

Cost Analysis of Bulkhead Refuge Chambers Using Data Provided by Foster-Miller.

Introduction

This cost analysis evaluates the industry cost of the bulkhead type of refuge chambers which are constructed underground within the coal mine. The cost estimates are provided by Foster-Miller, Inc. and are shown in Appendix A and Appendix B. All the assumptions made for generating these costs can be found in the report by Foster-Miller; Cost Estimates/Comparisons for Refuge Types.

The general assumptions that were reported in the “Cost Analysis of Portable Refuge Chambers,” are also applied to the bulkhead chambers. Differences in cost estimates occur with the purchase and installation, maintenance and inspection, and move costs. These differences are outlined as follows.

Purchase and Installation

The bulkhead refuge chambers require construction underground which makes their cost different from the portable refuge chambers. Appendix A shows the cost estimates for the initial construction and the cost estimates for redeploying the different types of bulkhead chambers when the chamber is moved every 1,000 feet. The costs for the Energy-Absorbing Chute System (Table 4) were used with the concrete wall costs (Table 6) as the chute system was the higher cost system.

For the bulkhead refuge chambers, there are no purchase costs. In the construction estimates, Foster-Miller includes material purchase cost with the labor cost for installation, and these were used for the installation costs. It is assumed that safety training will be required and follows the schedule reported in “Cost Analysis of Portable Refuge Chambers.” However, no costs of a manufacturer’s representative to supply training are incurred. Appendix B Table 7 sections 1 and 2, show additional costs for installation of the chamber that were used in this analysis.

It should be noted that the cost estimates by Foster-Miller use differing hourly rates for labor than the previous report. However, the rates do not differ by a significant amount. Therefore, the labor costs provided Foster-Miller were used in the installation and the labor costs in the previous report were used in the safety training costs.

Maintenance and Inspection

Maintenance and inspection costs will differ from the portable refuge chamber costs in that there will not be any manufacturer costs for maintenance and inspection. The Foster-Miller cost estimates for redeployment of bulkhead chambers incorporates a cost for inspection and certification after every move. Therefore, only daily mine foreman inspection costs are applicable which were considered incidental in the “Cost Analysis of Portable Refuge Chambers.” The cost of supplies remained the same as the original report, with most having a five year life.

Move

Move costs utilized the same schedule of moves reported in “Cost Analysis of Portable Refuge Chambers,” [60 moves/year]. Only the costs provided by Foster-Miller for redeployment

(Tables 4 and 6) were used. Additional costs shown in Appendix B Table 7 section 3 were also used. No costs of boreholes were included in this analysis.

Results

Using a 9.5% discount rate over a 10 year life, Table 1 shows the present worth costs of the bulkhead refuge chamber system. Table 2 shows the worksheet used to calculate these costs.

Table 1. Present worth cost of a bulkhead refuge chamber over its 10 year life.

	Present Worth Cost	Percent of Total Cost
Purchase cost		
Installation	\$85,500	1.2%
Training	\$64,500	0.9%
Maintenance & Inspection cost	\$12,000	0.2%
Moving costs	\$6,903,000	97.7%
Total	\$7,065,000	

This cost table shows that the move costs are significantly higher due to having to reconstruct the chamber for every move. Using a The Panelized Blast Reduction Media System (costs are shown in Table 5) reduces the total present worth cost to \$6,456,000 resulting in a reduction in cost of approximately 8.5%. Most of the cost savings with the Panelized Blast Reduction Media System is associated with the moving costs as the cost of redeployment of this system is lower [\$3,150 for panel vs. \$4,740 for chute].

A sensitivity analysis of the moving costs was completed to show the effect of the number of moves on the refuge chamber cost. The number of moves required was changed from 60 per year to 30 and 90 moves per year for comparison. The results are shown in Table 2 which shows that the number of moves has a significant effect on chamber costs.

Table 2. Sensitivity of moving costs on present worth cost of a refuge chamber over its 10 year life.

