A HISTORY OF METAL SHAFT/PORTAL CLOSURES IN UTAH[1]

by

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Abstract. Over the last twelve years the Utah Abandoned Mine Reclamation Program has utilized metal shaft and portal closures when physical constraints required an alternative method of closure to backfill or masonry seals. Eight types of metal closures have been installed with varying degrees of success. Relative advantages/disadvantages of these closures are discussed. The eight closure types are 1) A-frame "bird cages", 2) large diameter cyclone fence-type grid, 3) bar grates, 4) rebar grates, 5) cable nets, 6) steel doors, 7) angle iron bat grates, and 8) "jail bar" steel bat grates. The primary application of the fabricated metal closures has been in non-coal mines. Only the angle iron bat grate has been installed in abandoned coal mines to date. Bird cages placed in avalanche zones failed and the shafts were later backfilled. Large cyclone fence-type grids were placed in the Wasatch and Tintic mountains in 1985. Rebar grates have been used in the Wasatch and Tintic mountains as an alternative to backfill. Bar grating was used in the Tintic mountains when the aesthetics of an historical headframe dictated a less visible closure. Cable nets have been installed in Canyonlands National Park utilizing a design pioneered in Death Valley National Monument. Steel doors have been utilized where the landowner requests access or a need to access the adit exists. Two types of bat grates have been utilized in both coal and non-coal mines where sensitive or endangered bat species have been identified. The bird cage design has not been as effective as the others. Indications are the rebar grates, angle iron bar grates, and steel doors excel in giving long term protection to the public, with the second generation bat grate giving the maximum protection to the public.

Additional Key Words: Shaft and Adit Reclamation, Reclamation Costs, Metal Closures, Bat Protection, Hazard Mitigation

Introduction

During the last twelve years the Utah Abandoned Mine Reclamation Program (AMRP) has been utilizing a variety of metal closures to address the problem of effectively sealing abandoned shafts and adits when standard techniques are unsuitable. Securing dangerous abandoned mines with a less than permanent seal is affected by the location and ease of accessibility to the site. The easier the accessibility, the higher the visitation and possible vandalism. Thus, the closer and more accessible the site, the stronger the design must be to deter vandalism. Sites located on steep slopes at high elevations may experience not only vandalism problems but also snow loads and possible avalanche damage.

Eight designs of fabricated steel closures have been employed by the Utah AMRP with varying degrees of success in both longevity and durability. The eight closure types are 1) A-frame "bird cages", 2) large diameter cyclone fence-type grid, 3) bar grates, 4) rebar grates, 5) cable nets, 6) steel doors, 7) angle iron steel bat grates, and 8) "jail bar" steel bat grates. The primary application of the metal closures has been in non-coal mines. Only the first generation (angle iron) bat grate has been installed in abandoned

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coal mines in Utah to date.

Costs for the fabricated metal closures range from a high of \$2,675.37/m² (\$247.69/ft²) for a one time use bar grate closure to a low of \$72.06/m² (\$6.68/ft²) for installation of large rebar grate closures. A cost analysis was performed and shows a comparable cost for the metal closure when compared to the volume of backfill that would be required for filling the shaft or adit. Table 1 summarizes the costs of each closure completed by the Utah AMRP over the last twelve years.

<u>A-Frame "Bird Cage"</u>

The A-frame bird cages were first used in the Wasatch Mountains above Salt Lake City in 1982 and 1983 (Figure 1). The design consists of a 95 mm (3/8-inch) square mesh on 25 cm (10-inch) centers bolted to a 5 cm (2-inch) by 8 cm (3-inch) by 48 mm (3/16-inch) tubing frame on 61 cm (2-foot). The square mesh was secured by u-bolts to the framing. The bird cages were adjacent to and within the Wasatch-Cache National Forest near four ski resorts. Visitor use days within the Wasatch-Cache National Forest were in excess of 2,000,000 user days in the 1990-91 ski season alone. (Fjeldsted and Hachman 1991) The 2,000,000+ figure does not include the hiker traffic during the summer months. Many shafts in the area extend over 300 meters (1,000 feet) in depth and may be used as recharge or ventilation of the aquifer. Backfill material is limited or nonexistent at the sites.

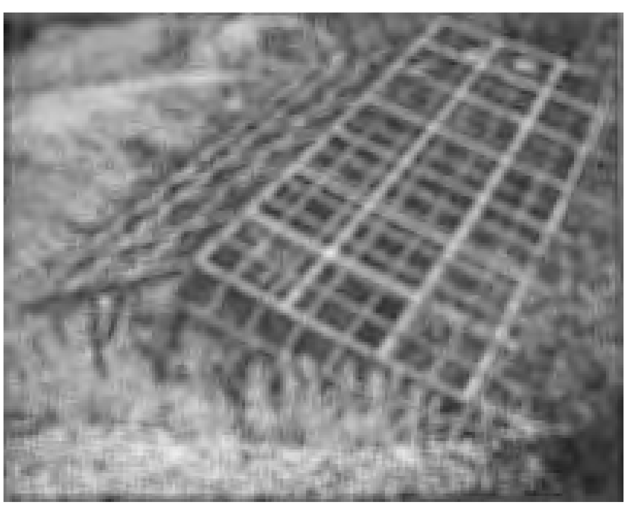

Figure 1. A-Frame "Bird Cage" Grate closure in Alta-Brighton Project, 1984.

