which achieves a mean peak horizontal and peak acceleration of 0.27 g (Assumption 4.3.3). Damage which might result from seismic activity in excess of the assumed magnitude will be repaired by replacing affected components.

7.1.5.9 Blockage in the Emplacement Access

Passage through a ventilation barrier may be necessary to aid in removing a blockage of the emplacement side access due to a transporter derailment that cannot be readily removed through normal approach. Only under such a condition might equipment be permitted to pass through the barrier system. Otherwise, development and emplacement equipment will be restricted to the respective sides of the barrier system in which they operate. One cause of such a situation might occur with the derailling of a waste package transporter in the access to the emplacement side in which the waste package is breached or may be possibly breached. Either situation requires an equivalent response; that is, an initial assessment of the scene, both upwind and downwind of the site. Access through one of the set of barriers may be required to perform mobile radiation monitoring. No guidelines are available which specify a quick response to this potentially rare event

but the ability to pass equipment of undetermined function through any given ventilation barrier may become a desirable design feature.

Remote monitoring equipment to assess a potential design basis event (DBE) involving a waste package while in-transit, has not been developed. As such, an opening configuration in each barrier of an airlock is only speculative. Should a nominal opening be allowed for the passage of a locomotive and a conveyance having a like profile, then most contingencies for monitoring and physical assistance should be met. An opening will be provided to allow the passage of a locomotive or other conveyance though a much smaller track conveyance may be used to assess any damage. This opening will be framed with steel members and covered with similar face plates as may cover the other portions of the ventilation barrier.

A rail-mounted conveyance might enter an airlock after the covering panel was removed on the development side barrier as shown in Figure 7.1-1. After the rail-mounted equipment is in the space between the barriers, the panel is replaced and the airlock is re-established. The panel on the emplacement side barrier is similarly removed, the rail-mounted equipment moves through the barrier, the panel is replaced, and the airlock is again re-established. Design features which are not discussed in this analysis can make the potential passage of equipment a less time-consuming process.

7.2 BARRIER DESIGN FEATURES

7.2.1 Materials of Construction

Ventilation barriers will be constructed to be structurally sound, relatively air-tight, and compatible with the repository performance requirements. The use of materials to meet these goals will be considered for potential leakage pathways through the drift wall, through the interface between the ventilation barriers and the drift wall, and through openings in the ventilation barriers. Only structures constructed either of concrete, steel, or a composite of both will be considered in this analysis. Though these barriers are currently considered temporary, a future option to leave one or more in place permanently can be considered without violating material usage requirements (Assumption 4.3.2). Grout, shotcrete, and similar cementitious materials are considered as acceptable concrete substitutes for construction of the barriers.

7.2.2 Attachment of the Barriers to the Drift Wall

A free-standing barrier system is not being considered in this analysis. For all alternatives, the barriers will be connected either to the drift liner or drift wall (if a liner is not present). The size, number, and spacing of rock bolts will be determined in a subsequent analysis.

As shown in Section A of Figure 7.2-1 for a steel barrier, a groove is formed in the concrete liner

LOCOMOTIVE ENTERING ISOLATION AREA

DEVELOPMENT SIDE PANEL RE-INSTALLED

LOCOMOTIVE THROUGH TO THE EMPLACEMENT SIDE

FIGURE 7.1-1
PASSAGE OF LOCOMOTIVE
DURING OFF-NORMAL CONDITIONS

FIGURE 7.2-1
 OPTION 1-STEEL VENTILATION BARRIER
 FRAMING ELEVATIONS & SECTIONS

to accept a horseshoe-shaped, segmented, steel member to which the barrier frame is connected. A wide flange (WF) member is curved to conform to the curvature of the drift liner and bolted in place at appropriate locations around the inner circumference of the opening. A C-section or other appropriate steel shape may also be used in place of a WF-section. The WF-section provides a space between the web of the steel member and the drift liner for grout to accumulate and squeeze around the flange of the WF-section forming a seal. If a groove is not formed in the drift liner, the WF-section may be replaced with a C-section which is placed against the concrete and bolted into place similarly to the WF-section. A non-flammable foam material or other suitable caulking may be applied along the contact of the steel and drift liner and liberally coated with shotcrete to promote sealing.