	30 Moves/ Year	60 Moves/ Year	90 Moves/ Year
Purchase cost			
Installation	\$85,500	\$85,500	\$85,500
Training	\$32,900	\$64,500	\$96,100
Maintenance & Inspection cost	\$12,000	\$12,000	\$12,000
Moving costs	\$3,451,600	\$6,903,000	\$10,354,700
Total	\$3,582,000	\$7,065,000	\$10,548,300

No sensitivity analyses were conducted on the other segments (installation, training, maintenance & inspection) as it is likely that the effect of their changes would be minimal compared to the move costs.

Table 3. Present worth cost analysis worksheet for a bulkhead refuge chamber.

Cost Analysis Sheet for Bulkhead Refuge Chamber

Years	0	1	2	3	4	5	6	7	8	9	10
Chamber Purchase & Training Costs											
Refuge Chamber											
Installation for chute system	\$20,960.00										
Installation for concrete wall	\$18,538.00										
Cost of living services	\$45,000.00										
Cost of borehole											
Labor costs											
Stocking labor	\$200.00										
Engineering oversite (const.)	\$800.00										
Training											
Personnel costs	\$1,341.12	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40	\$10,058.40
Total	\$86,839.12	\$10,058.40									
		PWC 10yrs.	\$149,893.78								
Chamber Maintenance costs											
Personnel costs											
Manufacturer Inspection		\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Mine personnel Insp.		\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Supplies											
Batteries						\$2,500.00					
CO2 Scrubber System						\$11,500.00					
First Aid Kit						\$1,000.00					
Food & Water						\$1,400.00					
Gas Monitors											
Oxygen						\$2,500.00					
Miscellaneous											
Total	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$18,900.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
		PWC 10yrs.	\$12,005.80								
Chamber move costs											
Chute redeployment		\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00	\$284,400.00
Concrete wall redeployment		\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00	\$749,040.00
Supply labor		\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00	\$18,000.00
Certification & insp.		\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00	\$48,000.00
Total	\$0.00	\$1,099,440.00									
		PWC 10yrs.	\$6,903,161.71								
Total Present Worth Costs			\$7,065,161.30								

Appendix A. Cost estimates for bulkhead refuge chambers.

This data is provided by Foster-Miller, Inc.

Table 4. Construction Cost Estimate For Energy-Absorbing Chute System

Item	Category	RU or NR	Unit Cost	Quantity	Total Cost
Fabricated Chute	Material	(RU)	\$ 5,000	1	\$ 5,000
Energy-absorbing Shrouds	Material	(RU)	\$ 60	64	\$ 3,840
Mechanical Chute Hardware	Material	(RU)	\$ 20	64	\$ 1,280
Chute Support Frame	Material	(RU)	\$ 500	1	\$ 500
Steel Perimeter Reaction Frame	Material	(RU)	\$ 7,200	1	\$ 7,200
Frame to Mine rock bolts	Mat+Labor	(NR)	\$ 65	36	\$ 2,340
Assembly and Checkout	Labor	(MH-NR)			
Skilled			\$ 30	16	\$ 480
Unskilled			\$ 20	16	\$ 320
Total For Installed System					\$ 20,960
Disassembly	Labor	(MH-NR)			
Skilled			\$ 30	8	\$ 240
Unskilled			\$ 20	8	\$ 160
Transport to new location	Service	(MH-NR)			\$ 1,200
Reassembly	Labor	(MH-NR)			
Skilled			\$ 30	16	\$ 480
Unskilled			\$ 20	16	\$ 320
New NR components	Mat+Labor	(NR)			\$ 2,340
Total For Redeployed System (after initial)					\$ 4,740
Notes:					
(RU) = Re-Usable					
(NR) = Non Recoverable					

