OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☒ Analysis — Check all that apply

Type of Analysis	☒ Engineering ☐ Performance Assessment ☐ Scientific
Intended Use of Analysis	☐ Input to Calculation ☐ Input to another Analysis or Model ☒ Input to Technical Document ☐ Input to other Technical Products

Describe use:

This is a design analysis per Section 3.1-2 of AP-3.10Q for input into a system description document.

3. ☐ Model — Check all that apply

Type of Model	☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model
Intended Use of Model	☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to other Technical Products

Describe use:

4. Title:

EMPLACEMENT VENTILATION SYSTEM

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-SVS-HV-000003 REV 00

6. Total Attachments:

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7. Attachment Numbers - No. of Pages in Each:

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	Printed Name	Signature	Date
8. Originator	Robert W. Vance	Robert W. Vance	4/5/00
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12. Remarks:

Mal Taylor contributed to Section 6.4.3 of the analysis describing an exhaust main partition.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

Complete Only Applicable Items

2. Analysis or Model Title:

EMPLACEMENT VENTILATION SYSTEM

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-SVS-HV-000003 REV 00

4. Revision/Change No.	5. Description of Revision/Change
00	Initial Issue

CONTENTS

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FIGURES

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ACRONYMS AND ABBREVIATIONS

EDA	Enhanced Design Alternative
VA	Viability Assessment

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1. PURPOSE

The purpose of this analysis is to identify conceptual design options for the emplacement ventilation system, specifically within the emplacement drifts. The designs are based on the Enhanced Design Alternative (EDA) II concept developed during the license application design selection exercise as described in the *License Application Design Selection Report* (CRWMS M&O 1999a) and in the emplacement drift *Ventilation Model* (CRWMS M&O 2000c).

The scope of this analysis, as outlined in the development plan (CRWMS M&O 2000a), includes the following tasks.

- Description of the air flow path in the emplacement drifts.
- Examination of the exhaust options for air exiting the emplacement drifts.
- Examination of the air control options in the emplacement drifts.
- Discussion of following system components and structures: emplacement isolation doors, portable shadow shield and exhaust main partition.

The objective of this analysis is to support site recommendation through input to the system description documents. Off-normal conditions are not discussed in this analysis.

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2. QUALITY ASSURANCE

The quality assurance classification of repository structures, systems, and components has been performed in accordance with QAP-2-3, *Classification of Permanent Items*. The repository ventilation system is classified as conventional quality by the *Classification of the MGR Subsurface Ventilation System* (CRWMS M&O 1999c, Section 7.1).

Because some items in the subsurface ventilation system may ultimately be classified as quality-affecting, this specific analysis is also determined to be quality-affecting (CRWMS M&O 1999d) in accordance with QAP-2.0, *Conduct of Activities*. It is subject to the requirements of the *Quality Assurance Requirements and Description* (DOE 2000). The analysis was developed in accordance with AP-3.10Q, *Analyses and Models*. In addition, document inputs are tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

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3. COMPUTER SOFTWARE AND MODEL USAGE

The following standard office automation and computer-aided design software, used solely for graphical representation of concepts, was used in the preparation of this analysis:

- Microsoft Word, Version 97 SR-2
- Microsoft PowerPoint, Version 97 SR-2
- Microstation, Version 05.07.01.14

The software is appropriate for the application and per Sections 2.1.1 and 2.1.5 of AP-SI.1Q, *Software Management*, is exempt from further verification and documentation.

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4. INPUTS

The following inputs are tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

4.1 DATA AND PARAMETERS

Not used.

4.2 CRITERIA

4.2.1 The ventilation system shall be capable of regulating airflow through each emplacement drift (CRWMS M&O 2000b, Section 1.2.1.2). This criterion is used in Section 6.3.

4.2.2 The ventilation system shall be designed to remove at least 70% of the heat generated by the waste packages during preclosure (CRWMS M&O 2000b, Section 1.2.1.9). Used in Section 6.2.1.

4.2.3 The system shall secure the emplacement drift entrances to limit unauthorized personnel access to high radiation areas (CRWMS M&O 2000b, Section 1.2.2.2.3). Used in Section 6.4.1.

4.2.4 The system shall be designed to prevent reverse airflow in the emplacement drifts (i.e., from emplacement drifts to the turnouts) (CRWMS M&O 2000b, Section 1.2.2.2.4). Used in Section 6.1.

4.3 CODES AND STANDARDS

Not used.

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5. ASSUMPTIONS

Not used.

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6. EMPLACEMENT VENTILATION SYSTEM

The primary focus of this analysis is to update current design options for emplacement drift ventilation. The preclosure emplacement drift ventilation rate is 10 to 15 m^3/sec as recommended in the emplacement *Ventilation Model* (CRWMS M&O 2000c, Section 7). This is significantly higher than the rate of 0.1 m^3/sec used in the Viability Assessment (VA) design (DOE 1998, Section 4.2.4) and is also higher than the rate of 2 to 10 m^3/sec developed in the EDA II design (CRWMS M&O 1999a, Table O-6).

Features important to emplacement ventilation include possible configurations of the exhaust main and options for controlling the airflow through the drifts. The following sections of this analysis present the air flow pathway in an emplacement drift, explore exhaust system options, discuss air control options, and describe system physical components or potential components (i.e., isolation doors, portable shadow shield, and exhaust main partition). Development of comparative capital and operating costs and construction schedules, however, is beyond the scope of this analysis.

6.1 AIR FLOW PATHWAY

The VA design (DOE 1998, Section 4.2.4) utilizes exhaust fans located on the surface to pull air through intake ramps/shafts into the subsurface repository. The ventilation air is then distributed to the east and west mains by the cross-block drifts. From the mains, the air enters the emplacement drifts and flows to a central exhaust raise. The air then travels down an exhaust raise to the exhaust system. Isolation doors are installed at the entrance to each emplacement drift to limit personnel access.

The EDA II design, recommended by the License Application Design Selection exercise (CRWMS M&O 1999a, Section O.3), utilizes the same air flow pathway described above. However, additional or enlarged ventilation shafts, drifts, and equipment are required to handle the higher air flow (CRWMS M&O 1999a, Section 5.1.5.5).