For a concrete barrier a grooved drift liner provides a keyway for the end of the concrete pour. A gap may occur somewhere along the seam of the concrete pour and the drift liner as the concrete cures and shrinks. The groove serves as a partial retardant for airflow. As with a steel barrier, caulking may be used in conjunction with shotcrete to form an effective seal.

7.2.3 Barrier Structural Alternatives

7.2.3.1 Steel Construction

Ventilation barriers may be designed using carbon steel structural shapes and plates and incorporate non-combustible materials except for seals and gaskets. Barrier surfaces may need fire-proofing protection which may be evaluated in a subsequent analysis. A segmented steel-framed structure as shown in Figure 7.2-1 is anchored to the tunnel liner and invert. The steel frame components as shown are mostly jointed by bolted connections. These connections will be minimized by welding only to the extent that the frame may be assembled, dismantled, and reassembled for multiple setups using common labor and equipment. Primary and secondary structural members will include standard steel shapes (angles, channels, WF-beams) which may be joined as shown in Figure 7.2-1. The primary members are the two vertical columns which are bolted to the top of the horseshoe member and to the concrete invert. The horizontal beams and upper ends of the columns are joined to the horseshoe member (not shown in this figure) by bolts through an angle which is welded to the web of the embedded WF-beam horseshoe segment. The horizontal members provide lateral support to the columns and bear the weight of the steel covering panels.

Multiple steel panels as shown in Sections A, B, and C of Figure 7.2-1 are installed to cover the face of each barrier. Six panels will be needed to cover the barrier frame. Each typical panel section may be fabricated using a steel plate and framed along all four edges of one side with angle steel to form a connecting flange. The angles are welded to the plate and have a single row of bolt holes evenly spaced along the extending leg of each angle. The size and weight of each panel may be reduced by adding additional support members in the barrier frame to facilitate installation, disassembly, and reuse. Rubber gaskets may be placed between the panel flanges and compressed

when the panels are bolted together to create an air-tight seal across the face of the barrier. The panels may be joined to the primary support members as shown in Sections A, B, and C of Figure 7.2-1.

A preliminary structural analysis of the typical ventilation barrier has been performed through hand calculations which are included in Attachment I. Structural members in the individual barriers conform to ASTM A36 standards (Standard 4.4.3) having a minimum yield strength of 248.22 mPa (36,000 psi) (Standard 4.4.1) and are designed for uniformity in component members. Loading of structural members has been estimated for a conservative (high) range of values with rounding-up of numbers where applicable. Barrier loads include the following:

Dead Load (D):	Self weight of steel 7849.8 kilograms/cubic meter (490 pounds/cubic foot) (Standard 4.4.1, p. 69)
Live Load (P):	Ventilation Pressure 3.75 kPa (15 inches w.g. or 78 pounds/square foot) (Assumption 4.3.1)
Seismic Load (E):	0.27 g horizontal and vertical (Reference 5.10, Table 1)

Computations in Attachment I have been performed as recommended (Standard 4.4.2) for the load combinations:

Case 1.	$D + P$
Case 2.	$0.75(D + P + E)$

A structure using W8 x 31 steel sections is satisfactory for the framing arrangement which is shown in Figure 7.2-1 and for the anticipated loading conditions in Cases 1 and 2 on this framing. The spacing of the steel frame members which are shown in Figure 7.2-1 may be varied and additional members may be installed without significantly affecting the effectiveness of the barrier structure. The middle member of the three horizontal beams which provide lateral stability to the two columns is positioned to provide the top frame for a potential equipment opening and may be raised or lowered without affecting the structural integrity of the barrier. A personnel access door will also be framed into the barrier adjacent to the equipment opening.

A steel structure which is fabricated in segments as shown in Figure 7.2-1 is preferred to a concrete barrier as it offers many advantages including pre-forming of components, components which can accommodate variability in the drift wall and floor (though variability may not be significant), simplicity in erection, and relative ease in dismantling.