Table 5. Construction Cost Estimate For Panelized Blast Reduction Media System

Item	Category	RU or NR	Unit Cost	Quantity	Total Cost
Fabricated Blast Media Panels (Costed on per sq ft basis, 130 sq ft req/d for 20 ft x 7 ft less door opg)					
Energy-absorbing Material Packs	Material	(RU)	\$ 36	150	\$ 5,400
Fabricated expanded metal panels	Material	(RU)	\$ 200	16	\$ 3,200
Assemble 1 set of panels	Assy Labor	(RU)	\$ 30	24	\$ 720
Assembly hardware (onto block wall)	Material	(NR)			\$ 750
Assembly and Checkout	Labor	(MH-NR)			
Skilled			\$ 30	16	\$ 480
Unskilled			\$ 20	16	\$ 320
Total For Installed System					\$ 10,870
Disassembly	Labor	(MH-NR)			
Skilled			\$ 30	8	\$ 240
Unskilled			\$ 20	8	\$ 160
Transport to new location	Service	(MH-NR)			\$ 1,200
Reassembly	Labor	(MH-NR)			
Skilled			\$ 30	16	\$ 480
Unskilled			\$ 20	16	\$ 320
New NR components	Mat+Labor	(NR)			\$ 750
Total For Redeployed System (after initial)					\$ 3,150
Notes:					
(RU) = Re-Usable					
(NR) = Non Recoverable					

Table 6. Construction Cost Estimate For Backup Fiber-Reinforced Concrete Block Wall & Manway System

Item	Category	RU or NR	Unit Cost	Quantity	Total Cost
Mine passage surface preparation					
Skilled	Labor	(MH-NR)	\$ 30	2	\$ 60
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Foundation Construction	Material	(NR)	\$ 40	12	\$ 480
Skilled	Labor	(MH-NR)	\$ 30	2	\$ 60
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Block wall construction	Material	(NR)	\$ 4	140	\$ 560
Skilled	Labor	(MH-NR)	\$ 30	8	\$ 240
Unskilled	Labor	(MH-NR)	\$ 20	8	\$ 160
Compliant sealing to roof and ribs	Material	(NR)	\$ 15	34	\$ 510
Skilled	Labor	(MH-NR)	\$ 30	4	\$ 120
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Rear surface fiber/composite reinforcement	Material	(NR)	\$ 10	130	\$ 1,300
Skilled	Labor	(MH-NR)	\$ 30	4	\$ 120
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Front surface surface sealing layer	Material	(NR)	\$ 8	130	\$ 1,040
Skilled	Labor	(MH-NR)	\$ 30	4	\$ 120
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Wall angle supports (front and rear)	Material	(RU)	\$ 36	68	\$ 2,448
Skilled	Labor	(MH-NR)	\$ 30	6	\$ 180
Unskilled	Labor	(MH-NR)	\$ 20	6	\$ 120
Attachments (rock bolts)	Inst Cost	(NR)	\$ 65	44	\$ 2,860
Manway blast door and support structure (front and rear)	Prefabr Assys				
	Front	(RU)	\$ 1,800	1	\$ 1,800
	Rear	(RU)	\$ 900	1	\$ 900
Skilled	Labor	(MH-NR)	\$ 30	4	\$ 120
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Attachments (rock bolts)	Inst Cost	(NR)	\$ 65	24	\$ 1,560
Furnish & Installation of Air Lock/Knife System (34" w x 42" h)	Purch Assy	(RU)	\$ 3,000	1	\$ 3,000
Skilled	Labor	(MH-NR)	\$ 30	4	\$ 120
Unskilled	Labor	(MH-NR)	\$ 20	4	\$ 80
Final Assembly and Checkout					
Skilled	Labor	(MH-NR)	\$ 30	2	\$ 60
Unskilled	Labor	(MH-NR)	\$ 20	2	\$ 40
Total For Installed System					\$18,538
Disassembly		(MH-NR)			
Skilled	Labor	(MH-NR)	\$ 30		\$ 210
Unskilled	Labor	(MH-NR)	\$ 20		\$ 140
Rock bolt (nut) removal, unit cost		(MH-NR)	\$ 8	68	\$ 544
Transport to new location	Service	(MH-NR)			\$ 1,200
Re-Installation	Matl +Labor				\$10,390
Total For Redeployed System (after initial)					\$12,484
Notes:					
(RU) = Re-Usable					
(NR) = Non Recoverable					
**Various items prop to change in ht w/2 ribs + 1 roof, others prop to wall area. Floor items unchanged. Avg proportion of .85 taken.					

