ENG.20070716.0026

BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: N/A

3. System	4. Document Identifier
Subsurface Ventilation and Mining Systems	800-KVC-VU00-00400-000-00A

5. Title

Shaft Collars and Fan Layout General Arrangement Analysis

6. Group

Subsurface Mining

7. Document Status Designation

☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

This calculation supersedes 800-KMC-SSD0-00400-000-00B

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1) CACN-001, DATED 01/22/2008

Attachments	Total Number of Pages
Attachment A	10

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
	Initial Issue	34	A-10	Jeff Steinhoff J. Steinhoff 7/12/07	Ed Thomas Edward Thomas 7/12/07	Hang Yang Hang Yang 07/13/2007	Robert Saunders Robert S. Saunders 7/13/07

DISCLAIMER

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1. PURPOSE

The purpose of this analysis is to revise the current shaft collar design (fans, ducting and shaft collar) configuration to enhance constructability and to reduce long term power consumption. In addition, this analysis provides an update of the overall exhaust and intake shaft designs including the shaft locations and shaft stations. The shaft locations are based upon the location of the individual shafts in the *Underground Layout Configuration for LA* (Ref. 2.2.10). Analysis of the individual shaft construction and operations pads for constructability is beyond the scope of the analysis. Also, the configuration of the shafts during construction is not included in the scope of this analysis.

2. REFERENCES

2.1 PROJECT PROCEDURES/DIRECTIVES

2.1.1 EG-PRO-3DP-G04B-00037, Rev 008, *Calculations and Analyses*

2.2 DESIGN INPUTS

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2.2.7 BSC 2006. *Main Fan Collar Arrangement Trade Study*. 800-3SW-VU00-00200-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20060315.0004

2.2.8 BSC 2006. *Project Design Criteria Document*. 000-3DR-MGR0-00100-000-006. Las Vegas, Nevada: Bechtel SAIC Company. ACC. ENG.20061201.0005. [DIRS 178308]

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2.2.10 BSC 2006. *Underground Layout Configuration for LA.* 800-KMC-SS00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061115.0001. [DIRS 178323]

2.2.11 BSC 2006. *Ventilation Network Model Parameters for LA.* 800-KVC-VUE0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061117.0006. [DIRS 178337]

2.2.12 BSC 2007. *Subsurface Ventilation Network Model for LA.* 800-KVC-VUE0-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070123.0008. [DIRS 179520]

2.2.13 BSC 2007. *Typical Ground Support for Ventilation Shafts*. 800-K00-SSD0-00101-000-00A. Las Vegas, Nevada. Bechtel SAIC Company. ACC: ENG.20070515.0001

2.2.14 Colorado School of Mines 2006. *Colorado School of Mines Yucca Mountain Initial Ventilation Option Selection*. V0-M00Z-NSRA-00004-00005-001-001. Golden, Colorado: Colorado School of Mines. ACC: ENG.20061220.0027.

2.2.15 Colorado School of Mines 2006. *Subsurface Mechanical Engineering Design Services Report, Task Order No. 8, Exhaust Shaft Collar Design Selection*. V0-M00Z-NSRA-00004-00006-001-001. Golden, Colorado: Colorado School of Mines, Mining Engineering Department. ACC: ENG.20061220.0028

2.2.16 DOE-STD-1090-2004. 2004. *Hoisting and Rigging (Formerly Hoisting and Rigging Manual).* Washington, D.C.: U.S. Department of Energy, Internet Accessible.

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2.2.18 Joy Manufacturing Company 1982. *Joy Axivane Fans Mining Catalog J-670.* New Philadelphia, Ohio: Joy Manufacturing Company. TIC: 244167.

2.2.19 McPherson, M.J. 1993. *Subsurface Ventilation and Environmental Engineering.* New York, New York: Chapman & Hall. TIC: 215345. [ISBN 0 412 35300 8]

2.2.20 Tri State Photogrammetry 2003. *Topographic Map*. V0-C00Z-NTA0-05435-00001-001. Sparks, Nevada. Tri State Surveying LTD. ACC: ENG.20031202.0002

2.3 DESIGN CONSTRAINTS

None.

2.4 DESIGN OUTPUTS

This document will provide support for the Plant Design System (PDS) model of the surface fans and the subsurface 3D model of the shaft collar structures.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

The dose rates from emplaced waste packages is expected to range from 1.1 to 1.8 rem/hour in the exhaust mains (Ref. 2.2.5, Section 7.2).

Rationale: The assumption will be verified when the referenced document is approved.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

None.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1). The shafts (non emplacement openings) and subsurface ventilation system, which consists of the emplacement ventilation system and development ventilation system, are classified as a non-Safety Category item in the *Basis of Design* (Ref. 2.2.9). Therefore, the approved version is designated as QA:N/A.

This calculation is intended to support the License Application (LA).

4.2 USE OF SOFTWARE

No software was used to perform calculations. Any calculations used are done by hand.

4.3 METHODOLOGY DESCRIPTION

4.3.1 Exhaust Fan Shaft Collar Structure and Fans

This document updates design information pertaining to the repository shafts and fan collar arrangements. The shaft collar and main fan configurations are updated to reflect work done by the Colorado School of Mines under Task Order No. 8 (Ref. 2.2.15). The task included ranking the maintenance, durability, access, monitoring, financial, and schedule factors for various exhaust fan shaft collar arrangements found in industry (Refs. 2.2.14 and 2.2.15). This analysis incorporates the recommended design as the exhaust shaft fan arrangement.

The shaft collar general arrangement supports the requirements found in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Ref. 2.2.9) and the *Project Design Criteria Document* (Ref. 2.2.8).

The analysis provides the current shaft and fan design information and facility interfaces necessary to support LA. The operating principle of the mining industry's use of multiple fans operating in parallel is presented for clarity.

Potential shaft pad arrangements for the collar locations designed for LA are provided in Attachment A.

4.3.2 Shaft Location and Size

Shaft locations and sizes were updated based upon *Underground Layout Configuration for LA* (Ref. 2.2.10). The topography from Tri State Photogrammetry (Ref. 2.2.20) was combined with the layout to show the ground surface above the entire repository.

4.3.3 Interfaces

Table 1 summarizes primary design interfaces and may not include all relationships.

Table 1 Interfaces

Function	Group	Comment
Shaft collar installation and subsequent use during repository construction	Construction	During construction, the shafts may be used for construction ventilation, hoisting men and supplies, emergency egress, and hoisting excavated material from the repository. The collar structure design would not preclude these uses.
Shaft collar design	Subsurface Civil, Structural, Architectural	Includes all structures at the intake and exhaust shaft collars.
Fan Design	Subsurface Ventilation	Includes turning vanes, fan specification (volume, pressure, in flight adjustability, etc.) ducting, back draft dampers, and evase.
Power	Subsurface Electrical	Includes power to the site and backup power if applicable.
Shaft location	Subsurface Design, Surface Design and Balance of Plant	Location of the shafts has to consider ventilation requirements in the subsurface repository, the overall layout developed by subsurface design, and access to the shaft collar that will be provided by Balance of Plant. Geology, hydrology and topography at the shaft locations effect construction of the facilities.
Monitoring	Subsurface Ventilation	Includes monitoring for equipment status, accommodates radiation monitoring, air quantity, and air quality.
Monitoring	Performance Confirmation	Includes monitoring for conditions relative to Performance Confirmation Plan.

Function	Group	Comment
Egress	Subsurface Life Safety	Exhaust shafts would not be a part of the egress system. However, the design will not preclude rescue operations that might be required by unforeseen events. Intake shafts may be provided with emergency evacuation equipment.
Radiation	Nuclear Engineering	Examination of radiological conditions that might exist at the exhaust fans prior to entry by personnel for inspection, maintenance or other reasons.
Maintenance and Inspection	All design groups	Includes providing designs that are maintainable and constructible.

5. LIST OF ATTACHMENTS

		Number of Pages
Attachment A	Shaft Collar Locations	10

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6. BODY OF ANALYSIS

6.1 SHAFT COLLAR, SHAFT, AND FAN DESIGN

The following sections describe the requirements that drive the shaft and collar design.

6.1.1 Subsurface Flood Protection

The shaft or raise collar openings shall be protected from water inflow by making the surface gradient at the portal openings and shaft collars down gradient and away from the openings (Ref. 2.2.8, Section 4.2.13.8.5). Shafts and shaft collar areas are protected or located away from water inflow caused by the probable maximum flood (2.2.9, Section 8.2.3.1.2).

6.1.2 Egress Through the Shafts (see Section 6.1.6 also)

The exhaust shafts will not be equipped as a facility for egress from the subsurface. Intake shafts may be equipped for egress. Several exit points for escape from a fire hazard or other emergency will be available to personnel working in the emplacement phase of the repository. These will include the North Portal, designated ventilation intake shafts, the South Portal and the North Construction Ramp (Ref. 2.2.4, Section 6.4.3). The *Project Design Criteria Document* (Ref. 2.2.8, Section 4.9.1.10.3) requires that egress shall be provided from the subsurface areas in accordance with the subsurface life safety performance criteria. The exhaust drifts in the subsurface repository and the exhaust shafts themselves would provide an unacceptable risk to personnel. The *Project Design Criteria Document*, (Ref. 2.2.8, Section 4.2.13.5.7, Table 4.2-5) shows that the exhaust mains, exhaust shaft access exhaust drifts, and exhaust shafts are inaccessible. The air temperature in these openings would normally be 42 degrees C to 74 degrees C (108 degrees F to 165 degrees F). It is an unacceptable risk for people to use normally inaccessible routes for egress. Additionally, in order to reach the exhaust shafts, personnel would have to travel past several intersections between the exhaust main and the emplacement drifts. The dose rate from emplaced waste packages is expected to range from 1.1 to 1.8 rem/hour in the exhaust mains (Assumption 3.1). If human entry near these areas were required, i.e., in an emergency, adequate temporary shielding would be necessary.

Similar radiation exposure conditions do not exist in the repository areas that are under construction. As a result, any suitably equipped shaft that has not been turned over for repository operations as an exhaust shaft could be used for egress for construction workers.

6.1.3 Access for Remote Inspection and Repair

The ducting at the exhaust shafts will include an access door to allow remote inspection of the exhaust shafts with a camera. The exhaust shaft collar/plenum will be designed so that the shaft collar can be exposed to facilitate the installation of a shaft repair work deck, if required during the operating life of the shaft. Although there are no fans and ducting at the intake shafts after they have been turned over to repository operations, the design cannot preclude use of inspection equipment, work decks or emergency egress equipment. The shaft liner (cement, shotcrete, or other ground support) will require periodic inspection (Ref. 2.2.15, Section 3.0). If the inspections indicate that repairs are necessary, then a repair work deck could be required.

