

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET**

1. QA: N/A

Page: 1 Of 13

2. Calculation Title
ECRB Refuge Chamber

MOL: 20020212.0259

3. Document Identifier (including Revision Number)
BABEAF000-01717-0210-00011 REV00

4. Total Attachments
None

5. Attachment Numbers - Number of pages in each
N/A

	Print Name	Signature	Date
6. Originator	Jerald W. Keifer	<i>Jerald W. Keifer</i>	12/03/01
7. Checker	Jeff Steinhoff	<i>Jeff Steinhoff</i>	12/03/01
8. Lead	Jerald W. Keifer	<i>Jerald W. Keifer</i>	12/03/01

9. Remarks

This calculation compiles requirements from requirement documents and provides calculations for refuge stations in the ECRB.

Revision History

10. Revision No.	11. Description of Revision
00	Initial Issue.

ECRB Refuge Chamber

1.0 Purpose

The purpose of this calculation is to identify the initial design requirements for refuge stations, including the client requirements, standards, codes, laws, and regulations, general discipline design criteria, and design basis events and hazards. The scope of this document is for the specific task of designing and constructing refuge stations in the Enhanced Characterization Repository Block (ECRB) subsurface openings as necessary personnel safety enhancements to the current construction, maintenance and testing operations.

This document is for the construction at the Exploratory Site Facility (ESF). The criteria is not intended to be incorporated into the proposed repository design and does not support Site Recommendation or License Application efforts. This calculation is prepared in accordance with AP-3.12Q as a field support calculation and was prepared using the *Technical Work Plan for Test Facilities Design FY01 Work Activities (TWP)* (CRWMS M&O 2000b).

2.0 Method

The ECRB Cross Drift is designated as a Test Support Area in the *QA Classification Analysis of Main Access Openings* (CRWMS M&O 1997 Section 7.2). Test Support Area systems, structures or components have been determined not to be Quality Affecting (QA) by the *QA Classification Analysis of Test Support Areas* (CRWMS M&O 1995, Section 8).

The *Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift* (CRWMS M&O 2000a, Section 13.3) provides a list of QA controls on construction activities in the Cross Drift. Review of the listed activities has determined that none of these QA controls is directly applicable to the design of refuges in the ECRB. These QA Controls will affect construction activities in the ECRB cross drift, which have been incorporated into the *Cross Drift Subsurface General Construction, Specification Section 01502* (BSC 2001b). Therefore, the specific subject of this calculation is not Quality Affecting. Unqualified inputs are used throughout.

A system safety analysis will be required to establish the Functional Class Levels (FCL) to ensure that the system, structures and components used in the refuge chamber meet the requirements of the *Integrated Safety Management Quality Assurance Program* (DOE 2001). The FCL designations from the analysis will be design inputs for implementing design documents.

The calculation consists of: identification of client requirements, standards, codes, laws, and regulations, general discipline design criteria, and design basis events and hazards; mathematical calculations to determine parameters based upon inputs; determination of design limitations; identification of interfaces; and criteria for selection of material and equipment. This calculation does not affect any management and control of electronic data.