The air flow pattern through the emplacement side of the repository is illustrated in Figure 1 (derived from CRWMS M&O 1997b, Figures 7.4.1.3, 7.4.1.6b and 7.8.6).

Exhaust system options, described in Section 6.2, are:

- Single exhaust main with the emplacement exhaust contained in ducts as outlined in the VA design (DOE 1998, Section 4.2.4.1).
- Dual, parallel exhaust mains, one for service air and the other for emplacement exhaust (CRWMS M&O 1997b, Section 7.4.5).
- Single, large-diameter exhaust main with an internal partition to separate service and emplacement exhaust air (CRWMS M&O 1997b, Section 7.4.5).

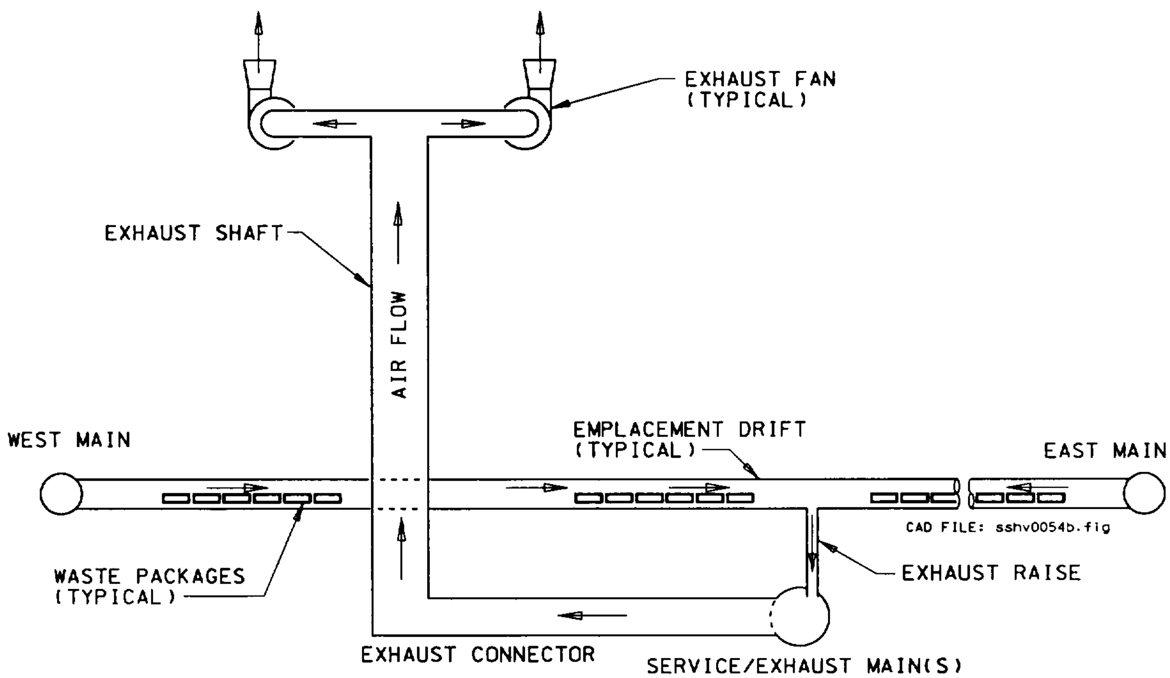

Figure 1. Emplacement Drift Airflow Diagram

Air control options, described in Section 6.3, include:

- Louvers located on an emplacement drift isolation door with an additional regulating valve located at the outlet of the exhaust raise (CRWMS M&O 1997a, Section 7.3 and DOE 1998, Section 4.2.4.2). This is the VA design.

- Dual isolation doors with louvers located in the turnout and inlet to the emplacement drift.

All of the above options will be designed to prevent reverse air flow through an emplacement drift (Criterion 4.2.4). This can be achieved by the automatic closure of the regulating louvers and/or valves in the event of a power failure (i.e., fail closed). Further discussion of off-normal events including the impact of natural air circulation, however, is beyond the scope of this analysis.

6.2 EXHAUST SYSTEM OPTIONS

The exhaust system configuration options are explored below. In each case, hot exhaust air from active emplacement drifts is isolated from human contact. Return air from empty emplacement drifts, cross-block drifts, and performance confirmation drifts will be used to provide cooler air for ventilating the service side of the exhaust system where personnel access is allowed (CRWMS M&O 1997b, Sections 7.4.1.3, 7.4.1.5, and 7.4.1.6).

6.2.1 One Exhaust Main with Ducts

This option was selected for the VA design and is illustrated in Figure 2. Exhaust air from the emplacement drifts is diverted into a pair of insulated, 1.83 m diameter, metal ducts located in a 7.62 m diameter exhaust main (DOE 1998, Sections 4.2.4.1, 4.2.4.2, and Figure 4-45). This concept is based upon a very low ventilation rate of 0.1 m^3/sec for each emplacement drift designed for radiation monitoring only (CRWMS M&O 1999a, Section 5.1.5.5) and is not based on current thermal management goals (Criterion 4.2.2).

To better manage thermal loading, increased ventilation rates were evaluated in a *Ventilation Model* (CRWMS M&O 2000c). The modeling in this document indicates that an emplacement drift ventilation rate of 10 to 15 m^3/sec (inlet volume) is required to remove at least 70 percent of the heat generated by the waste packages during preclosure (Criterion 4.2.2 and CRWMS M&O 2000c, Section 6.5). Because friction in a tube is directly proportional to the square of fluid velocity (Hartman et al. 1997, Section 7.1), it can quickly be observed that ducts become impractical in the exhaust main for handling the present air requirement (i.e., approximately 100 to 150 times larger than that in the VA design).

6.2.2 Dual Exhaust Mains

For higher emplacement drift ventilation rates, a second, similarly sized exhaust main is an alternative to the use of two insulated ducts inside a single main. The second main is installed parallel to and at the same level as the single exhaust main (CRWMS M&O 1997b, Section 7.4.5).