6.1.4 Back Draft Dampers

If one fan becomes inoperable and requires repair or replacement, the airflow through the fan must be stopped. The back draft damper provides a way to isolate each fan. (Ref. 2.2.15, Appendix F, Letter from Fred Stockhaus to McIntosh Engineering Ltd.)

6.1.5 Fan Silencers

The *Basis of Design for the TAD Canister-Based Repository Design Concept* (Ref. 2.2.9, Section 22.2.4.2) requires that the subsurface ventilation system be installed in such a manner to facilitate accessibility for maintenance, repair, replacement, and in-service inspection with consideration for space requirements under which these activities are performed. Although noise attenuation is not specifically mentioned, silencers would be required for the protection of workers that maintain and inspect the fan installations.

6.1.6 Emergency Egress (See also Section 6.1.2)

The intake shafts are one of several exit points from a fire hazard or other emergency that will be available to personnel working in the emplacement side of the repository (Ref. 2.2.4, Section 6.4.3). Detailed evacuation plans and requirements will be developed prior to repository operations (Ref. 2.2.4, Section 6.6.5). This analysis recommends that a suitable mobile crane be used to evacuate people from the subsurface repository to surface via an intake shaft. The operation, design, testing, and inspection requirements for the use of personnel lift platforms or baskets suspended from mobile or overhead cranes are described in DOE-STD-1090-2004 (Ref. 2.2.16, Chapter 4). Use of a mobile crane would remove the need for a ground mounted hoist and headframe at the intake shaft collar.

6.1.7 Intake Shaft Collar

Intake shaft collars and exhausts collar structures can be similar. This analysis recommends that, from a ventilation standpoint, no special structure be installed at the intake shaft collars, such as a rollout that is used at the exhaust shafts. From a ventilation standpoint, a sharp edged entrance for air entering the repository is consistent with the parameters used in the ventilation network model (Ref. 2.2.11, Section 6.2.2).

6.1.8 Service Life

The subsurface ventilation system is accessible. Any component that fails or is worn out will be replaced.

6.1.9 Blast Cooling

The subsurface emplacement ventilation system, including shafts that have not been turned over to repository operations, shall support the option for retrieval of spent nuclear fuel by being able to cool the emplacement drifts to a temperature that would allow retrieval of spent nuclear fuel (Ref. 2.2.9, Section 22.2.2.3). Blast cooling is the term that is used to describe the process of increasing airflow in emplacement drifts to produce rapid cooling. Increasing airflow in emplacement drifts requires additional fan capacity.

6.1.10 Monitoring

The ventilation system is required to provide instrumentation test ports for testing and balancing. Other necessary measuring instruments shall be provided at strategic locations of the system to test, collect data, and monitor system performance (Ref. 2.2.9, Section 22.2.1.2). Monitoring requirements for shafts are summarized in Table 2.

Table 2 Monitoring Requirements

Parameter	Location	Reference
Air temperature, quantity, relative humidity because all three monitoring parameters are required for heat removal control	All three parameters would be measured at both intake and exhaust portals and shafts. The information is required to control temperature in the emplacement drifts and to determine the performance of the ventilation system.	Ref. 2.2.9, Sec. 22.2.1.3
Air temperature and relative humidity	Ambient conditions for worker comfort	Ref. 2.2.9, Sec. 22.2.1.5
Radon, radon daughter concentration	Work places and exhaust emissions	Ref. 2.2.9, Sec. 22.2.3.1
Particulate concentration and other non radioactive emissions	Work places per ACGIH and exhaust emissions at exhaust shafts	Ref. 2.2.9, Sec. 22.2.3.2 and 22.2.3.5
Air pressure differential, rotation speed, air quantity, bearing temperature, vibration	Fans to verify fan performance parameters	Ref. 2.2.9, Section 22.2.4.1
Smoke	At intake portals and shafts	Ref. 2.2.8, Sec. 4.9.1.10.2

6.1.11 Closure Requirements

The shaft design cannot preclude removal of any non-committed material used in the shaft liner and collar structures and backfilling as shown in Table 3. Closure is discussed in other documents and is not further discussed here.

Table 3 Closure Requirements

Requirement	Description	Reference
Removal of non committed materials	Non committed material which is material that will not be left in the repository after closure includes the cementitious shaft liners	Ref. 2.2.6, entire drawing
Closure backfilling	Closure of the shafts and ramps shall include backfilling the openings for their entire length	Ref. 2.2.9, Sec 8.2.1.15

6.1.12 Pad Design Interface (See Also Section 6.3.2)

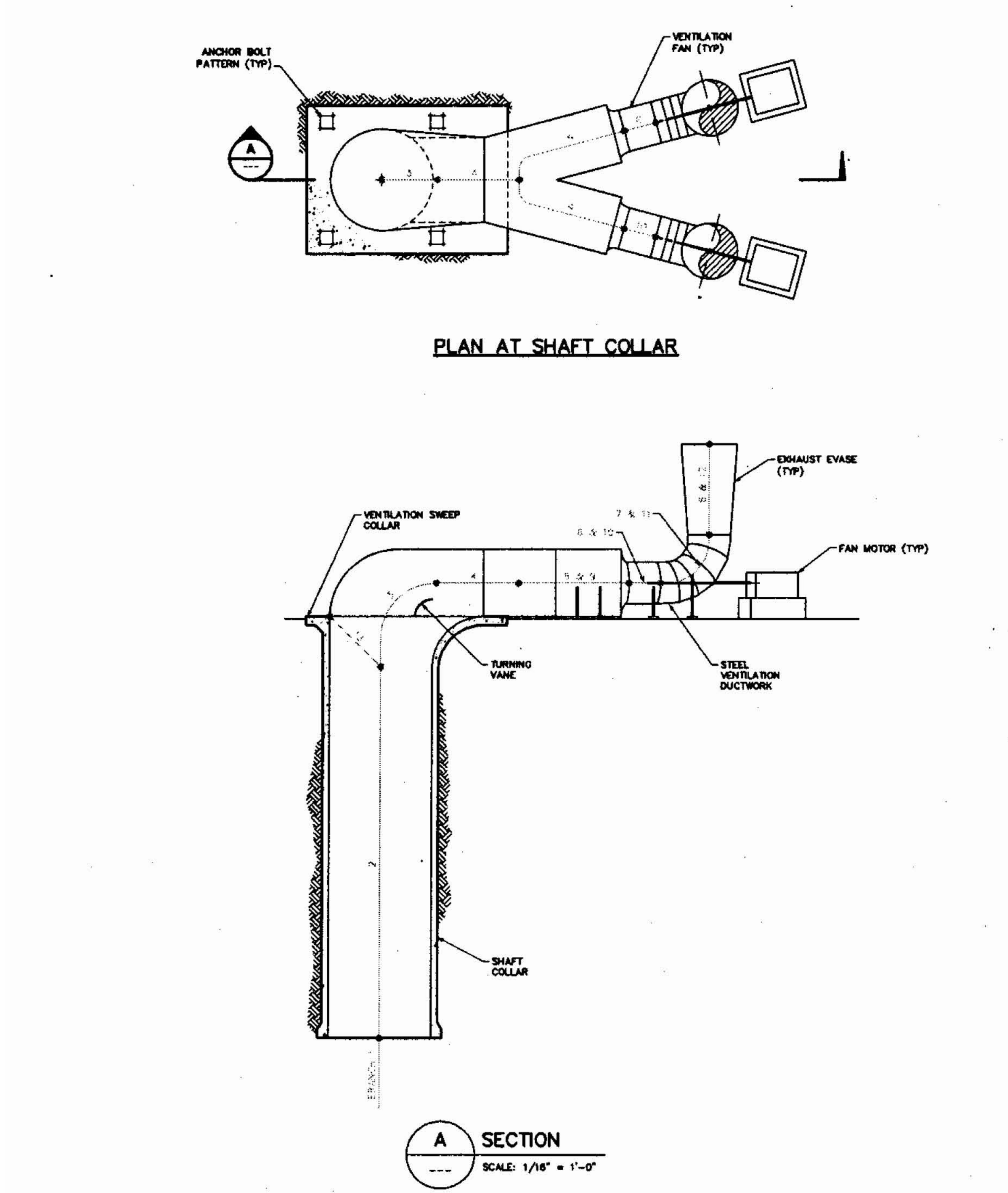
The pad design at the exhaust and intake shafts is part of the subsurface design. The infrastructure required to support activities at the exhaust and intake shaft pads such as water and roads is the Balance of Plant responsibility (Ref. 2.2.9, Section 9.10.2.1.7). The construction pad requirements during shaft construction will be developed in the detailed design.

6.2 FANS AND COLLAR STRUCTURE

The design consisting of two exhaust fans connected to each exhaust shaft collar by ductwork was developed in BSC ventilation documents. The design was carried forward into the calculation entitled *Shafts Preliminary Design Calculation* (Ref. 2.2.3) to develop a preliminary design of the repository ventilation shafts. The design was prepared to support the License Application and to provide the basis for preliminary shaft engineering drawings. These drawings were: structural, geotechnical instrumentation, and other layout drawings of the exhaust and intake shafts. The design for the collar structure met ventilation and other project requirements.

Although the collar structure met ventilation and other project requirements, it was not easily constructible. As a result, the *Main Fan Shaft Collar Arrangement Trade Study* (Ref. 2.2.7) was initiated. The task was to recommend a constructible shaft collar arrangement with minimum operating cost and with convenient access for shaft and fan maintenance. The results of the trade study are documented in *Colorado School of Mines Yucca Mountain Initial Ventilation Option Selection* (Ref. 2.2.14) and *Subsurface Mechanical Engineering Design Services Report, Task Order No. 8, Exhaust Shaft Collar Design Selection* (Ref. 2.2.15).

A review of 16 existing, parallel fan installations at shaft collars common to the mining and tunneling industries was done to formulate the recommendation. Of the 16 options considered, four were selected as applicable to Yucca Mountain. A uniform set of assumptions were used to determine the relative days to construct, capital cost, operating cost, pressure loss and horsepower per fan for each of the four options. This schedule and cost data were included in a more subjective comparison of the safety, maintainability, durability, shaft access, and monitoring features of each option (Ref. 2.2.14). The recommended option is shown in Figure 1.



Ref. 2.2.15, Section 4.4

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Figure 1 General Layout: Collar Elbow Plenum

6.2.1 Other Yucca Mountain Requirements

6.2.1.1 Exhaust Shaft Collar and Fan General Arrangement

Figure 1 depicts the fan and collar general arrangement for exhaust shafts that best meets the criteria used to evaluate the surface fans and collar structure. To apply this arrangement to the repository exhaust shafts, the following features need to be added or deleted:

- The headframe, hoist house, work deck and winches shown on previous general arrangements will not be required (Section 6.1.2).