3.0 Assumptions

- 3.1 It is assumed that procuring medium size respirators for the maximum design number of personnel in the station and procuring large and small sizes at 1/3 of the maximum design number of personnel for both large and small size orders will supply all the required sizes in event of an emergency. The assumption is based upon the order for medium size respirator masks which, comprise 70% of total orders (Determination, Decision, or Directive Documentation. DF: 02-0013, BSC 2001c, Section 7). Projecting size quantity needs as a normal distribution these quantities are more than double the number projected for large and small statistical requirements. The medium size quantity will meet the maximum possible demand. No confirmation required. (Used in section 5.2.6.3)
- 3.2 It is assumed for the 21 MW fire case that a 9-hour cooling period is the minimum time period to allow emergency travel in the cross drift. It is assumed for the 8 MW and alternative fire cases that a 2-hour cooling period is the minimum time period to allow emergency travel in the cross drift. The basis of the assumptions are the fire load calculations results from the *Calculation of ECRB Cross-Drift Worst-Case Fire and Effects* (BSC 2001a, Section 6). It is expected that the heated gases will be adequately spread, by natural ventilation, along the tunnel surface and that the rock will be a sufficient heat sink to provide cooling within the assumed times. No confirmation required. (Used in Section 5.2.6.4)
- 3.3 It is assumed that the personnel in the refuge Station at Alcove #8 while wearing supply-air respirators will spend 85% of the time sitting or laying down, 10% standing and 5 % walking. Personnel will be sitting to conserve air most of the time. The walking time is for trips to toilet and for cramp relief. Standing for stretching and position changes. The basis for this assumption is that personnel will be trained to conserve air demand. This assumption is for air demand rates. No confirmation required. (Used in Section 5.2.6.4)

4.0 Use of Computer Software and models

Microsoft Word, a word processing program, is the only software used. It is exempt from validation and control requirements in accordance with AP-SI.1Q.

5.0 Calculation

5.1 System Design Criteria

5.1.1 Exploratory Site Facilities Design Requirements - System Safety Requirements

ECRB Refuge Chamber

"All workplaces shall be designed to be free from recognized hazards that are likely to cause death or serious physical harm to employees. 'Free from recognized hazards' means that the identified hazards are eliminated or mitigated to the point that they no longer pose a serious threat." (YMP 1997, 3.2.1.1.2.4.A)

"The first priority shall be to eliminate hazards by design. If an identified hazard cannot be eliminated, the associated risk shall be reduced to an acceptable level through design selection." (YMP 1997, 3.2.1.1.2.4.B.1)

"30 CFR 57 shall apply only to subsurface facilities and equipment and to those mining-related surface facilities and equipment specifically addressed therein." (YMP 1997, 3.2.1.1.2.4.H)

"29 CFR 1910 and 29 CFR 1926 shall apply to all other surface facilities and equipment. 29 CFR 1910 and 29 CFR 1926 shall also apply to subsurface facilities and equipment not addressed by 30 CFR 57." (YMP 1997, 3.2.1.1.2.4.I)

"A minimum of two accesses shall be incorporated into the underground ESF to ensure adequate alternative routes of egress. A method of refuge shall be provided while a second opening to the surface is being developed." (YMP 1997, 3.7.2.3.1.A)

"A refuge chamber shall be provided with sufficient capacity and facilities to accommodate personnel and visitors underground in accordance with the applicable MSHA requirements." (YMP 1997, 3.7.2.4.1.H)

5.1.2 DOE Technical Direction

"TECHNICAL DIRECTION - EXPLORATORY STUDY FACILITY SITE CHARACTERIZATION DESIGN AND INSTALLATION BASE CODE COMPLIANCE. (Dyer 1998)

The Civilian Radioactive Waste Management System Management and Operating Contractors shall insure that all site characterization and test support utilities in the Exploratory Study Facility meet the minimum requirements established in the U.S. Department of Labor 29 CFR Part 1926, Occupational Safety and Health Standards for the Construction Industry. Based upon programmatic or institutional needs, this direction does not preclude the design and installation of support systems that provide a higher degree of protection for the worker or equipment."

5.1.3 Safety and Health Standards--Underground Metal and Nonmetal Mines

All cited MSHA standards in this document are "Best Practice Standards".

5.1.3.1 Escapeways and refuges

"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. A method of refuge shall be provided while a second opening to the surface is being developed. A second escapeway is recommended, but not required, during the exploration or development of an ore body." (30 CFR 57.11050(a))

"In addition to separate escapeways, a method of refuge shall be provided for every employee who cannot reach the surface from his working place through at least two separate escapeways within a time limit of one hour when using the normal exit method. These refuges must be positioned so that the employee can reach one of them within 30 minutes from the time he leaves his workplace." (30 CFR 57.11050(b))

5.1.4 Application of Requirements

A hazard of entrapping personnel does exist in the ECRB if a disruptive event, such as a fire, prevents egress to the main TS loop. This hazard must be addressed to the point that it is eliminated; or, mitigated to the point that it no longer poses a serious threat. (YMP 1997 3.2.1.1.2.4.A) In the mining industry, this hazard is addressed by the Mine Safety and Health Administration (MSHA) regulations (30 CFR 57.11050) which direct the use of multiple escapeways and refuge chambers to mitigate the hazard.