7.2.3.2 Concrete Construction

Concrete may be used instead of a steel frame and panel arrangement. Light weight precast concrete panels supported by a steel frame or cast-in-place concrete are possible alternatives. As shown in Figure 7.2-2, concrete is formed and poured into one monolithic structure as is common for cast-in-place construction. Construction includes erecting a network of reinforcing bars which completely cover the drift opening except for the potential openings, installing structural steel members to frame the potential openings, drilling and installing connection pins into the drift liner, building forms around the reinforcing bars, and pouring the concrete in one continuous batch to avoid cold-joints, shrinkage, and other discontinuities in the finished concrete. The groove in the drift liner which is shown in Section A of Figure 7.2-1 performs a similar function in Figure 7.2-2. With a steel horseshoe member, the outer curvature of the steel may not always match the inner curvature of the drift liner and a gap between steel and concrete may occur which is covered in part by the recess. Likewise, the concrete pour for the barrier upon curing may shrink from the drift liner and create a gap which will be partially compensated by the recess. Concrete shrinkage may be minimized so that a groove in the drift liner does not add any significant advantage. Shotcrete or caulking can be applied along the seam between the barrier and the drift liner.

As an alternative, pre-cast concrete panels are formed elsewhere and transported to the barrier site. Precast panels are anchored by clips to the steel frame of the horseshoe ring in the drift liner and to each other or to a steel frame.

A concrete barrier is more difficult to fabricate and install than a steel frame and panel arrangement. A cast-in-place concrete barrier can not be relocated and can only be left in place or removed. While a light weight precast concrete panel and support frame system can be dismantled and reassembled, concrete panels are heavier than steel panels and more difficult to handle and assemble. If a steel frame is to be used in any case, steel plate panels are a reasonable substitute for precast concrete panels. The all steel frame and panel barrier is easily fabricated, erected, sealed, dismantled, and relocated as needed.

7.2.4 Potential Openings through Barriers

The design alternatives discussed below do not preclude that any number of openings may be provided through the ventilation barrier. For steel barriers, primary members are overlapped with steel panels which may be individually removed at any time and replaced with modified panels to provide the opening size desired. For concrete barriers, potential openings must be blocked-out and framed prior to pouring the concrete. These openings may be closed with panels as discussed for the steel barriers. As presented in this analysis, steel barriers may have six or more removable panels. Concrete barriers will have one potentially removable panel only. One small swinging door is proposed for either type of barrier to provide the second means of egress for personnel as discussed in Section 7.1.2.

FIGURE 7.2-2
OPTION 2-CONCRETE VENTILATION BARRIER
FRAMING ELEVATIONS & SECTIONS

7.2.5 Leakage Prevention

A partitioning of the development and emplacement ventilation systems is required (Criterion 4.2.1) to ensure that separation of the two sides will be maintained. The ventilation system is designed so that for any leakage, the direction of airflow is from development to the emplacement side of the repository (Criterion 4.2.2). To accomplish a preferential leakage pathway, the development side is over pressurized by providing a positive pressure on the development side and a negative pressure on the emplacement side. During normal ventilation, the air pressure differential should be close to the maximum of about 3,000 Pa (Assumption 4.3.1). The pressure differential should also remain somewhat constant as the barriers are relocated from the north end of the repository to the south end due to a balancing net pressure difference; as the pressure on one side increases and the pressure on the other side decreases accordingly. Leakage, if it occurs, will be from the development side to the emplacement side. However, the barriers should be designed to prevent leakage under normal conditions.

Air leakage for a monolithic structure having no seams or joints and being without any covered openings will likely be comparable for either a single or dual barrier system. When multiple joints, covered openings, and other accessories are included in the barrier design for a steel structure, then overlapping steel plates, interlocking components, compressed gasketing, and shotcrete coatings are desirable. Control joints between concrete segments or between construction pours may become pathways for leakage. The potential for flow through these and other cracks can be reduced by stops composed of metal, bitumen, or epoxies. During the time that cracks are sealed, airflow can be expected to be minimal. Over time, the seals will lose effectiveness, allowing flow to occur through previously existing cracks and resulting in an increase in gas permeability. New cracks will likely form over time, resulting in additional increases in permeability in the structure. These cracks may be caused by differential settling and overburden-caused stresses. A steel structure may deform to a greater degree without breaking a seal than concrete. The ventilation barriers will not likely be kept in place long enough in either case for post-installation cracking or structural deformation to become a significant problem.

Personnel passageways and other service openings, if provided, should be large enough to provide access through the barriers but small enough to be easily sealed. The sills of the manways may be raised so that an oversized swinging door will close over the entire opening. Sealing features around personnel passageways may include tight-fitting latches, gasketed doors, and external hinges. If an opening is framed for passage of rail-mounted equipment, a molded sill member may be formed which conforms to the configuration of the rails and provides at least a moderate seal along the bottom of the barrier structure. In addition, shotcrete may be placed along the contact of the barrier and the drift invert to provide a seal.