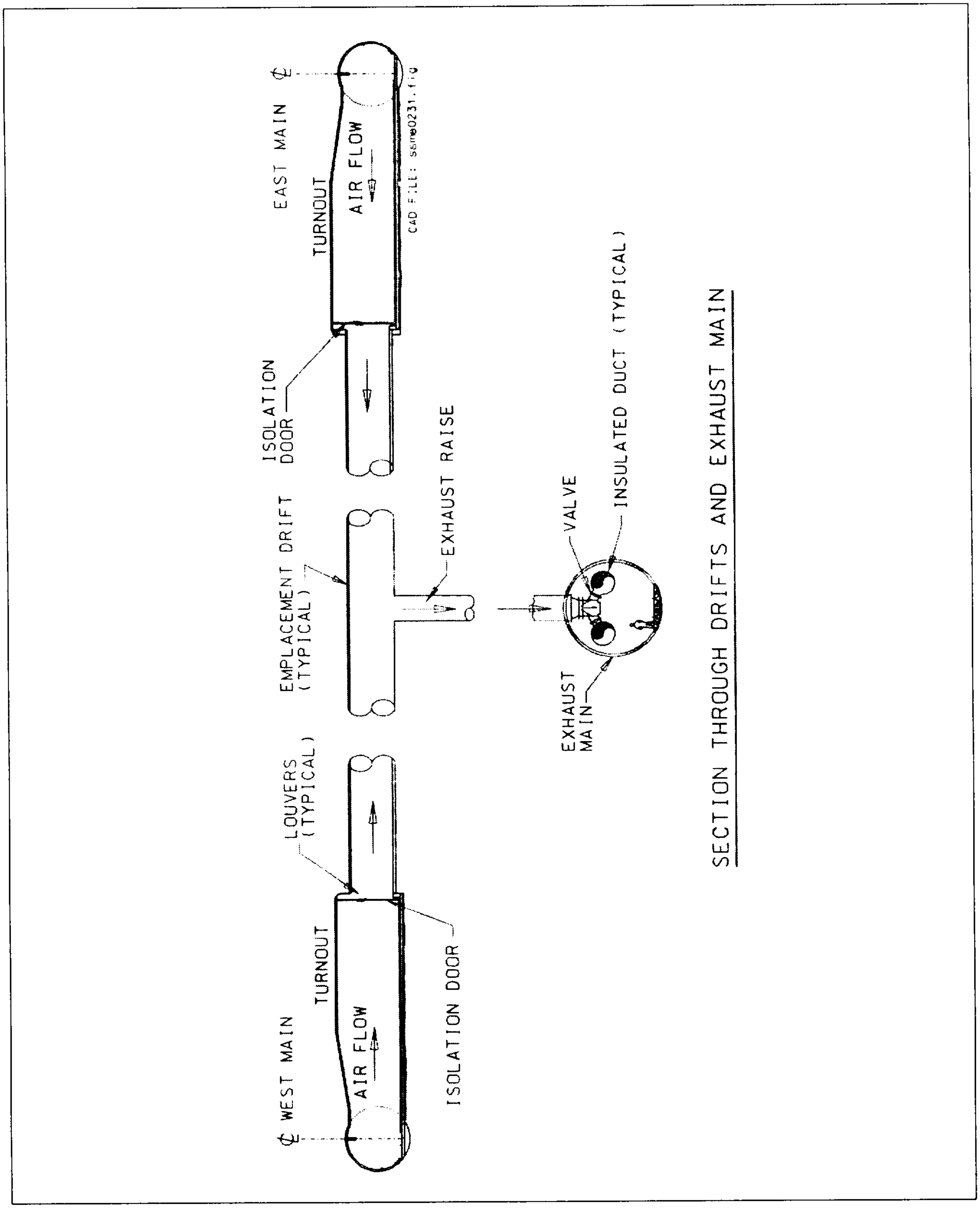

Figure 2. One Exhaust Main with Ducts

The two exhaust main concept is illustrated in Figure 3. The west exhaust main is connected to the emplacement drift through a central exhaust raise and a horizontal connecting drift between the west exhaust main and the east exhaust main.

Generally, hotter air from the emplacement drifts containing waste packages will be channeled to a single exhaust main; the other main, or service main, will be kept at a suitable temperature for personnel access. Cooler air from the performance confirmation, cross-block, and empty emplacement drifts will be used to ventilate the service main. If desired, a portion of this air can be used to lower the temperature in the exhaust main.

The major disadvantage of the dual exhaust main concept is the additional excavation required in this option. Not only is there an additional exhaust main, but also a horizontal connecting raise between the service main and the exhaust main that must be excavated for each emplacement drift. Increased construction complexity is another concern.

6.2.3 Split Exhaust Main

Figure 4 illustrates the last exhaust option. In this concept, a single exhaust main is separated into an exhaust side and a service side by a partition (CRWMS M&O 1997b, Section 7.4.5). In order to handle the total air volume, the single exhaust main may need to be excavated to a larger diameter than each of the individual exhaust mains discussed in the previous section. Factors that affect the effective ventilation area include the dimensions of the concrete lining, the exhaust raise, the invert, the service transporter, and the geometry of the connecting drifts between the exhaust shaft and the exhaust main.

As with the dual exhaust mains concept, 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 much hotter than the access side, the partition will need to be insulated. The service main 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. Potential radiation scattering effects were calculated for the VA outlet structure and were found to be low enough to allow personnel access for up to 40 hours per week (CRWMS M&O 1998, Section 6.4). This calculation should be updated for the split main option to ensure that radiation shielding is not required on either the outlet structure or the partition itself.

The advantage of using a single, large diameter exhaust main is that less excavation is required, compared to the dual exhaust main concept. Disadvantages include the need to minimize air leakage between the service and exhaust sides of the partition, and to ensure that any leakage will occur from the service to the exhaust side.