Based upon the Department of Energy technical direction letter (Dyer 1998), which established Occupation Safety and Health Administration (OSHA) Regulations contained in 29 CFR 1926 as the "Base Code" for ESF design, the ESF design is not mandated to follow the MSHA regulations contained in 30 CFR 57. This supercedes the ESFDR requirements which invoke 30 CFR 57. The OSHA "Underground Construction" Section, 29 CFR 1926.800, does not address safe refuge areas or secondary egress. MSHA regulations represent "Best Practices" and their adoption does achieve "a higher degree of protection for the worker" as allowed in the technical direction letter. By using 30 CFR 57.11050 and 30 CFR 57.11052 as a best practices standards, quantitative and qualitative criteria are provided to assess the hazard and the mitigation.

ECRB Refuge Chamber

30 CFR 57.11050 (b) requires that personnel be able to exit the underground by two separate escapeways within one hour or have a method of refuge within 30 minutes from the time the person leaves their work place.

5.2 Physical Design Criteria

5.2.1 Fire Resistance

"Any structure located underground or within 100 feet (30.48 m) of an opening to the underground shall be constructed of material having a fire-resistance rating of at least one hour." (29 CFR 1926.800(m)(12))

5.2.2 Atmosphere Requirements

"The atmosphere in all underground work areas shall be tested as often as necessary to assure that the atmosphere at normal atmospheric pressure contains at least 19.5 percent oxygen and no more than 22 percent oxygen." (29 CFR 1926.800(J)(1)(ii)(A))

Carbon Dioxide (CO₂) Threshold Limit Value (TLV) weighted level average is 5000 ppm; TLV Short Term Elevated Level (STEL) is 30000 ppm. Carbon Monoxide (CO) Threshold Limit Value (TLV) weighted level average is 50 ppm. (29 CFR 1926.55)

5.2.3 Refuge areas

"Refuge areas shall be --
(a) Of fire-resistant construction, preferably in untimbered areas of the mine;
(b) Large enough to accommodate readily the normal number of persons in the particular area of the mine;
(c) Constructed so they can be made gastight; and
(d) Provided with compressed air lines, waterlines, suitable handtools, and stopping materials." (30 CFR 57.11052)

5.2.4 Communication with Refuge Chambers

"Telephone or other voice communication shall be provided between the surface and refuge chambers and such systems shall be independent of the mine power supply." (30 CFR 57.11054)

5.2.5 Subsurface Conditions - ESFDR

"The permanent and temporary items of the ESF shall be designed to withstand the applicable seismic environment specified in Appendix A." (YMP 1997, 3.2.1.2.1.2.A)

ECRB Refuge Chamber

"For the seismic design of temporary ESF subsurface Facilities, the peak ground acceleration shall be 0.3 g at the earth's surface. This acceleration is consistent with Zone 3 of the Uniform Building Code." (YMP 1997, Appendix A-A.2)

"The ESF subsurface facilities and equipment shall be designed to withstand and operate in a dusty environment." (YMP 1997, 3.2.1.2.1.2.B)

"The ESF subsurface facilities and equipment shall be designed to operate in temperatures ranging from a low of 50 degrees F to a high of 70 degrees F." (YMP 1997, 3.2.1.2.1.2.C) Note: This requirement is not applicable to the one-hour fire rated bulkheads.