A multiple or dual barrier system includes an airlock which acts as a "stilling chamber" for air flowing either through an open personnel door or for air seepage through cracks and joints. The pressure differential on either side of a barrier of a two barrier system tends to equalize over time

and reduce the potential for airflow. An airlock has other advantages which are discussed in the conclusion.

7.2.6 Monitoring and Control

A monitoring and control system may be provided to ensure that the seal between the two ventilation systems is maintained throughout the development phase of repository operations. This system can be designed to only detect the presence of personnel and rail-mounted equipment or provide active control for any barrier door or covering.

A system of control is suggested which provides local supervisory control and monitoring from a surface-based operations center. As passage through the ventilation barriers should not normally occur, a remote monitoring system may be installed just to observe the barriers. A remote lock-out system for a manway door may also be installed but off-normal conditions which make a manway desirable may also prevent a remote locking system from unlocking (normally-open actuators can stick and prevent unlocking).

Remote control and monitoring systems will use basic technology and infrastructure which includes monitoring input to a console or series of consoles which are positioned in a surface operations center. Laser beams, motion detectors, and real-time video feedback may be provided to the surface by a subsurface fiber-optic cable link between the barrier positions and surface consoles.

7.3 BARRIER LOCATION

Ventilation barriers will be located in the main access, exhaust and performance confirmation drifts such that incoming and return airflow for either the development or emplacement side will not mix with the other. The barriers will normally be installed at straight, consistently round sections of any main drift and be offset from emplacement drift turnouts, curves, and cutouts. Dual barriers forming airlocks will be placed to accomodate these inconsistencies in the drift cross-section while single barriers may be placed with some degree of randomness. Single barrier placement will not be discussed further.

The distance between dual ventilation barriers in a straight, circular section of a main drift is highly variable with a minimum of a few tenths of a meter of linear length for opening a swinging personnel door to an indefinite maximum. Some advantage exists for placing the dual barriers in reasonably close proximity to achieve better control of the barrier for personnel or equipment passage and to decrease time in breaking the vacuum between the airlock and the active side of the barrier. Two barriers may be placed to form a closely-spaced airlock as shown in option A of Figures 7.3-1 and 7.3-2. In option A, the thermal loading of the waste packages may place the emplacement drifts sufficiently wide apart so that an airlock may be constructed between either two turnouts from the

main access drifts or two raises from a main exhaust drift. The exact placement of the individual barriers in such an arrangement is not critical and construction of these barriers only needs to avoid the turnouts.

Other thermal loading conditions can affect the placement of the ventilation barriers as shown in options B and C of Figures 7.3-1 and 7.3-2. Closely-spaced emplacement drifts may either require that a turnout or raise be included in the airlock formed by dual barriers as shown in option B of both figures or that two turnouts or raises be included as shown in option C of both figures. For both options B and C, the doors at the entrance of each included emplacement drift and the openings at the bottom of each included raise must be closed for the airlock to function correctly. Any deviation could threaten the isolation of the two ventilation systems.

7.4 BARRIER COMMISSIONING AND DECOMMISSIONING

Ventilation barriers will be constructed and placed into service as development of the repository progresses. In any main access or exhaust drift, an installed barrier which separates the development and emplacement ventilation systems will supersede in function all previous barriers in the same drift which will not be needed after the new barriers are in place. Removal of the superseded barriers will be performed soon after the new barriers have been installed as the superseded barriers have not been designed for emplacement operations. Commissioning of the new barriers will be coordinated with the decommissioning of the old barriers in a manner as described below. In the main access drifts, a sequence of activity may include:

- 1) Erection and sealing of new barriers. The groove is cut into the drift wall. The horseshoe member is bolted into place in the groove. The main columns and support beams as shown in Figure 7.2-1 are bolted to the horseshoe wall member, the personnel door is hung and gasketed, and covering plates are gasketed and bolted to the steel frame of the barrier. Caulking and sealing is applied to the barrier-wall joint.
- 2) Dismantling of old barriers. Covering plates are removed, the steel frame or the concrete structure (Figure 7.2-2) is dismantled and the materials are removed from the drift. For the single barrier system, erection of the new barriers will be performed from the development side while dismantling of old barriers will be performed from the emplacement side. For the dual barrier system, all or a major portion of the construction and dismantling activities can be performed from the development side.
- 3) Installation of emplacement utilities and removal of development utilities. If the two utility systems are dissimilar, the emplacement side utilities are extended to the next barrier position while the development utilities are dismantled and removed.