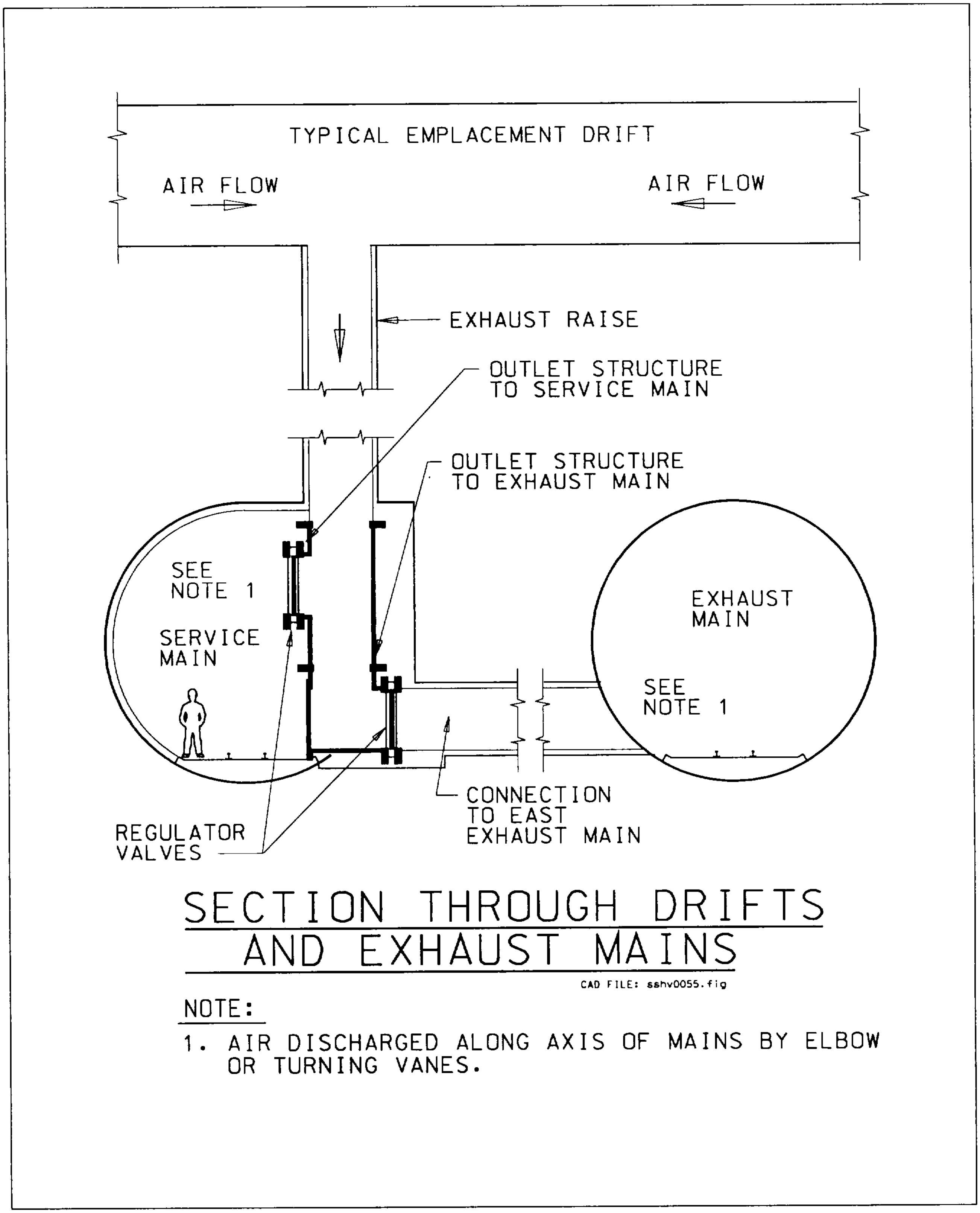

Figure 3. Two Exhaust Mains

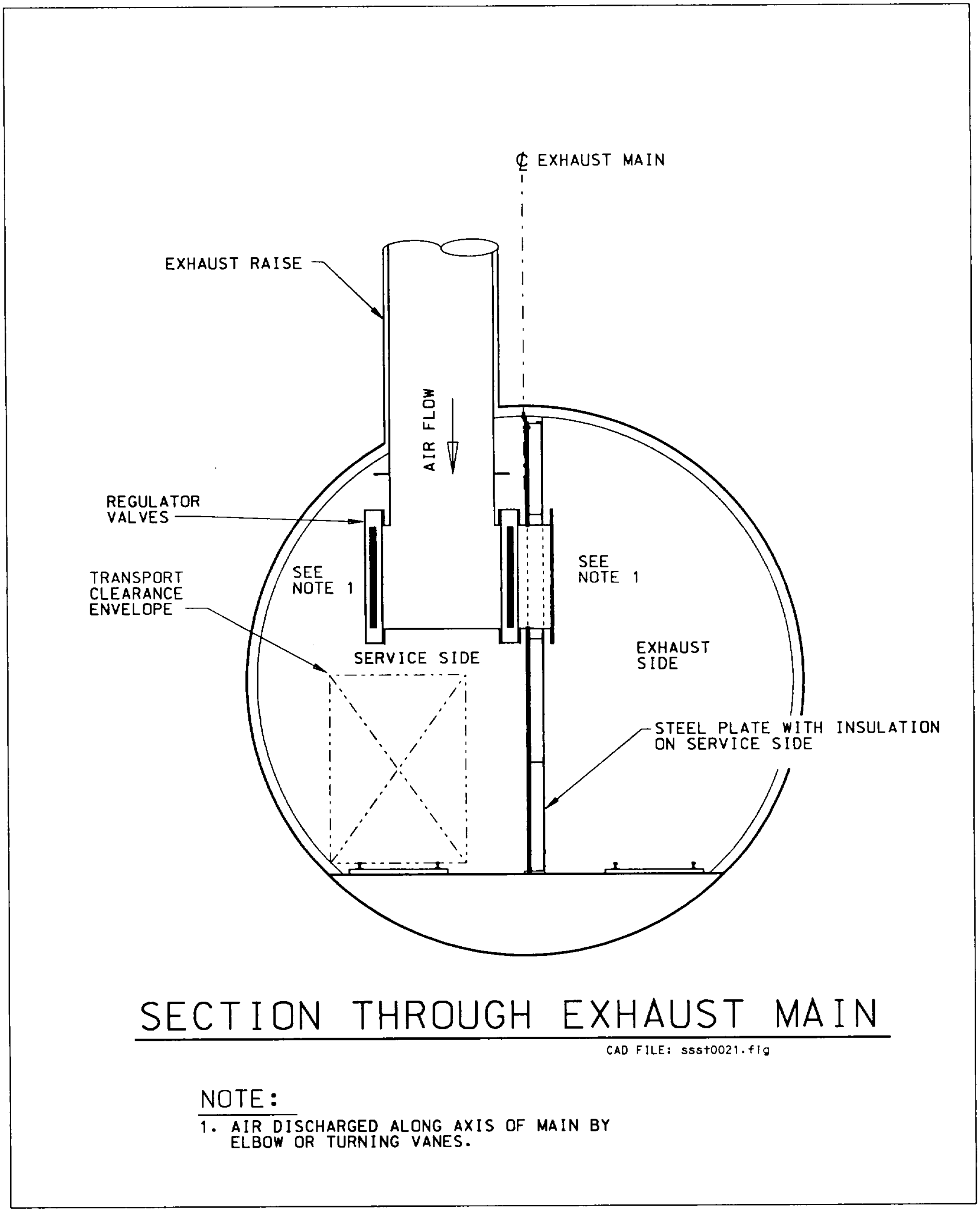

Figure 4. Split Exhaust Main

6.3 AIR CONTROL OPTIONS

Air flow regulation is required in the emplacement drifts (Criterion 4.2.1). Two concepts are discussed below. The first alternative consists of louvers on each emplacement drift isolation door and a valve located in the bottom of the exhaust raise. The second option uses a pair of isolation doors located in each emplacement drift turnout to form an airlock. Louvers are installed in each door to regulate the airflow.

6.3.1 Isolation Door with Exhaust Regulators

This system, utilized in the VA design, consists of two emplacement isolation doors, one located in the east turnout and the other in the west turnout. Louvers built into the doors serve as inlets for ventilation air. The air passes through the drift and exits down the exhaust raise. Dual control valves installed in an outlet structure at the bottom of the raise then direct air to either the service or exhaust systems (CRWMS M&O 1997a, Section 7.1 and DOE 1998, Section 4.2.4).

This system provides redundancy by providing continued control of airflow through the drift in the event of a damaged isolation door or louver. Another advantage is that an emplacement drift can be positively isolated from the rest of the ventilation system if radionuclides are detected in the exhaust main (CRWMS M&O 1997a, Section 7.3.4 and DOE 1998, Section 4.2.4.2).

When an emplacement isolation door is open to receive a waste package, the pressure and airflow balance in the drift is disturbed. The regulating valve in the outlet structure at the exhaust raise that controls air flow to the exhaust main then automatically constricts to prevent excessive flow disturbances in the subsurface ventilation air balance.

When repair to the system is necessary, the louvers in the emplacement isolation door are easily accessible from the main. However, the regulating valve in the raise is in a remote location and maintenance would be more difficult. The time required for cooling the raise air sufficiently to allow work on the valves is another disadvantage of this air control option.

6.3.2 Dual Isolation Doors (Airlock)

The second method of air control involves the use of airlocks. In this system, a pair of doors are installed in both the east and west turnouts. The doors for each airlock must be adequately spaced to accommodate the transport locomotive and the waste package transporter.

Louvers in the airlock doors control airflow to the emplacement drift; both pairs of doors in an airlock have louvers. This arrangement does not rely on a valve at the exhaust raise to regulate airflow when an emplacement drift accepts waste. Instead, 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. Figure 5 illustrates this sequence for an emplacement drift accepting waste.