"The ESF subsurface facilities and equipment shall be designed to withstand and operate in a relative humidity environment of 13 to 71%." (YMP 1997, 3.2.1.2.1.2.D)

"The BSF non-permanent items shall be designed for a 25 year maintainable service life." (YMP 1997, 3.2.1.2.2.A)

5.2.6 Features, Events And Processes That Affect Design.

5.2.6.1 Design Basis Fire (Events).

The design basis fire events for the ECRB has determined the duration of the postulated fires to be 9 hours for each of the 8 MW, the 21 MW and the alternative fire events." (BSC 2001a, section 6.1.5.1, 6.2.5.1 and 6.2.5.1).

5.2.6.2 Detailed Design Criteria

Building codes and national consensus standards applicable to features, events and processes that affect the design of refuge chambers do not exist. The best available information which specifically addresses underground refuge chamber design issues, design options, hazard mitigation, and accepted practices is a U. S. Department of Interior Bureau of Mines report entitled *Development of Guidelines for Rescue Chambers* (McCoy 1983). The design shall follow the recommendations and address the issues presented in the report to ensure a functional design.

5.2.6.3 Site Specific Features

Compressed air lines, water lines and mine phones exist behind the bulkhead at ECRB 17 + 63 (BSC 2001c, Section 7). Compressed air lines, water lines and mine phones exist behind the bulkhead at ECRB

ECRB Refuge Chamber

Alcove #8 (BSC 2001c, Section 7). The compressed airline in the ECRB cross drift will be exposed to damage from the design basis fire. Although the compressed air line is steel pipe, it uses the Vicraulic coupling system which has rubber gaskets (BSC 2001c, Section 7). The rubber gaskets could be compromised by the heat of the fire. This would cause leaks that would decrease the amount of air delivered to the refuge chamber. This prevents reliance on air supplied from the compressed air line as the primary emergency system.

If compressed air is unavailable, there is no impact in the area behind Sta. 17 + 63 because a large volume of air is available. There is 918 meters of 5m diameter tunnel between the bulkhead at Sta. 17+63 and the end of the tunnel at Sta. 26 + 81 (GS990408314224.006). A second bulkhead exists at Sta. 25 + 03 which could serve as an additional barrier, in the event that elevated levels of toxic gas diffuses behind Sta. 17+63 (CRWMS M&O 1998).

If compressed air is unavailable, there is an impact in the area behind the bulkhead in Alcove #8. The volume of air contained in the area is not large enough to sustain the number of people for the time required. This impact can be mitigated. Supply-air respirators using demand regulators attached to compressed air bottles must be worn by personnel in the refuge chambers, if air delivered by the compressed air line fails. The respirators would protect personnel from respired CO₂ build up and any diffusion of CO through the bulkhead into the Alcove.

The maximum allowed number of miners, visitors and support personnel in the ECRB is 30 (BSC 2001c, section 7). Administrative control can be placed on number of personnel when Maintenance Rail Car (MRC) is in the ECRB, which is the maximum fuel load condition. Minimum number of personnel in the ECRB to support activities with the Maintenance Rail Car is 5 (BSC 2001c, section 7).

To ensure proper respirator mask fit for personnel in the alcove, multiple mask sizes must be provided or one size that fits all personnel. The number of medium masks should be equal to the designated personnel capacity of the refuge chamber. The number of small masks should be equal to one-third of the designated capacity and the number of large masks should be equal to one-third of the designated capacity. (Assumption 3.1)

The bulkhead at 17+63 will be sealed for test purposes. The sealing tape is expected to retard the opening of the double wide doors at the bulkhead. A two foot by two foot pressure relief door is located on the bulkhead shown in submitted as-built drawings, *Transmittal Of Shop Drawings, Equipment Data, Material Samples, Or Manufacturer's Certificates Of Compliance (SDT) For Exploratory Study Facility*,

Area 25 With Submittal Evaluation Record For ECRB Bulkhead As-Built As Sta. 17+63 And Sta. 25+03 With Drawings (C). 01-C027-1 (CRWMS M&O 1999, p. 3). A two foot by two foot opening meets the MSHA Clearance regulations for ladder ways in 30 CFR 57.11037, and is considered adequate for emergency passage. The height of the pressure relief door will required a platform to be installed for easy access. The pressure relief door is held by magnets, and sealing tape. Pushing with the leg, when standing on a platform will readily open the door to provide access behind the bulkhead.