PLAN

A. AIRLOCK INCLUDES NO TURNOUTS

PLAN

B. AIRLOCKS INCLUDES ONE TURNOUT

PLAN

C. AIRLOCKS INCLUDES TWO TURNOUTS

FIGURE 7.3-1
ISOLATION BARRIER PROXIMITY
TO MAIN DRIFT TURNOUTS

SECTION
A. AIRLOCK INCLUDES NO VENT RAISES

SECTION
B. AIRLOCKS INCLUDES ONE VENT RAISE

SECTION
C. AIRLOCKS INCLUDES TWO VENT RAISES

FIGURE 7.3-2
ISOLATION BARRIER PROXIMITY
TO EXHAUST MAIN VENTILATION RAISES

The relocation of the barriers is coordinated with the development and completion of a number of emplacement drifts. The new locations and scheduling of commissioning and decommissioning activities are evaluated in other analyses.

8. CONCLUSIONS

This analysis has examined the use of subsurface barriers to isolate the development and emplacement ventilation systems from each other to allow emplacement of waste to proceed while completing the construction of the repository. In reviewing the requirements and various operating considerations for these barriers, four preliminary design features are recommended which are given as follows:

- **Airlocks.** Ventilation barriers will be arranged in airlocks to equalize the air pressure on either side of any single barrier when equipment or personnel must pass through the barrier system during a specific off-normal condition which does not permit access or egress through standard passageways. The space between the dual barriers will be large enough to accommodate currently undefined equipment.
- **Personnel Doors.** A personnel door will be provided to permit passage of personnel from the emplacement side to the development side during life-threatening off-normal conditions. The door will utilize a simple latching mechanism to secure the door.
- **Steel Frame and Removable Panels.** Steel panels which connect to a steel frame will cover the drift opening at each barrier location. The primary support members will be spaced to permit removal of specific panels for the passage of equipment through the barriers if required.
- **Bolted Connections.** The barriers will be designed with standard steel members with bolted connections. These structures will be easily installed in a timely manner and likewise dismantled either totally or partially as the situation dictates. As multiple barriers may be erected simultaneously, interchangeability and reuse of components will be a desirable design feature.
- **Material Reuse.** The barriers are designed to be assembled, disassembled, and reused through the repository as needed. The barrier structure is segmented and bolted together for ease in joining.

The preliminary design of the ventilation barriers discussed in this analysis is a viable means of isolating the two ventilation systems but does not preclude any other design which maintains a

separation of development and emplacement. Due to the unqualified/unconfirmed input data used in this analysis, the output/conclusions from this analysis cannot be used as input into documents supporting procurement, fabrication, or construction unless they are controlled and tracked as TBV or TBD in accordance with NLP-3-15 or other appropriate procedures.

9. ATTACHMENT

Attachment I. Ventilation Barrier System Structural Analysis

ATTACHMENT I

**Ventilation Barrier System
Structural Analysis**

Ventilation BarrierVentilation Pressure Load (P) Analysis: (Section 4.3.1)

$$P = 3750 P_0 = 0.544 \text{ psi} = 78.32, \text{ Use } 78 \text{ psf}$$

Column
Load Pattern
for P on
bulkhead

Frame Elevation

Dimensions of frame
are for analysis of
loading only.

$$P = 78 \text{ psf}$$

$$w_1 = 4.92 \text{ ft} (78 \text{ psf})$$

$$= 384 \text{ P/ft}$$

$$w_{11} = 7.58 \text{ ft} (21.91 \text{ ft}) (78 \text{ psf})$$

$$= 6477 \text{ P}^2$$

$$M_1 = \frac{wL^2}{8} = \frac{384 \text{ P/ft} (21.91 \text{ ft})^2}{8} = 23042 \text{ P-ft} \quad (\text{AISC, p. 2-296})$$

$$R_1 = R_2 = \frac{wL}{2} = \frac{384 \text{ P/ft} (21.91 \text{ ft})}{2} = 4207 \text{ P}$$

$$M_{11} = \frac{w_{11}L}{6} = \frac{6477 \text{ P}^2 (21.91 \text{ ft})}{6} = 23652 \text{ P-ft} \quad R_{11} = R_{12} = \frac{6477 \text{ P}^2}{2} = 3239 \text{ P}$$

$$M_{\max} = M_1 + M_{11} = 23042 \text{ P-ft} + 23652 \text{ P-ft} = 46694 \text{ P-ft} \quad R_{\max} = R_1 + R_{11} = 4207 \text{ P} + 3239 \text{ P} = 7446 \text{ P}$$