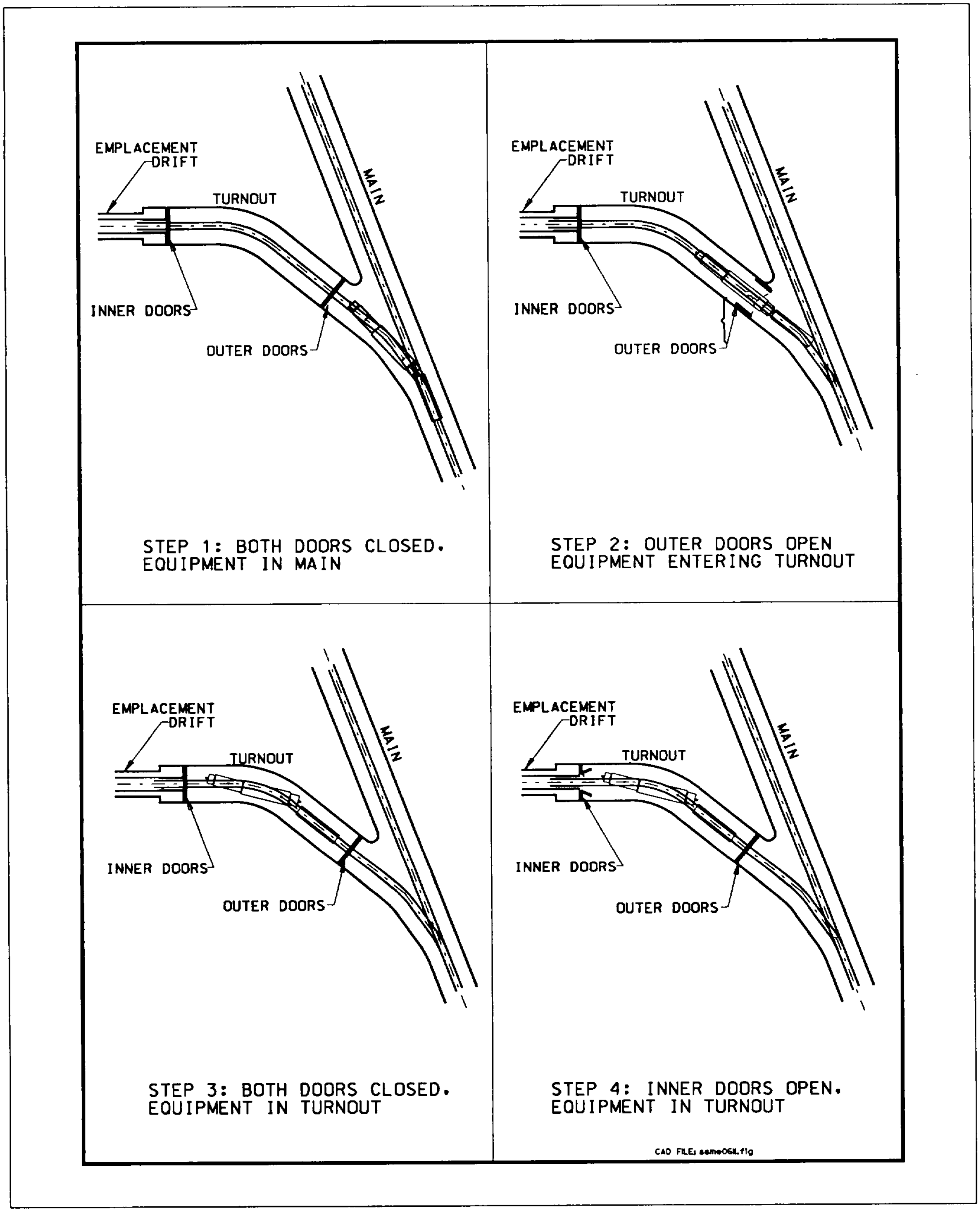

Figure 5. Dual Isolation Door (Airlock) Concept

An advantage to the airlock system is that the regulating valves in the exhaust raise are eliminated. All the airflow controls are located in a turnout on the emplacement drift level of the repository.

Although valves are unnecessary at the bottom of the exhaust raise, a structure to direct airflow to the appropriate exhaust system is still required. Bolted steel plates would be used in place of the regulating valves shown in Figure 2 through Figure 4.

Airlock door spacing requirements should be investigated. Any extension of a turnout or additional excavation for door installation is a disadvantage for this method of air control.

6.4 SYSTEM COMPONENTS

Physical components of the emplacement drift ventilation system, which include the emplacement isolation doors and a rail-mounted shadow shield for use during door maintenance, are described below. Design and construction considerations for installing a partition wall in the split exhaust main alternative are also presented.

6.4.1 Emplacement Isolation Doors

In addition to being a key component in the control of air flow in the emplacement ventilation system, the emplacement isolation doors also control human access to the emplacement drifts (Criterion 4.2.3) and provide some level of radiation protection (CRWMS M&O 1997a, Section 7.3).

The isolation doors may be constructed of steel or concrete. A door made entirely of reinforced concrete could crack due to the different thermal expansion properties of the steel reinforcement and the concrete. The cracks would weaken the door structurally and allow leakage between the emplacement drift and the mains. A composite door with a steel exterior and a concrete-filled interior would not be subject to the same concerns (CRWMS M&O 1997a, Section 7.3.1).

An alternative is to have an all-steel emplacement door. This type of door is 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 (CRWMS M&O 1997a, Section 7.3.1).

Each door is installed in a concrete bulkhead. 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. This minimizes leakage around the bulkhead (CRWMS M&O 1997a, Section 7.3.1).

The doors may be of a single-swing or a double-swing design as illustrated in Figure 6 (derived from CRWMS M&O 1997a, Figures 7 and 8). Double-swing doors were chosen to illustrate ventilation concepts in this report. Although establishing a tight seal to prevent leakage may be more difficult with a double-swing door than a single-swing door, this disadvantage is offset by the reduction in weight of each door section and associated counterweights.