- Ducting will include an airlock access to facilitate inspection of the shaft with remotely lowered camera equipment. (Section 6.1.3). The access area will be equipped with suitable barriers to prevent personnel from falling down the shaft.

- Ducting will include back-draft dampers (Section 6.1.4).

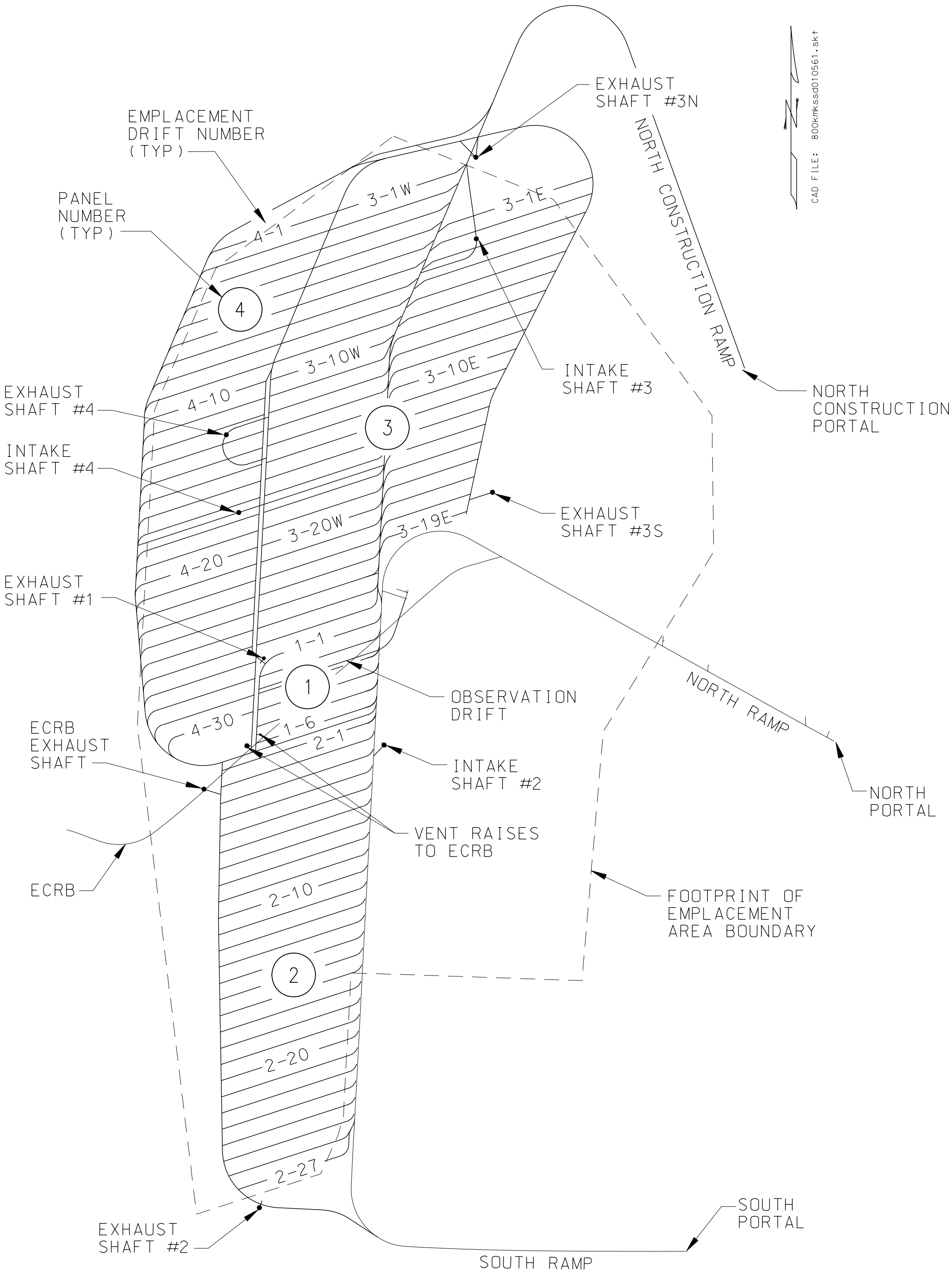
- Ducting will include fan silencers (Section 6.1.5).

- Elevations of the fans and collar structures will depict the ground surface near the collar sloping away from the shaft to promote drainage (Section 6.1.1).

6.3 SHAFT DETAILS

6.3.1 Shaft Location and Size

Figure 2 shows both the exhaust and intake shafts in relation to the subsurface layout. Portals and ramps are also shown because they form a significant part of the intake system. The intake and exhaust airflow allocations, by panel, are shown in *Subsurface Ventilation Network Model for LA* (Ref. 2.2.12, Figures 3 and 4) and are not duplicated here.



Reference: 2.2.10, Figure 10

Figure 2 Subsurface Repository Configuration

The shaft sizes are based upon the quantity of air required to operate the repository and air velocity guidelines. Table 4 summarizes the collar coordinates and diameter of each shaft.

Table 4 Shaft Summary

Underground Layout Configuration [Designation] [a]	Underground Layout Configuration for LA [Designation] [b]	Diameter (feet)	Length/Ref (feet) [a]	Northing (feet) [a]	Easting (feet) [a]
Exhaust Raise #1	Exhaust Shaft #1	16 [b]	1,167 [b]	766,773 [b]	560,013 [b]
Exhaust Shaft #3	Exhaust Shaft #2	26	958	757,356.9	559,937.3
Exhaust Shaft #2	Exhaust Shaft #3 North	26	1,404	775,360.3	563,658.3
Exhaust Raise #2	Exhaust Shaft #3 South	16	915	769,617.9	563,942.4
ECRB Exhaust Shaft	ECRB Exhaust Shaft	26	1,306	764,531.1	558983.5
Exhaust Shaft #1	Exhaust Shaft #4	26	1,329	770,604.1	559,368
Intake Shaft #3	Intake Shaft #2	26	814	765,288	562,080.6
Intake Shaft #2	Intake Shaft #3	26	1,148	773,959.8	563,666.7
Intake Shaft #1	Intake Shaft #4	26	1,240	769,271.6	559,581.8

Source Information: [a] Reference 2.2.1, Tables 7 and 8 unless noted as [b] Reference 2.2.10, Tables 2, 7, and 15

6.3.2 Shaft Pad Design

The footprints necessary for the construction and emplacement shaft pad dimensions have not been developed at this time. The shaft pad configuration for construction will be determined by the contractor and will include a foot print necessary to support the shaft excavation. The construction shaft pad footprint may include offices, change rooms, heavy equipment, batch plants and associated materials, trucks for muck haulage, sinking supplies, water tanks, air compressors, hoists, electrical load centers, parking areas and other necessary items. Placeholders for these types of facilities are shown on the figures in Attachment A.

The footprint needed during emplacement includes room for the security fence, the fan installation and associated electrical equipment. Enough clearance between the fans, the fence and electrical equipment would also be provided to facilitate fan maintenance (Ref. 2.2.9, Section 22.2.4.2). As a result, the pad required during emplacement operation will occupy only a portion of the construction pad footprint.

No ventilation equipment is required at the intake shaft pads during emplacement. Therefore, the space required for these shafts is the security fence, an area to facilitate rescue operations (Section 6.1.2), access for remote inspection and repair (Section 6.1.3), and minimal space for electrical support.

Attachment A includes preliminary figures of the exhaust and intake shaft pads. The figures show an un-dimensioned pad for construction, a pad for repository operations, pad orientation on the topography, and the subsurface layout at each shaft collar. In addition, the figures show an allowance for the Primary Intrusion Detection and Assessment System (PIDAS) (Ref. 2.2.9, Section 8.2.3.2.

6.3.3 Shaft Lining

Lined shafts which are common in the mining industry (2.2.17, Fig. 17.4.40) reduce ventilation costs because of reduced resistance to airflow. The lining also increases the stability of the openings and reduces maintenance when compared with an unlined shaft. The overall ground support, including the lining thickness, is important to shaft stability and reduced maintenance (Ref. 2.2.2, Section 9.3.1). Figure 3 shows the baseline design for LA which may be subject to revisions as the design evolves and details are specified (Ref. 2.2.13, after Note 6). For ventilation raises and smaller diameter shafts, the ground support method at the shaft or raise station will be as shown in Figure 3. Shaft openings' ground support for small diameter shafts and raises will be based on a scaled version of the ground support used in shafts (Ref. 2.2.13, after Note 4).