Ventilation Barrier

Frame Design: ASTM A36 Steel

$$F_{bx} = 0.66 F_y = 24000 \text{ psi} \quad (\text{AISC, p 5-45, F1-1})$$

$$M_{max} = 466.94 \text{ P-ft}$$

$$S = \frac{466.94 \text{ P-ft} (12 \text{ in/ft})}{24000 \text{ psi}} = 23.35 \text{ in}^3$$

$$\text{Try } W8 \times 31, A = 9.13 \text{ in}^2, S = 27.5 \text{ in}^3 > 23.35 \text{ in}^3$$

$$f_{bx} = \frac{466.94 \text{ P-ft} (12 \text{ in/ft})}{27.5 \text{ in}^3} = 20376 \text{ psi}$$

Axial Load (Use $\frac{3}{8}$ " plate for handling purposes)
 Dead Load (0) (15.3 psf, AISC, p 1-11)

$$W_1 = 4.92 \text{ ft} (21.91 \text{ ft}) (15.3 \text{ psf}) = 1649 \text{ P}$$

$$W_2 = 7.58 \text{ ft} (21.91 \text{ ft}) (\frac{1}{2}) (15.3 \text{ psf}) = 1270$$

$$W_3 = 21.91 \text{ ft} (31 \text{ P/ft}) = \frac{679}{3598 \text{ P}}$$

$$f_a = \frac{3598 \text{ P}}{9.13 \text{ in}^2} = 394 \text{ psi}$$

$$\text{Unsupported Length} = 11.49 \text{ ft} \quad r_x = 3.47 \text{ in} \quad r_y = 2.02 \text{ in}$$

$$\frac{KL}{r_x} = \frac{11.49 \text{ ft} (12 \text{ in/ft})}{3.47 \text{ in}} = 39.7$$

$$\frac{KL}{r_y} = \frac{11.49 \text{ ft} (12 \text{ in/ft})}{2.02 \text{ in}} = 68.3$$

$$\text{Use } \frac{KL}{r_x} = 40, F_{ax} = 19.19 \text{ ksi} \quad (\text{AISC, p 3-16})$$

$$\text{Use } \frac{KL}{r_y} = 69, F_{ay} = 16.53 \text{ ksi}$$

$$\frac{f_a}{F_{ax}} = \frac{394 \text{ psi}}{19190 \text{ psi}} = 0.02$$

$$\frac{f_a}{F_{ay}} = \frac{394 \text{ psi}}{16530 \text{ psi}} = 0.02$$

Ventilation BarrierFrame Design:Adding Vertical Seismic (E_v)

$$\frac{\delta_o}{F_{ox}} = 0.02(1.3) = 0.03$$

$$\frac{\delta_o}{F_{oy}} = 0.03$$

Horizontal seismic (E_{HN}) normal to the bulkhead will be less than ventilation pressure (P)

Horizontal seismic (E_{HL}) lateral to the bulkhead will be transmitted through the frame to the tunnel walls by compression and shear forces.

Loading Combination (ASCE 7-95, Section 2.3)Case 1: D + P

$$D: \frac{\delta_o}{F_o} = 0.02$$

$$P: \frac{\delta_{bx}}{F_{bx}} = \frac{20376 \text{ PSI}}{24000 \text{ PSI}} = 0.85$$

$$D + P = 0.02 + 0.85 = 0.87 < 1.0 \quad (\text{AISC, p. 5-54, Eq. 4-1-3})$$

$$\text{Case 2: } [D + P + E] 0.75 \quad E = 0.01 = (0.03 - 0.02)$$

$$[0.02 + 0.85 + 0.01] 0.75 = 0.66 < 1.0$$

W8x31 is satisfactory for bulkhead framing