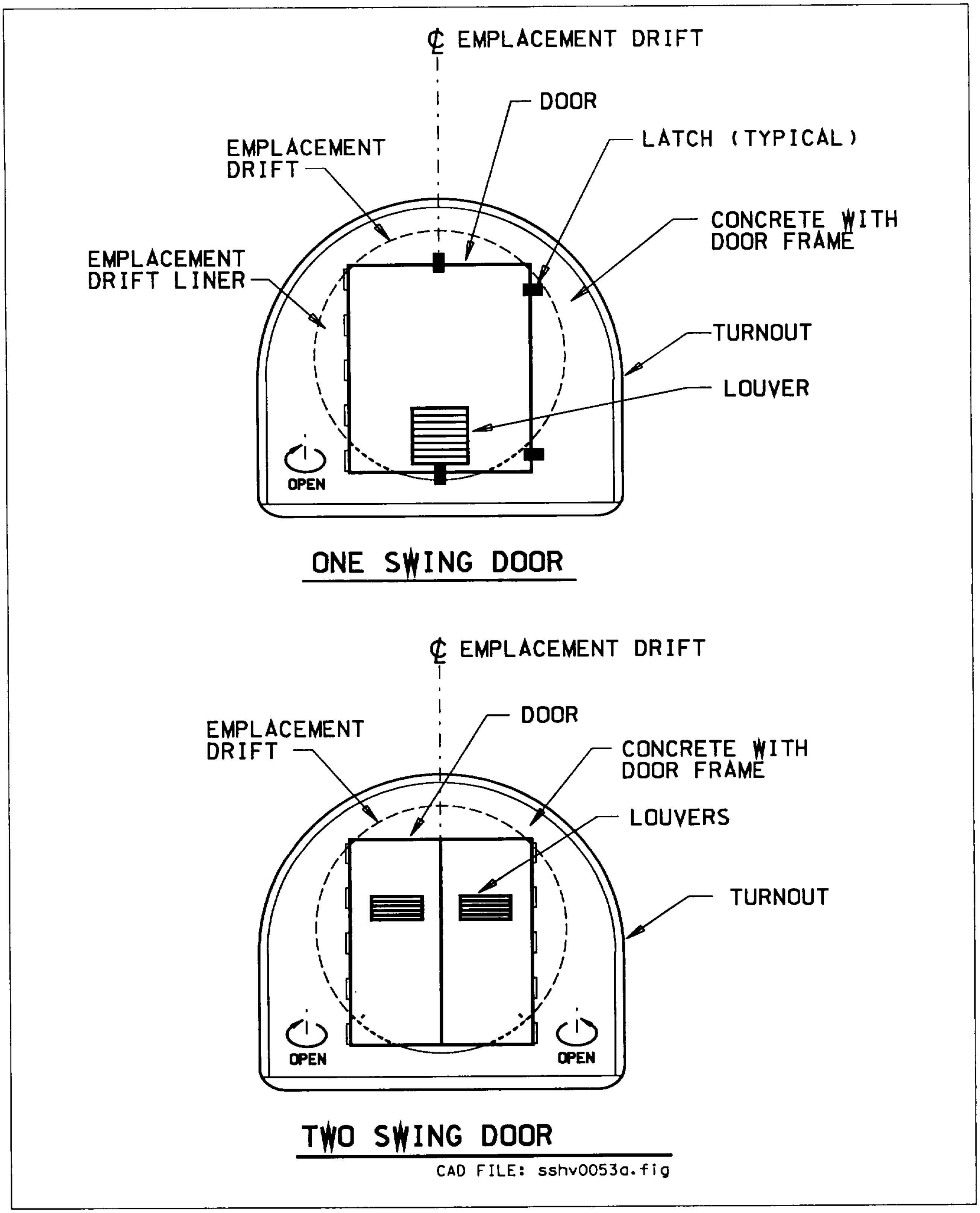

Figure 6. Emplacement Isolation Doors

Double-swing doors can open in one direction or in opposing directions. Doors that swing open outward in the same direction are preferred for this installation because the pressure of the ventilation air will tend to help keep them closed.

6.4.2 Portable Shadow Shield

In the dual isolation door (airlock) concept, adequate worker protection must be provided when the inner door is open for repair. In this event, a rail-mounted concrete seal can be moved into the drift opening to shield maintenance personnel. The gaps between this portable seal and the bulkhead are then overlaid with bags containing iron pellets. Initial definition of this concept is illustrated in Figure 7.

6.4.3 Exhaust Main Partition

In the split main alternative, a partition wall is used to divide the main into two sides (CRWMS M&O 1997b, Section 7.4.5); the service side is used for access, monitoring, and maintenance, while the other side is reserved for emplacement drift exhaust air (Figure 4). The service side of the main accommodates the exhaust raise, the air regulating valves, and rail access for construction, inspection, monitoring, and maintenance. The exhaust side of the main also has rail access for monitoring and maintenance. Removable steel panels are provided in the partition wall to allow access between the exhaust side and the service side when required.

The exhaust main will be lined with cast-in-place concrete to minimize air leakage between the divided portions of the main. Leakage can occur through rock fractures and around steel set ground support, if used. The partition will be constructed within and anchored to the concrete liner.

The partition will be constructed of concrete or steel to minimize fire hazard potential. Concrete materials would consist of lightweight structural aggregates with inherent insulative qualities. If concrete were selected, either cast-in-place concrete or precast concrete panels could be used. Steel materials would consist of structural framing covered with plates. Underground construction of the partition, regardless of the type of materials, will be difficult. The difficulty of installing cast-in-place concrete for the partition would be compounded by the necessity of scheduling, forming, transporting, handling and placing concrete materials, while interfacing with the tunnel construction effort. The use of precast concrete panels would require transporting, handling, and erecting the panels in an extremely confined space, where there could be interferences with utilities and the muck handling system. Steel materials, however, can be erected in a modular manner that will allow frame installation first, followed by the installation of the wall plates. Constructibility concerns associated with concrete make steel the most likely material of construction for a partition wall.