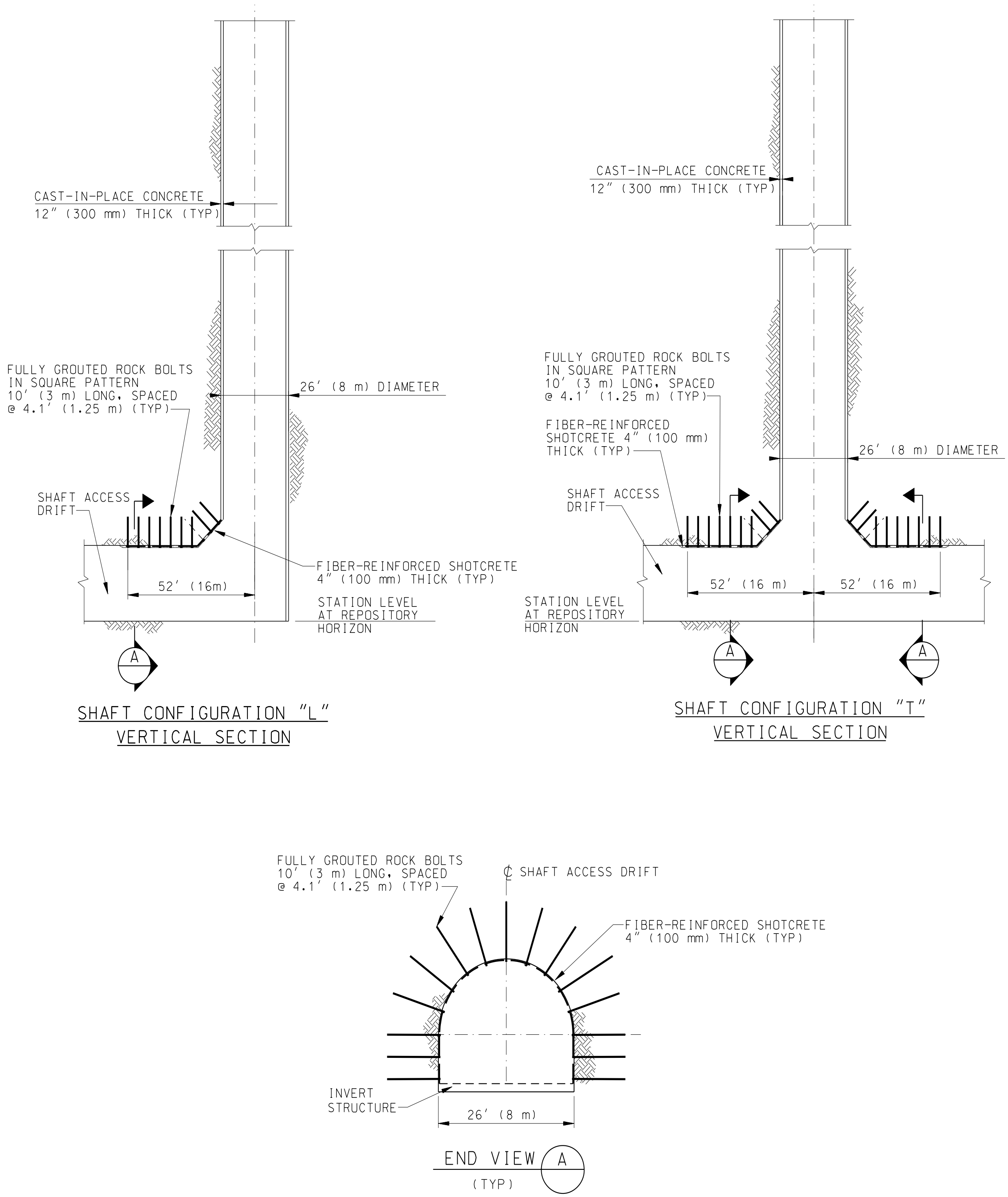
6.3.4 Shaft Stations

A shaft station will be located at the bottom of each intake shaft. The design of the station will be a compromise between the needs of the constructor during shaft excavation, the requirements for emplacement, and the requirements for closure, including backfilling. The shaft station is excavated and the ground support installed during construction and turned over to the repository operations for the preclosure and closure periods. Ground support is described in the *Shaft Liner Design* (Ref. 2.2.2, Sec. 9.3.2).

As stated in Section 6.1.2, the major use of the ventilation shafts during emplacement is for ventilation air intake or exhaust. Additionally, the shafts will be inspected using remotely controlled cameras. If shaft maintenance is needed, maintenance equipment will be installed at that time.

The shaft bottom will be a flat slab of concrete. A small platform will be located at the intake shaft station to provide for access to the emergency egress conveyance. The platform will be located under the shaft brow to provide overhead protection to personnel getting into the emergency conveyance. The conveyance platform will be located approximately 7-10 feet above the shaft bottom to allow for over travel of the conveyance. The shaft brow is beveled for constructability and to reduce ventilation shock loss at the intersection between the shaft and the shaft access.

Figure 3 is an example of a typical shaft station during emplacement operations showing the excavation and ground support. Other details will be designed later.



After Reference 2.2.13

Figure 3 Typical Shaft Station

6.4 MULTIPLE FANS OPERATING IN PARALLEL

The classification of the Subsurface Ventilation Systems, as explained in Section 4.1, is not important to waste isolation and not important to safety. The reasons for the classification are: 1) The ventilation system is not required to perform radiological release prevention or mitigation, and 2) Off-normal conditions affecting the ventilation system are designed to be remedied within 30 days to prevent overheating. For these reasons, redundant ventilation fans with 100% capacity are not required. The major operational requirement for the parallel exhaust fans is flexibility. The emplacement area expands and requires a greater volume of cooling air as the amount of waste emplaced in the repository increases. For example, the air volume exhausted at a particular shaft could be as low as 160,000 cfm (5 emplacement drifts x 15 m^3 per second per drift x 2,119 cfm per m^3 per second) to as high as 845,000 cfm at a pressure of 5.75 inches of water gage (Ref. 2.2.12 Table 1). In the following discussions about fan capacity, the term "reasonably close to" is used. This term is used because fan characteristics are shown on graphs depicting fan performance at a specific blade angle and speed. "Reasonably close to" means that small adjustments in blade angle or speed would produce the required performance.

At least two design options could be used to meet the air volume requirements. Option A consists of two identical fans operating continuously in parallel. Option B consists of a single fan and another standby fan of the same size as 100% back up.

Option A (current fan layout design) could consist of two Joy Axivane Mine Fan Model M120-72 (Ref. 2.2.18, Fan curves C-8232 and C-5986). The Joy fan is presented for this discussion. Each fan would have a 120 inch diameter housing, a hub diameter of 72 inches, a rotation speed of 500 rpm, and a blade tip speed of 15,700 ft/minute. The size of the drive motor is about 750 brake horsepower including power for an airflow contingency of 15%. Other fan sizes and fans from different vendors could also work.

Option B consists of a single, larger fan delivering the total shaft airflow of 845,000. This fan, a Joy Axivane Mine Fan Model M132-72 (Ref. 2.2.18, Fan curves C-8240 and C-5985) has a 132 inch diameter housing, a hub diameter of 72 inches, a rotation speed of 730 rpm and a blade tip speed of 25,230 feet per minute. The size of the drive motor is approximately 1,500 brake horsepower including contingency for 15% increased airflow. As with Option A, other fans from different vendors could also work. The Joy fan is presented for this discussion.

Figure 4 Option A illustrates the operation of two fans in parallel (current design). The figure shows the System Resistance Curve that describes the relationship between pressure and airflow volume in the repository ventilation system. The Single Fan Curve shows the operating capability of a single fan. The Combined Characteristics Curve shows the capability of the two fans operating in parallel. The intersection of the System Resistance Curve and the Combined Characteristics Curve defines the operating point of the fan installation. In this case, the operating point is reasonably close to the 845,000 cfm requirement (See Section 6.4, 1st paragraph) at about 5.7 inches of water gage pressure. If one fan becomes

Reference: Derived from 2.2.18, C-8232

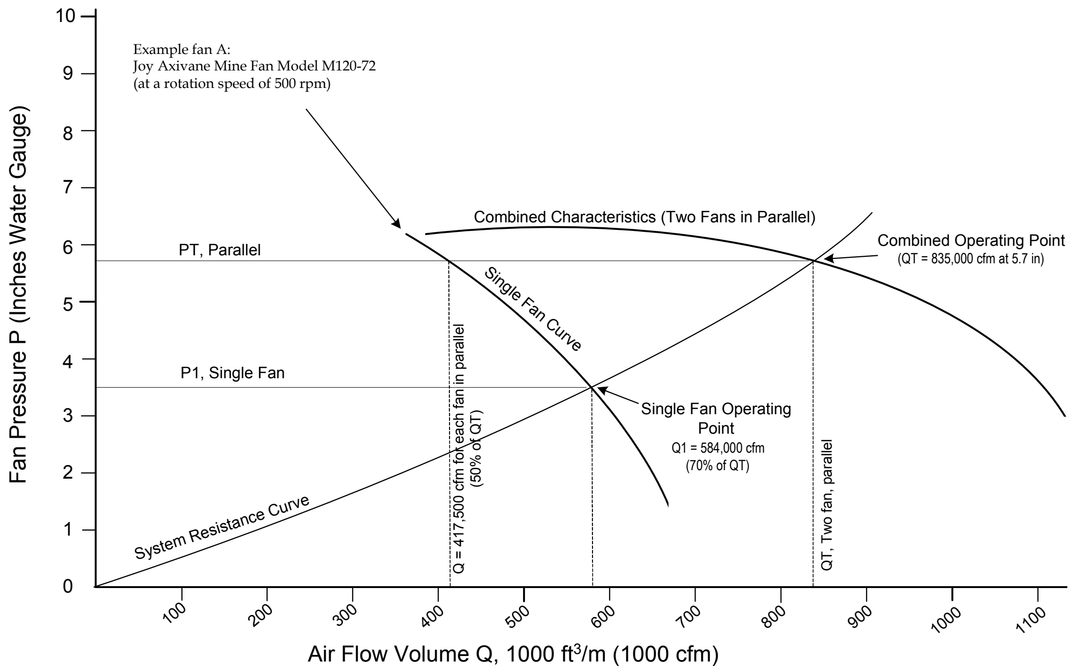
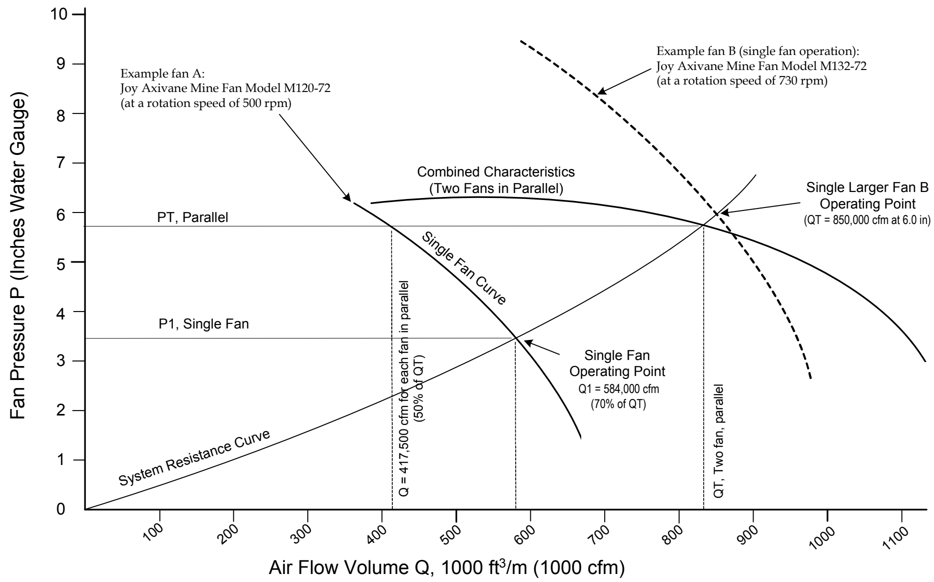


Figure 4 Option A

inoperable, then the operating point of the remaining fan intersects the System Resistance Curve at about 584,000 cfm at a pressure of about 3.6 inches of water gage. In this particular case, the reduced airflow is about 70% of the combined fan volume. This is an expected result. "An advantage of employing fans in parallel is that if one of them fails then the remaining fan(s) continue to supply a significant proportion of the original flow" (Ref. 2.2.19, pg. 349). An example cited on the same page of the reference demonstrated that 70% of the airflow resulted when one fan in a two-fan parallel system was shutdown. The actual value of the airflow depends on the number of fans employed, the shape of their pressure-volume characteristic curves and the provision of non-return baffles [back draft dampers].

Figure 5 Option B is the same as Figure 4 Option A except that the characteristic curve for the Example Fan B for single fan operation is shown. Figure 5 Option B shows that a single large fan will meet the maximum airflow/pressure requirement. However, if an exhaust shaft were equipped with the single Option B fan and the fan shuts down, then the mechanically induced airflow in the shaft would drop to zero. The figure also shows that an Example A fan and an Example B fan operating in parallel could produce the required air volume.