Appendix B. Additional costs for installation and relocation of bulkhead refuge chambers.

This data is provided by Foster-Miller.

Table 7. Refuge Station Cost Comparisons

		Portable Chamber	Portable Chamber	Bulkhead Station	Bulkhead Station
	Item	Rigid shell	Inflatable	Energy absorbing chute system	Panelized blast reduction media system
1	BASIC STATION STRUCTURE				
1.1	Commercial portable, relocatable refuge chamber	\$80,000 - 100,000	\$80,000 - 100,000		
1.1.1	Anchoring system for portable chamber	\$1,000	\$1,000		
1.2	Mine-constructed, 2-part bulkhead refuge station (partially relocatable); all materials and labor for <i>initial installation</i>				
1.2.1	Energy-absorbing chute system			\$20,000 - 21,000	
1.2.2	Panelized blast reduction media system				\$10,400 - 10,900
1.2.3	Inner fiber-reinforced concrete block wall and manway system			\$17,600 - 18,500	\$17,600 - 18,500
1.2.4	Stocking refuge station with all supplies (air cylinders, CO2 scrubbing, food, water, sanitation supplies) - LABOR ONLY assumes 8 manhours for a laborer			\$200	\$200
1.2.5	Engineering services for oversight (16 hrs) (bulkhead only)			\$800	\$800
2	SERVICES				
2.1	Lot price for basic living services per "Mine Lifeline" outby refuge system; includes: Breathable air cylinders, Carbon dioxide scrubbing (LiOH curtains), Living supplies (food, water, blankets, medical, tools, reading materials), Chemical toilet and related equipment	Included	Included	\$45,000	\$45,000
TOTAL for Initial Installation (see Note 1)		\$81,000 - 101,000	\$81,000 - 101,000	\$83,600 - 85,500	\$74,000 - 75,400

		Portable Chamber	Portable Chamber	Bulkhead Station	Bulkhead Station
	Item	Rigid shell	Inflatable	Energy absorbing chute system	Panelized blast reduction media system
3	REFUGE STATION REDEPLOYMENT (each movement to new location)				
3.1	Commercial portable, relocatable refuge chamber (assumes one 8-hr shift for 2 workmen)	\$500 - 700	\$500 - 700		
3.1.1	Anchoring system removal and redeployment	\$1,000	\$1,000		
3.2	Mine-constructed, 2-part bulkhead refuge station (partially relocatable); all materials and labor for <i>each redeployment</i>				
3.2.1	Energy-absorbing chute system			\$4,500 - 4800	
3.2.2	Panelized blast reduction media system				\$3,000-3,200
3.2.3	Backup fiber-reinforced concrete block wall and manway system			\$11,900 - 12,500	\$11,900 - 12,500
3.2.4	Removal, movement and restocking of all station supplies and equipment - LABOR ONLY assumes 12 manhours for a laborer			\$300	\$300
3.2.5	Engineering services for oversight (16 hrs) (bulkhead only)	\$600	\$600		
3.2.6	Inspection and certification, after relocation (portables only)			\$800	\$800
SUBTOTAL for each redeployment		\$2,200	\$2,200	\$17,500 - 18,400	\$16,000 - 16,800
SUBTOTAL (for example of 5 redeployments)		\$11,000	\$11,000	\$87,500 - 92,000	\$80,000 - 84,000
TOTAL (Installation and 5 Redeployments)		\$92,000 - 112,000	\$92,000 - 112,000	\$171,100 - 177,500	\$154,000 - 159,400

4	BOREHOLE PLACEMENT (assumes 700 ft depth; 6-in. diameter) (Bulkhead Station receives cost credit from elimination of stand-alone atmosphere control system)	\$42,000	\$42,000	\$2,000*	\$2,000*
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Note 1 - Bulkhead-based station estimates show a range based on lower costs for smaller bulkheads in lower coal seams.