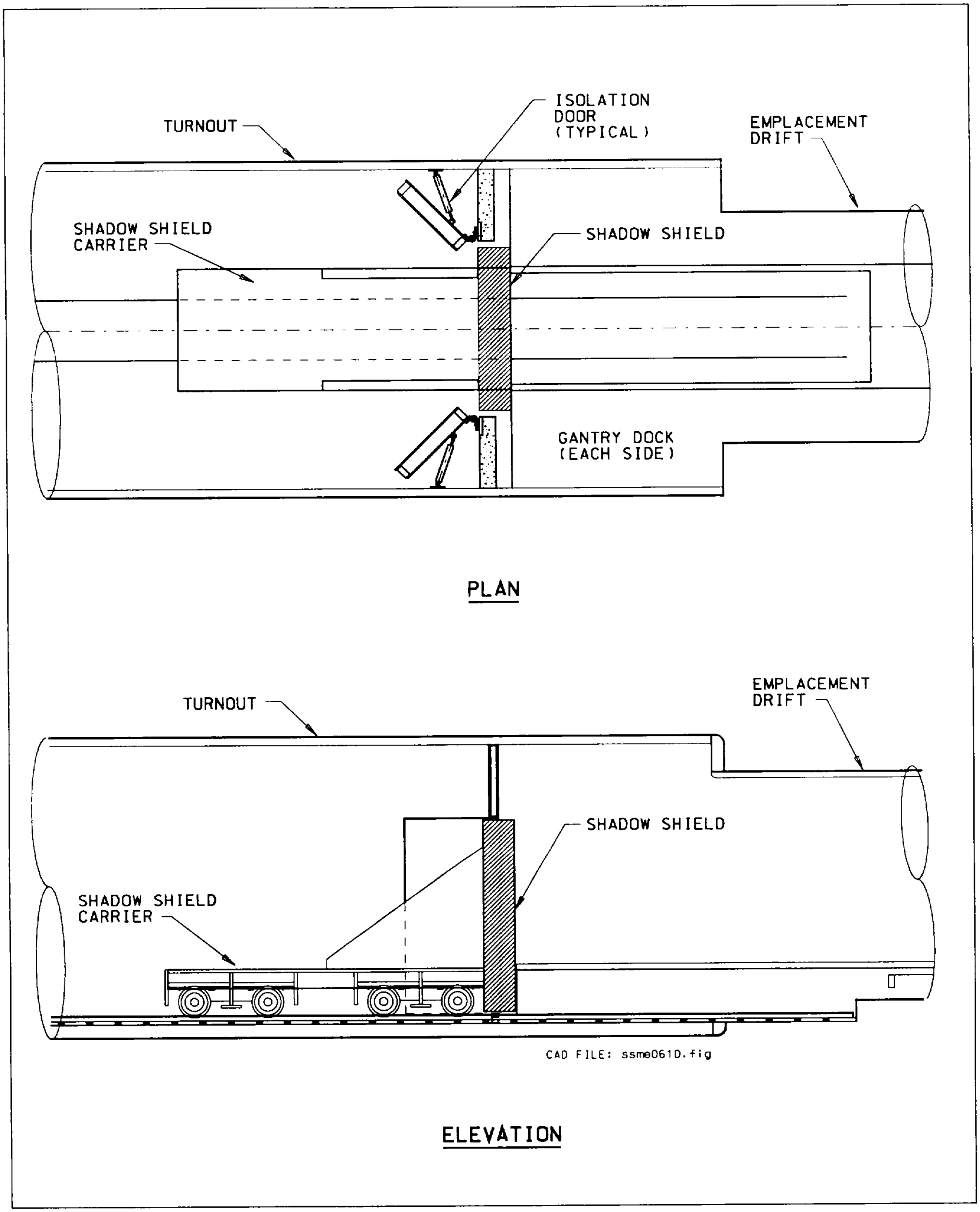

Figure 7. Portable Shadow Shield Concept

The ventilation partition will span the distance between the invert and the crown of the exhaust main and will be located to provide equipment clearance and adequate area for air flow. The wall will be configured so that the structural steel frame is anchored to the concrete tunnel liner at the invert and crown. The steel frame will be covered on the exhaust side with steel plate continuously welded to the frame. Insulation will be installed on the service side of the partition. The insulation should be of a rigid, non-flammable material for maintaining the service side of the drift at a temperature suitable for personnel access. Steel pins, spot-welded to the steel plates with spring washers fastened onto the pins and against the insulation board, may be used to anchor the insulation board. The overall height of the ventilation partition wall will depend on the diameter of the tunnel and the thickness of the concrete liner and invert.

7. CONCLUSIONS

This analysis updates design concepts for emplacement ventilation based upon the increased air flow required through the drift in the EDA II design (CRWMS M&O 1999a, Table O-6) and by current thermal modeling results compared to the VA design (DOE 1998, Section 4.2.4). It reviews the air pathway in the emplacement drift, describes three exhaust system options, discusses two air control options, and examines concepts for several system physical components including isolation doors, a portable shadow shield, and a partition in an exhaust main.

The air path through the emplacement drift, itself, remains the same as described in the VA and EDA II design; that is, exhaust fans located on the surface pull air through an intake shaft into the subsurface repository. The ventilation air is distributed to the east and west mains by the cross-block drifts. From the mains, the air enters the emplacement drifts and flows to a central exhaust raise. The air then travels down an exhaust raise to the exhaust system. See Figure 1 in Section 6.1.

7.1 EXHAUST SYSTEM OPTIONS

The three exhaust system options are: one exhaust main with ducts for the emplacement exhaust air (Section 6.2.1), dual exhaust mains (Section 6.2.2), and a split exhaust main (Section 6.2.3).

The first option is impractical due to the large size ducts needed for the current air volume. The other options, dual, parallel exhaust mains and a large, split exhaust main, are both viable concepts. They provide for the separation and containment of high volumes of emplacement exhaust air.

The dual, parallel mains concept requires more excavation than the split main concept. Dual mains also require the excavation of cross-connection drifts at each emplacement drift exhaust raise, which increases construction complexity.

In the split main concept, construction of the partition dividing the main is also relatively complex. Provisions for minimizing air/radiation leakage between the service side and the emplacement exhaust side of the partition must be considered in the design (Section 6.4.3).

Further evaluation, including the development of comparative capital and operating costs and schedules, in conjunction with the selection of the air control method discussed below, is needed before an exhaust system design can be recommended. In addition, radiation scattering calculations must be updated for the new exhaust main arrangements to determine if shielding is necessary (Section 6.2.3).

7.2 AIR CONTROL OPTIONS

The two options discussed for controlling airflow in an emplacement drift are the single isolation door and valve system (Section 6.3.1) and the dual isolation door system (Section 6.3.2). Both arrangements are sufficient for regulating airflow through the emplacement drifts.

In both options, louvers are installed in the emplacement drift isolation doors to control inlet airflow. In the single door alternative, a regulating valve located in the exhaust raise controls airflow when the door is open. This function is accomplished by the inner isolation door in the dual door arrangement.

The single isolation door concept with a regulating valve at the bottom of the exhaust raise provides redundancy by allowing continued control of airflow through an emplacement drift in the event of a damaged door or louver. This valve also provides positive isolation of the drift in the event that radionuclides are detected in the exhaust main.

The regulating valves are eliminated in the dual isolation door concept. However, a structure is still required at the bottom of the exhaust raise to divert flow to either the service or exhaust side of the collection system. Because all of the airflow controls in the dual isolation door concept are located in a turnout on the emplacement drift level of the repository, access for maintenance is easier than in the single door concept.

The dual isolation doors are configured as an airlock, which minimizes airflow disturbances in the drift during waste package emplacement. Door space requirements, as illustrated in Figure 5, need to be evaluated with the planned repository layout configuration and emplacement/retrieval equipment designs. The layout and equipment designs are currently in development. Since any extension of the turnouts could impact the repository layout, a recommendation for controlling airflow cannot be made without further evaluation.

Isolation doors (Section 6.4.1) are key components in both of the emplacement drift air control concepts described above. In addition to controlling human access to the drift and providing some level of radiation protection, they provide a suitable platform for mounting louvers, the principle means of controlling airflow. Doors that swing outward in the same direction are preferred from a ventilation system design perspective because air pressure outside of the emplacement drift is higher than inside. This will tend to force the doors closed and minimize leakage.

When maintenance is required on an interior door facing an emplacement drift, adequate worker protection must be provided when the door is open. This may be accomplished by moving a rail-mounted, portable shadow shield (Section 6.4.2) into the drift opening.

8. REFERENCES

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8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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9. ATTACHMENTS

None.

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