Reference: Derived from Ref. 2.2.18, C-8232 and C-8240

Figure 5 Option B

Figure 5 Option B also addresses the flexibility of two-fan systems. The operating range for the Example Fan A is from about 600,000 cfm to about 975,000 cfm at a specific blade setting and speed. The range for Example Fan B is from about 350,000 cfm to over 1,100,000 cfm at a specific blade setting and speed. The air flow capacity of fans can be changed by varying the pitch angle and/or the rotation speed. An inspection of the Joy Fan catalog (Ref. 2.2.18, Fan Curve C-8232) shows that for a single Example A Fan operating at a pressure of about 6 inches of water gage, the blade tip angle can be changed to produce airflow in the range of about 150,000 cfm to about 590,000 cfm. This would allow combinations of one or two fans in parallel to produce the required range of airflow. Inspection of the curve for Example B Fan (Ref. 2.2.18, Fan Curve C-8240) shows that at the same fan pressure, the range of flow is from about 325,000 to over 1,000,000 cfm. The Example B Fan can meet the high end of the requirement but could not operate at the low end. In order to reach the lower end, the speed would also have to be adjusted. By reducing the speed from 730 rpm to about 300 rpm, the lower volume requirement could be met. However, the fan efficiency would drop to about 67%.

The rationale for choosing multiple fans operating in parallel as opposed to a single fan at each exhaust shaft is:

- Multiple fans minimize the effect of a fan outage on repository ventilation. During a fan outage, a high percentage of the normal air flow volume is still produced by the fan that is still operating.

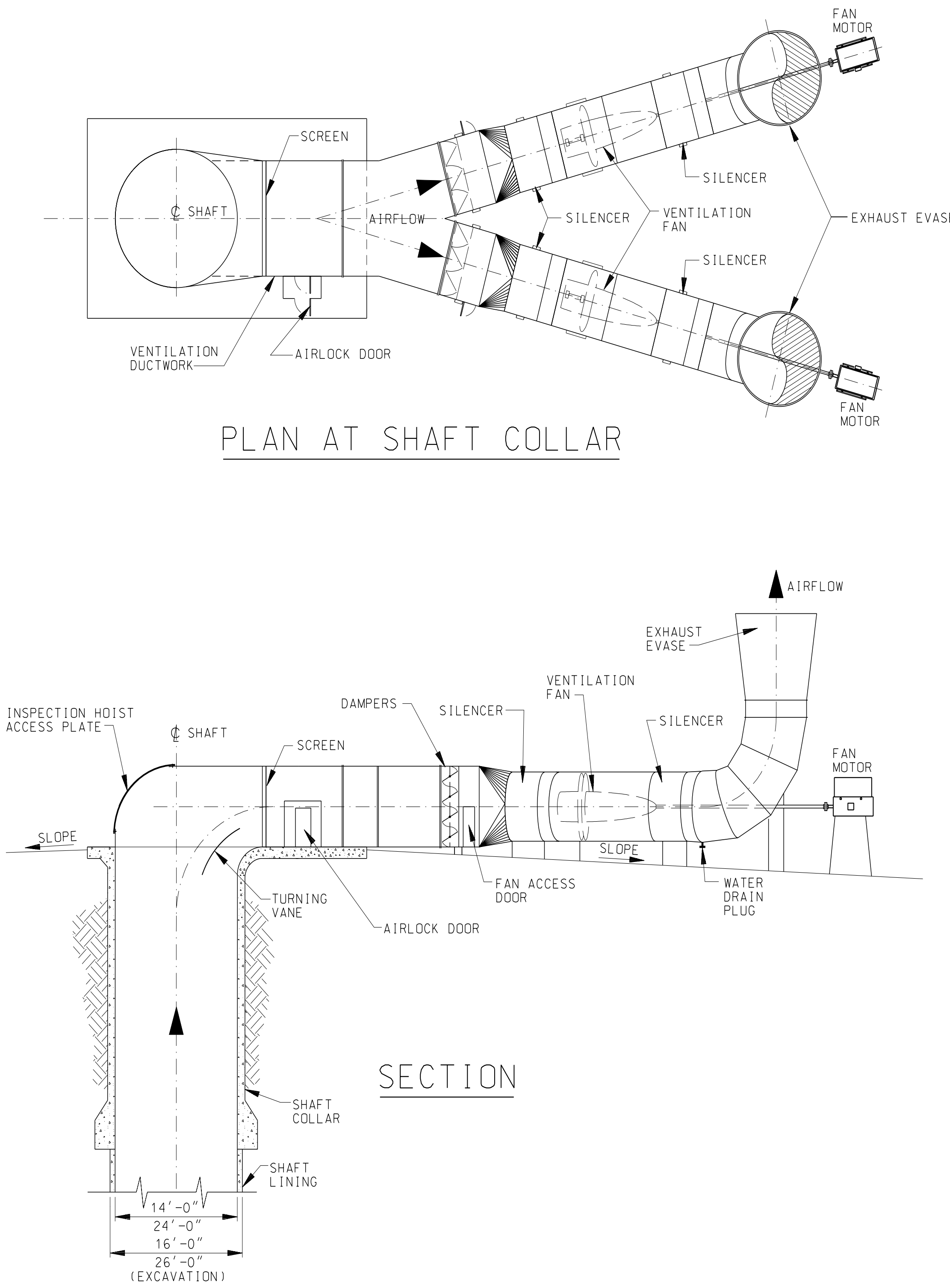
- Multiple fans are more flexible. Because the amount of airflow required increases as the amount of waste emplaced in the repository increases, multiple fans will meet minimum through maximum airflow requirements by varying the number of fans running and the blade pitch. Adjustment of both the pitch and the fan rotation speed would not be required.

- Multiple fans would be more efficient at the low end of the volume requirement than a single fan at each shaft.

7. RESULTS AND CONCLUSIONS

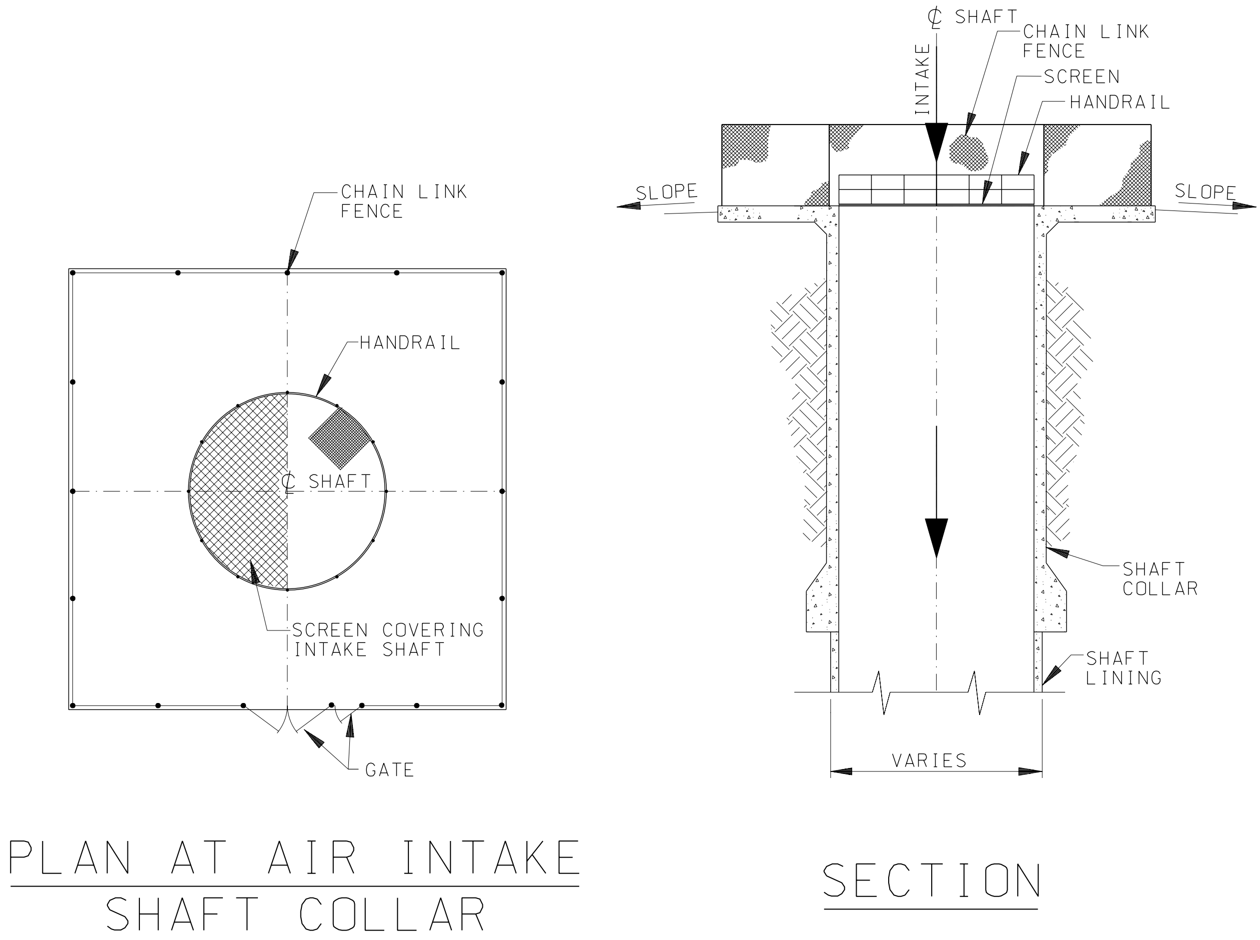
Figure 6 depicts the general arrangement of the exhaust shaft collar and exhaust fans incorporating findings of work done with the Colorado School of Mines and requirements presented in Section 6.1 of this analysis.

Figure 7 shows the recommended general arrangement layout for intake shafts. The layout is based upon discussion developed in Section 6.1.7.