Since, the bulkhead will be sealed, the air behind the bulkhead should be monitored to ensure that the ambient atmosphere is adequate to support life. The monitoring should ensure that the oxygen levels are within the OSHA standards. The monitoring should also ensure that Carbon Dioxide and Carbon Monoxide levels are below the Threshold Limit Values adopted by OSHA. (See Section 5.2.2)

5.2.6.4 Minimum air supply

The minimum air supply design criteria from compressed air bottles, using supplied-air respirators with demand regulators, in Alcove #8 refuge chamber shall be: 18 hours, given the 21 MW fire of 9 hours (see section 5.2.6.1), assuming a 9-hour cooling and contingency period (Assumption 3.2); and 11 hours, given the 8 MW and alternative fire of 9 hours (See section 5.2.6.1), assuming a 2 - hour cooling period (Assumption 3.2).

Breathing volumes for the average male: sitting is 9 Liters per minute, standing is 12 Liters per minute and walking 2.5 mph is 24 L per minute (Homes 1994). Assuming personnel will primarily be sitting or lying with limited standing and walking, (85% sitting, 10% standing and 5% walking- Assumption 3.3), the design criteria average breathing volume is 10 L per minute. The parameter is applicable only to supplied-air respirators.

The recommended air volume requirements for ambient air breathing in a refuge chamber is 2680 scf/person/per day. (McCoy 1983)

5.2.6.5 Limitation on Number of Personnel

Based upon the 30 bottle space limitation (see section 5.2.6.3) the Average compressed bottle life using 243 Cu. Ft. bottle (McCoy 1983, Appendix D) and 10 L per minute (see section 5.2.6.4) is 11.5 hours.

ECRB Refuge Chamber

Based upon an 11 hour duration (see section 5.2.6.4) the alcove #8 can accommodate 30 people using one bottle per person (see section 5.2.6.3).

Based upon an 18 hour duration (see section 5.2.6.4) the alcove #8 can accommodate 15 persons using two bottles per person which is sufficient to handle the minimum personnel requirements for the MRC (see section 5.2.6.3).

Station behind bulkhead at 17 + 63 the volume of air is:
918m tunnel length & 5m diameter (see section 5.2.6.3)

$$V = L (\pi r^2) = 918m(\pi (5m/2)^2) = 18025 \text{ m}^3$$

$$V = 637,000 \text{ cf. rounding to 3 significant figures}$$

Using 2680 (see section 5.2.6.4) cf./person/day the area behind 17 + 63 is sufficient for 238 person days. At 30 persons (see section 5.2.6.3), the available air will support 30 people for 7.9 days.

6.0 Results

6.1 Identified Requirements

Client requirements, standards, codes, laws, and regulations, general discipline design criteria, site specific criteria, design basis events and hazards criteria in section 5 shall be addressed by the design.

6.2 Design Interfaces

6.2.1 The refuge area will require location in the ECRB alcoves and cross drift opening which are Test areas. Coordination is required with the TCO in accordance with the TWP (CRWMS M&O 2000b).