Reference: 2.2.15, Figure 3-12 and Section 6.1

Figure 6 Recommended Exhaust Shaft Collar

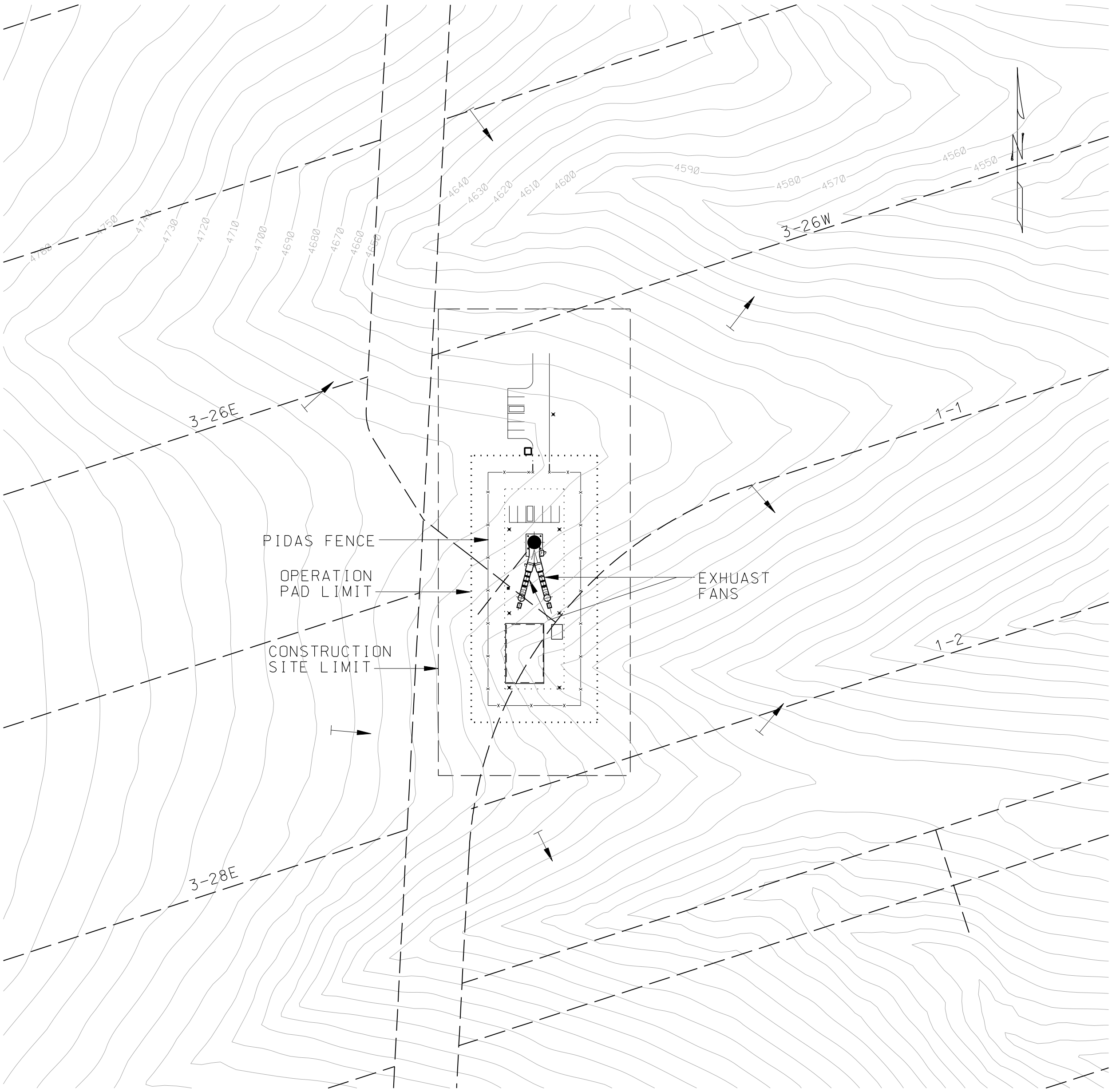


Reference: Derived from discussion in Section 6.15

Figure 7 Recommended Intake Shaft Collar Configuration

END

Attachment A Shaft Collar Locations



References: Topography (Ref. 2.2.20),Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

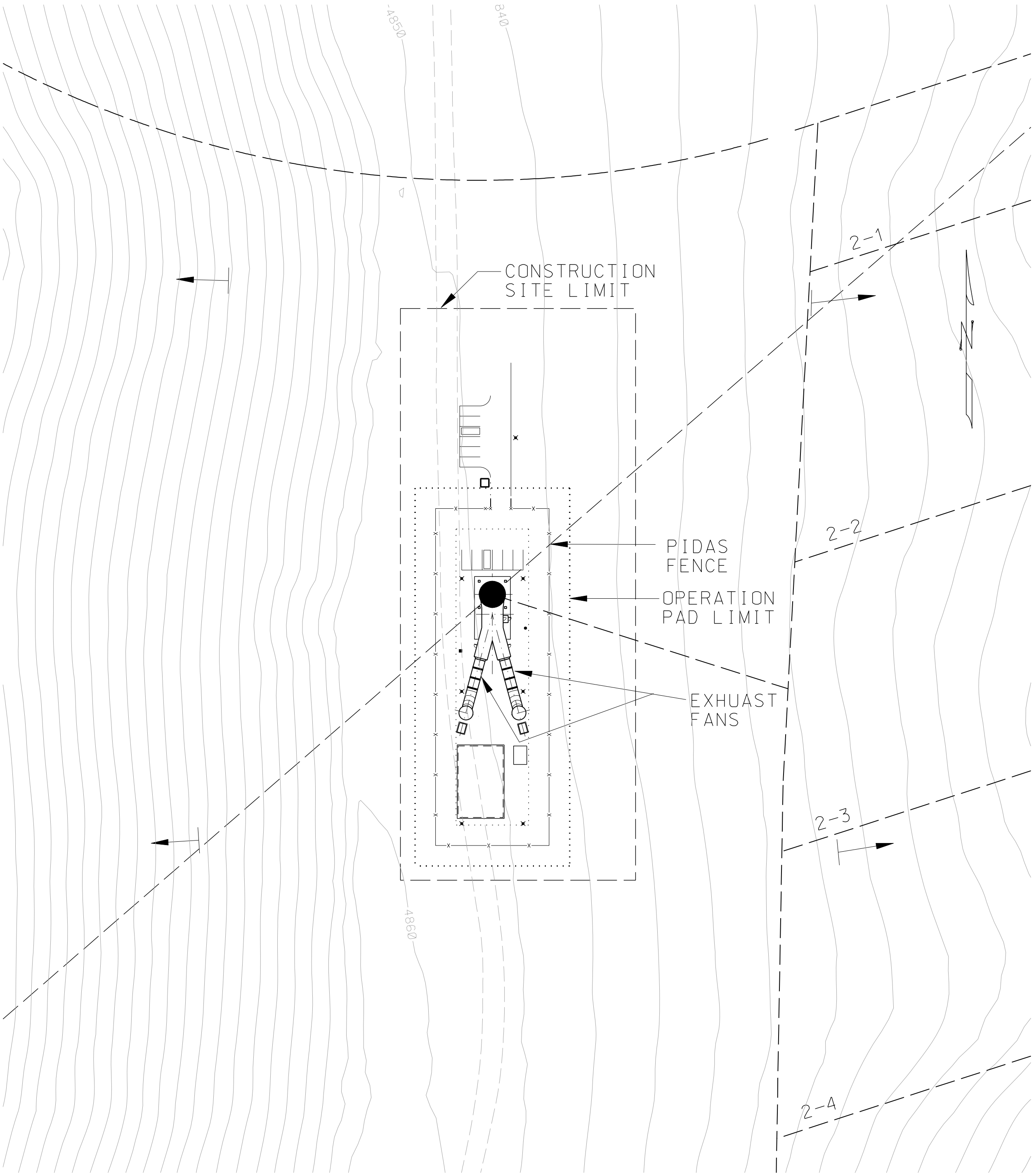
Note: Elevation contours are in feet above mean sea level.

Exhaust Shaft #1

References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

Exhaust Shaft #3 South



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

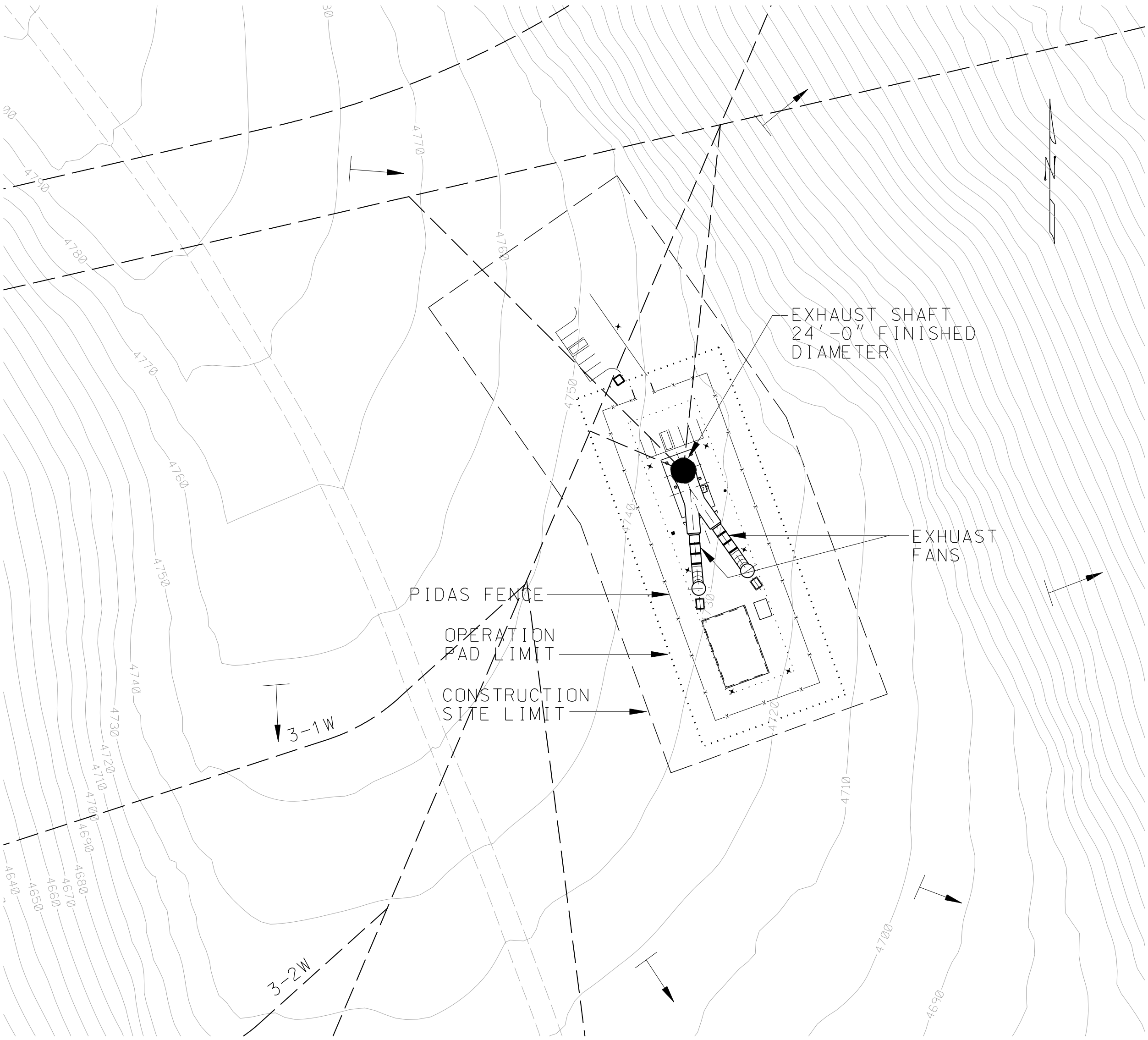
Note: Elevation contours are in feet above mean sea level.

ECRB Exhaust Shaft

References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

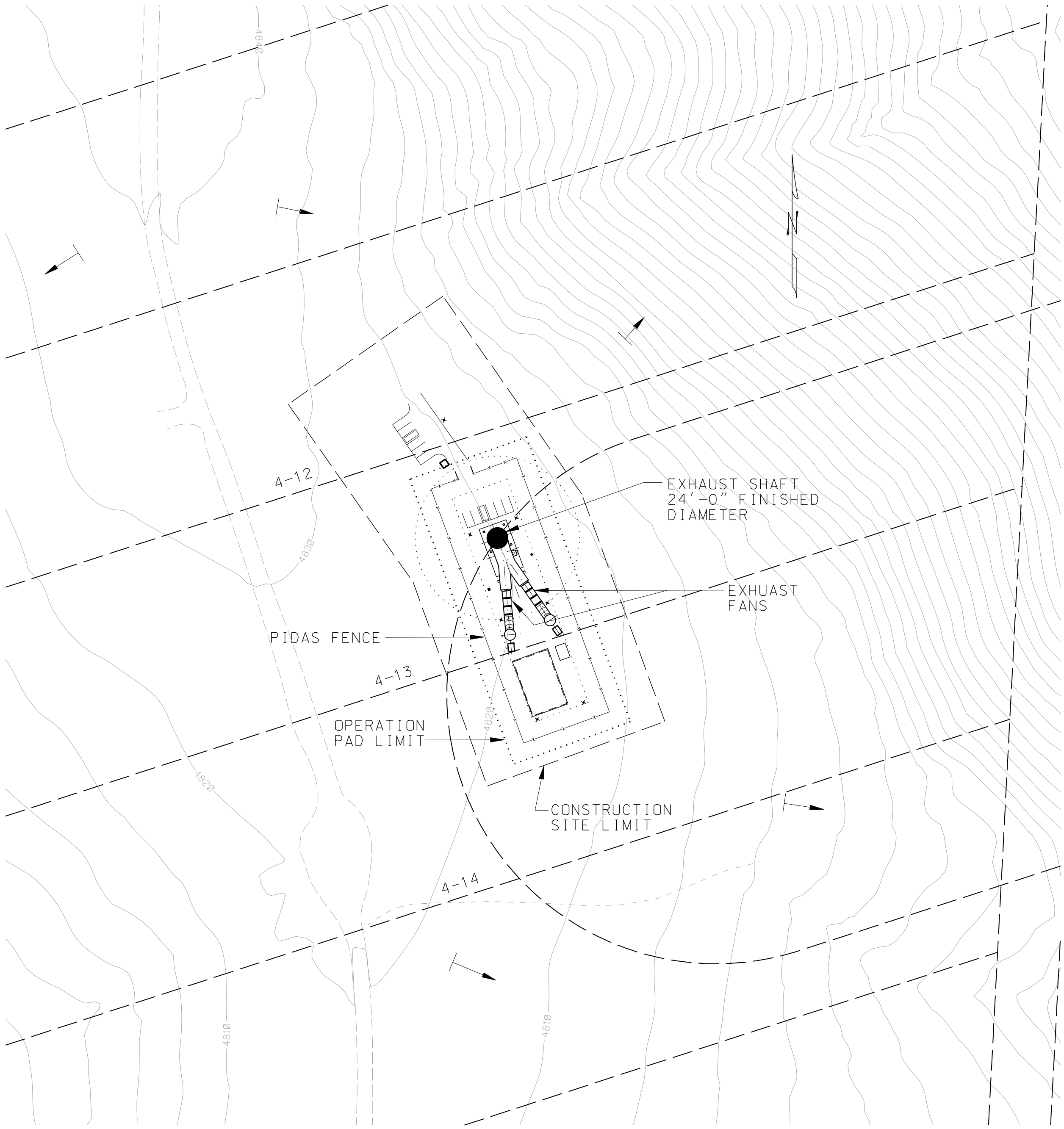
Exhaust Shaft #2 South



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

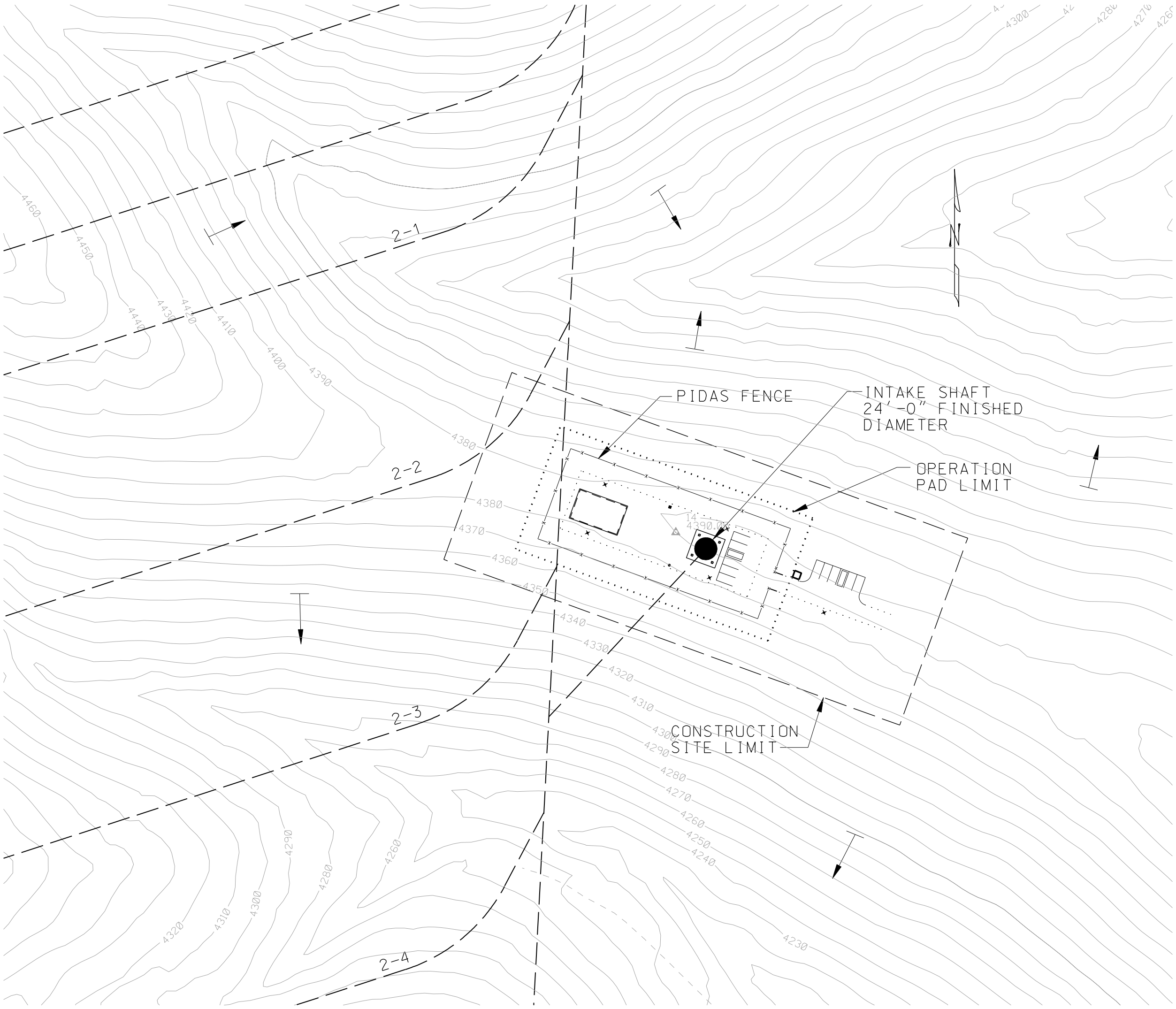
Exhaust Shaft #3 North



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

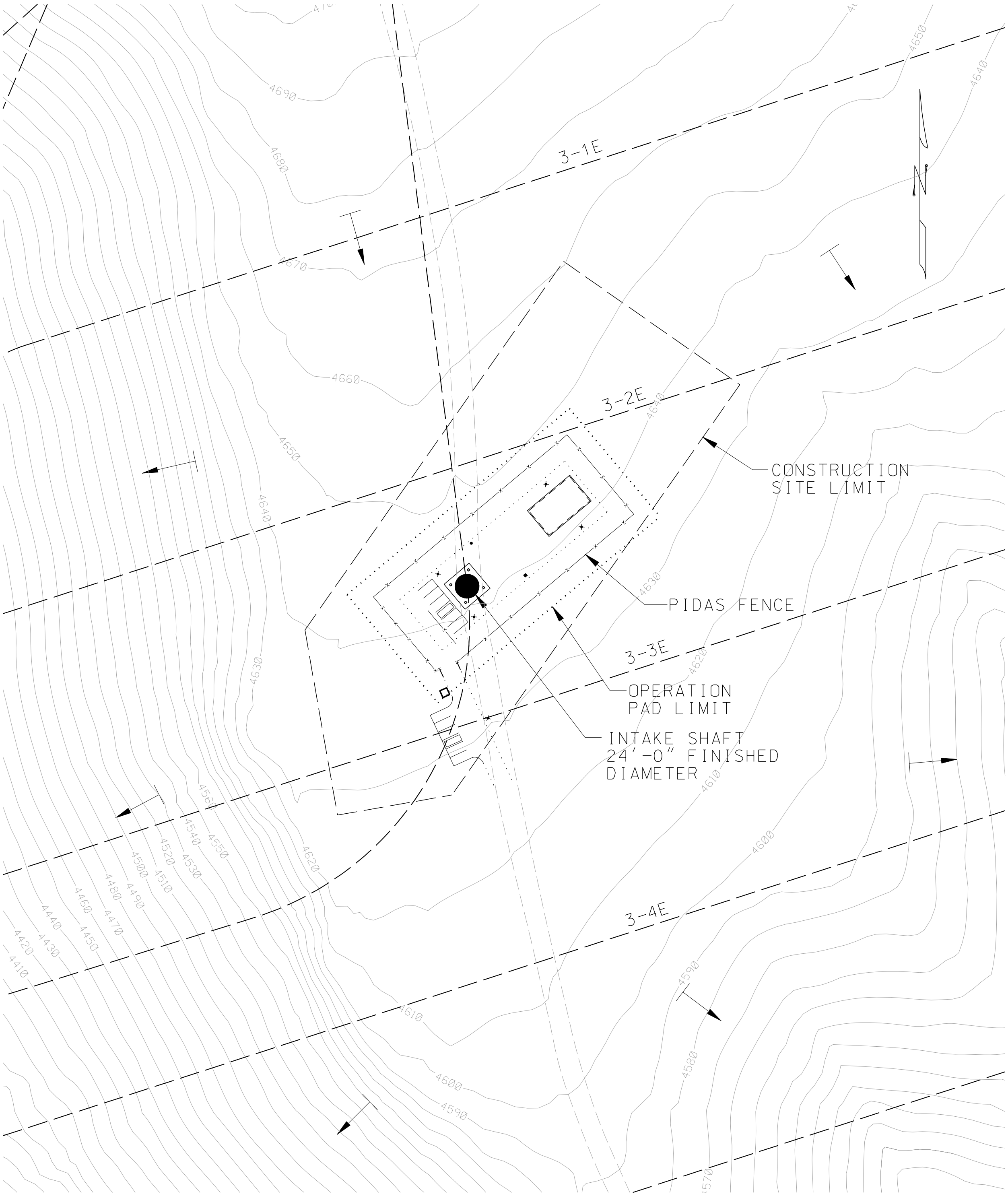
Exhaust Shaft #4



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

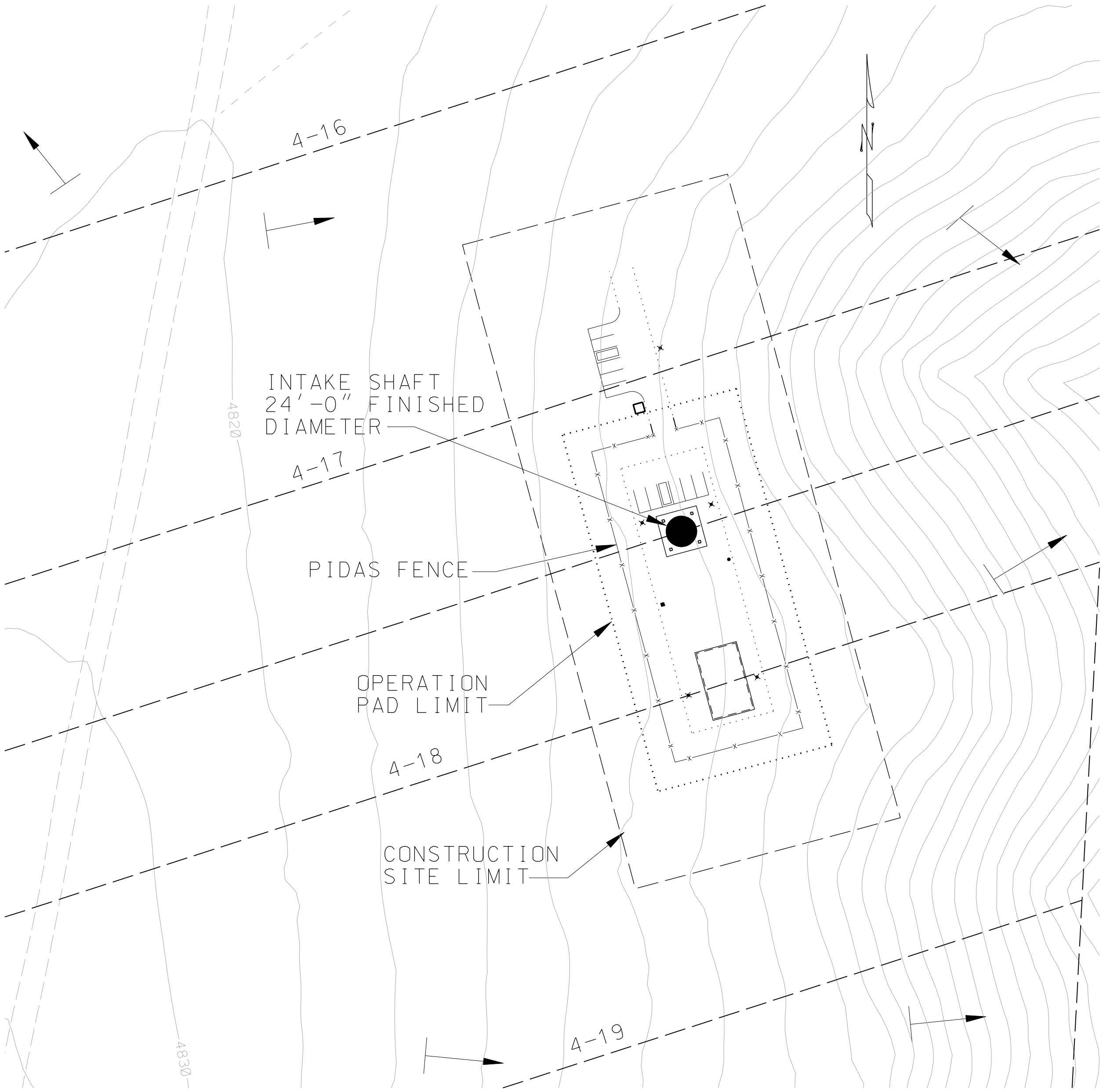
Intake Shaft #2



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

Intake Shaft #3



References: Topography (Ref. 2.2.20), Subsurface Layout (Ref. 2.2.10, Figure 10), Pad (See Sec. 6.3.2)

Note: Elevation contours are in feet above mean sea level.

Intake Shaft #4

BSC

Calculation/Analysis Change Notice

Complete only applicable items.

1. QA: N/A

3. Document Identifier:	4. Rev.:	5. CACN:
800-KVC-VU00-00400-000	00A	001

6. Title:
Shaft Collars and Fan Layout General Arrangement Analysis

7. Reason for Change:

1. As described in section 7 of the calculation, Figure 6 depicts the general arrangement of the exhaust shaft collar and exhaust fans. Contrary to the description, Figure 6 shows specific shaft dimensions and is not consistent with Figure 7 which depicts the intake shafts with no dimensions provided.

2. The title in the header on pages 3 through A-10 is incorrect.

These issues are identified in CR 11676 BR 1/22/08

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: ______ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes	☒ No	Results Impacted:	☐ Yes	☒ No
Assumptions Changed:	☐ Yes	☒ No	Design Impacted:	☐ Yes	☒ No

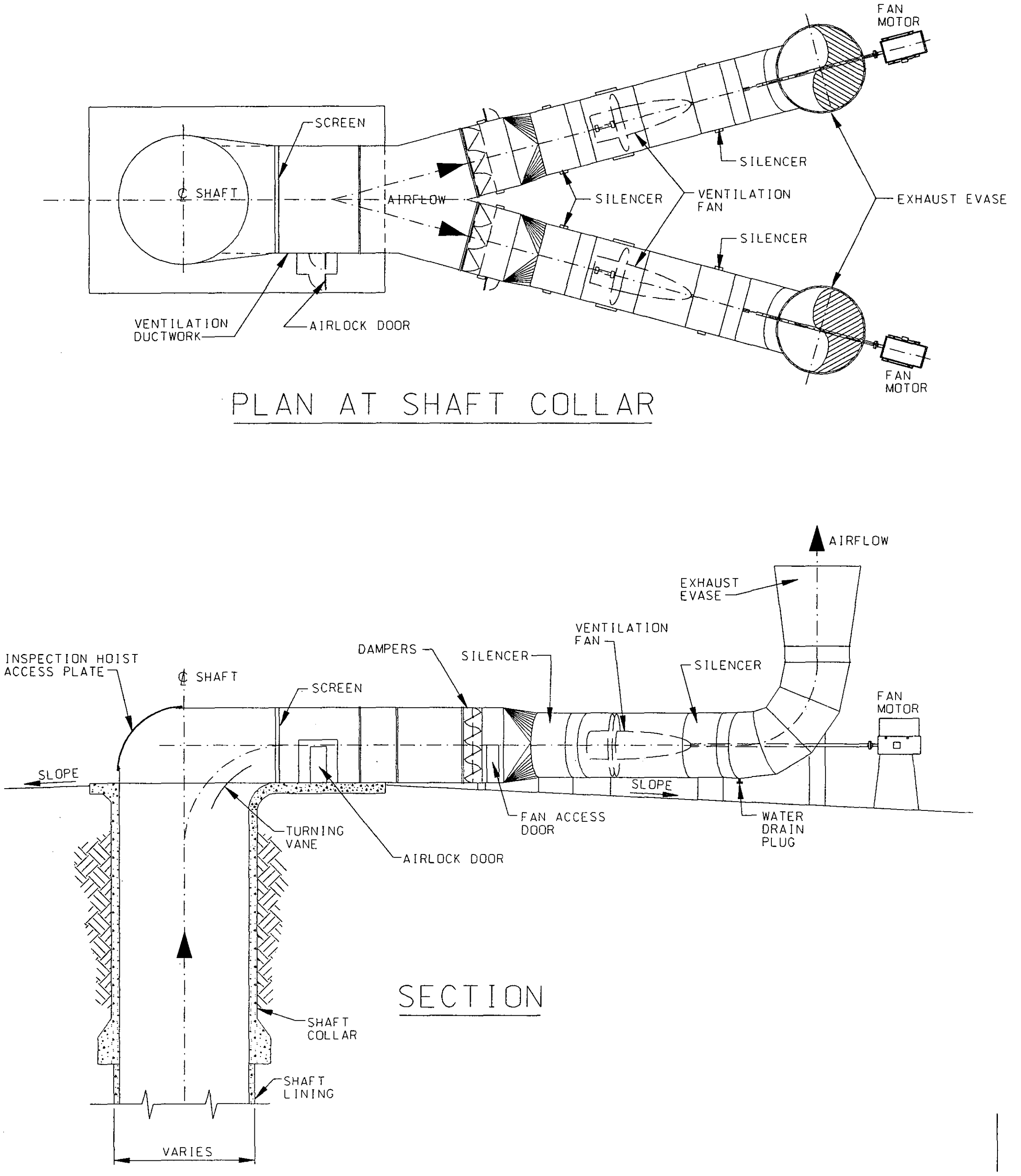
10. Description of Change:

1. Revise Figure 6 as follows: Remove the dimensions and replace with the word "VARIES".
2. Remove the word "Main" from the title in the header on pages 3 through A-10.

11. REVIEWS AND APPROVAL

Printed Name	Signature	Date
11a. Originator: Jeff Steinhoff	Jeff Steinhoff	1/21/2008
11b. Checker: Edward Thomas	Edward Thomas	1/21/08
11c. EGS: Hang Yang	[signature]	01-21-2008
11d. DEM: Robert Boutin	Robert Boutin	01/21/08
11e. Design Authority: B. Rusinko	BRusinko	1/22/08

Pg 2 of 2



Reference: 2.2.15, Figure 3-12 and Section 6.1

Figure 6 Recommended Exhaust Shaft Collar