6.2.2 Administrative controls by Site Construction must be placed on the number of personnel in the ECRB, for regular work and when the RMC is in the ECRB to ensure meeting the bounds of the requirements. (See section 5.2.6.5)

6.2.3 Periodic Air monitoring behind bulkhead 17+63 is necessary to ensure area is a viable refuge station. (See Section 5.2.6.3)

6.3 Features Required to be Designed and Installed

6.3.1 Bulkheads at 17+63 and Alcove #8 must be upgraded to one-hour fire rating. (See Section 5.2.1)

ECRB Refuge Chamber

6.3.2 Platforms are required at pressure relief door to facilitate emergency access.
(See Section 5.2.6.3)

6.3.3 Gas detection equipment for the monitoring of the atmosphere behind bulkhead at 17+63 for O₂, CO₂ and CO is required. A penetration through the bulkhead is required to accomplish the monitoring. (See Section 5.2.6.3)

7.0 References

7.1 Cited Input Documents

29 CFR 1926. Labor: Safety and Health Regulations for Construction. Readily available.

30 CFR 57. Mineral Resources: Safety and Health Standards. Underground Metal and Non-Metal Mines. Readily available.

BSC (Bechtel SAIC Company) 2001a. *Calculation of ECRB Cross-Drift Worst-Case Fire and Effects*. BAB000000-01717-0210-00001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company.

BSC (Bechtel SAIC Company) 2001b. *Cross Drift Subsurface General Construction, Specification Section 01502*. BABEAF000-01717-6300-01502 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011018.0007.

BSC (Bechtel SAIC Company) 2001c. *Determination, Decision, or Directive Documentation*. DF: 02-0013. Las Vegas, Nevada: Bechtel SAIC Company.

CRWMS M&O 1995. *QA Classification Analysis of Test Support Areas*. BABEAF000-01717-2200-00001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960212.0219.

CRWMS M&O 1997. *QA Classification Analysis of Main Access Openings*. BABEAD000-01717-2200-00002 REV 04. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980210.0154.

CRWMS M&O 1998. *EXPLORATORY STUDIES FACILITY, CROSS-DRIFT COMMUNICATION PLAN (C)*. BABFAB000-01717-2100-44145-00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980409.0689.

CRWMS M&O 1999. *Transmittal Of Shop Drawings, Equipment Data, Material Samples, Or Manufacturer's Certificates Of Compliance (SDT) For Exploratory Study Facility, Area 25 With Submittal Evaluation Record For ECRB Bulkhead As-Builts As Sta. 17+63 And Sta. 25+03 With Drawings (C)*. 01-C027-1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990727.0233.

CRWMS M&O 2000a. *Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift*. BABEAF000-01717-2200-00011 REV 04 ICN 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000609.0264.

CRWMS M&O 2000b. *Technical Work Plan for Test Facilities Design FY01 Work Activities*. TWP-MGR-MD-000012 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001108.0004.

DOE (U.S. Department of Energy) 2001. *Integrated Safety Management Quality Assurance Program*. Addendum 1, DOE/RW-0333P, Rev. 1. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010530.0147.

Dyer, J.R. 1998. "Technical Direction - Exploratory Study Facility Site Characterization Design and Installation Base Code Compliance." Letter from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), April 2, 1998. ACC: MOL.19980902.0316.

GS990408314224.006. Full-Periphery Geologic Maps for Station 20+00 to 26+81, ECRB Cross Drift. Submittal date: 09/09/1999.

Homes, J. R. 1994. "How Much Air Do We Breathe?." Sacramento, California: California Environmental Protection Agency. Accessed 11/21/2001. <http://www.arb.ca.gov/research/resnotes/notes/94-11.htm>

McCoy, J.F.; Berry, R.B.; and Mitchell, D.W. 1983. *Development of Guidelines for Rescue Chambers*. JO387210. 2. Washington, D.C.: Bureau of Mines, United States Department of the Interior. TIC: 251285. Copyright Requested

YMP (Yucca Mountain Site Characterization Project) 1997. *Exploratory Studies Facility Design Requirements*. YMP/CM-0019, Rev. 2, ICN 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980219.0893; MOL.19960724.0138.

7.2 Procedures Cited

AP-3.12Q, Rev. 0, ICN 4. *Calculations*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010404.0008.

AP-SI.1Q, Rev. 3, ICN 2, ECN 1. *Software Management*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011030.0598.

ECRB Refuge Chamber

8. Attachments

Not Used.