The bird cages were designed to protect the public from entering the shafts and performed well to restrict the recreational skier or hiker. The more inquisitive public found that the square mesh could be bent back and the framing used to anchor ropes for descending down the shafts. Sloughing of the shaft collar was a problem with a loss of support for the concrete pillars or epoxy roof bolts near the edge of the collar. The bird cages were transported to the sites by ski, snow cat, and helicopter. Three of the bird cages collapsed due to heavy snow loads from avalanches. The location of the shaft in relation to potential avalanches and competence of the collar material must be evaluated when any type of closure other than backfill is utilized.

The costs for this type of closure range from \$1,200 for a 1 m x 1.4 m (3.5' x 4.5') cage to \$6,640 for a 13 m x 7 m (42' x 23' m) cage with an average size of 5 m x 4 m (15' x 12') cage at an average cost of \$3,512 or \$483.76/m² (\$46.63/ft²) including the fabrication of the custom fit cages.

To date eight of 15 bird cages are still secure in the Wasatch Range. Five shafts with failed bird cages ranging in depth from 6 meters (20 feet) to 212 meters (400 feet) were later backfilled by hand. One bird cage was repaired by expanding the size of the 95 mm (3/8-inch) mesh by 3 m (10 feet).

<u>Large Cyclone Fencing Grid</u>

The large cyclone fencing grid was designed to withstand the heavy snow loads encountered high in the Wasatch Range, and in response to the failures seen with the bird cages under heavy loading (Figure 2). Based on the known capability of cyclone fencing to distribute the load and flex, a design consisting of 95 mm (3/8") diameter hot dipped galvanized wire twisted into a cyclone fence on 15 cm (6-inch) centers was fabricated. Agutter Engineering of Salt Lake City designed a jig to turn the 95 mm (3/8") diameter bar for the cyclone fencing in 4 m (12') lengths which were threaded together for the required length of "fencing". Where the length exceeded 4 m (12'), the sections

Table 1 - Metal Closure Costs by Site

SITE	SIZE (FEET)	SIZE (METERS)	TYPE	COST
AB-1	3.5' x 4.5'	1.07 m x 1.37 m	Bird Cage	$1,200
AB-2	6' x 8'	1.83 m x 2.44 m	"	$3,575
AB-3	6' x 10'	1.83 m x 3.05 m	"	$2,950
AB-4	6' x 5'	1.83 m x 1.52 m	"	$2,750
AB-5	10' x 10'	3.05 m x 3.05 m	"	$3,000
AB-6	42' x 23'	12.8 m x 7.01 m	"	$6,640
AB-7	17' x 14'	5.18 m x 4.27 m	"	$4,000
AB-13	26' x 8'	7.92 m x 2.44 m	"	$5,575
AB-15	13' x 17'	3.96 m x 5.18 m	"	$3,650
AB-18	15' x 15'	4.57 m x 4.57 m	"	$2,600
AB-22	5' x 8'	1.52 m x 2.44 m	"	$2,450
AB-38	6' X 8'	1.83 m x 2.44 m	"	$3,750
BB-BB	5' x 11'	1.52 m x 3.35 m	Bar Grate[3]	13,623
BB-EH	16' x 32'	4.88 m x 9.75 m	Cyclone Fence[4]	$6,245
BB-GE	24' x 34'	7.32 m x 10.36 m	"	13,007
BB-RV	44' x 36'	13.41 m x 10.97 m	"	13,781
BB-SA	32' x 38'	9.75 m x 11.58 m	"	11,136
A-17	12' x 16'	3.66 m x 4.88 m	"	$4,375
W-2	4' x 8'	6.10 m x 6.10 m	Rebar Grate[5]	$ 384
W-35	4' x 6'	1.22 m x 1.83 m	"	$ 792
W-119	4' x 4'	1.22 m x 1.22 m	"	$ 500
W-312	12' x 15'	3.66 m x 4.57 m	Rebar Grate[6]	$1,485
W-324	18' x 24'	5.49 m x 7.32 m	"	$2,376
W-350	8' x 16'	2.44 m x 4.88 m	"	$3,200
T-3	20' x 20'	6.10 m x 6.10 m	Rebar Grate[7]	$2,300
T-7	36' x 36'	10.97 m x 10.97 m	"	$8,976
T-8	13' x 16'	3.96 m x 4.88 m	"	$1,700
T-13	35' x 40'	10.67 m x 12.19 m	"	$5,400
T-14	15' x 18'	4.57 m x 5.49 m	"	$2,000
T-15	9' x 13'	2.74 m x 3.96 m	"	$1,000
T-16	24' x 24'	7.32 m x 7.32 m	"	$3,400
T-17	34' x 35'	10.36 m x 10.67 m	"	$7,100
T-19	24' x 25'	7.32 m x 7.62 m	"	$3,500
T-21	12' x 14'	3.66 m x 4.27 m	"	$2,100
T-22	20' x 25'	6.10 m x 7.62 m	"	$3,000
T-27	12' x 16'	3.66 m x 4.88 m	"	$1,092
T-28	14' x 14'	4.27 m x 4.27 m	"	$1,100
T-30	18' x 22'	5.49 m x 6.71 m	"	$2,300
T-36	32' x 35'	9.75 m x 10.67 m	"	$6,632
T-38	10' x 10'	3.05 m x 3.05 m	"	$4,000
L-H1b	7' x 6'	2.13 m x 1.83 m	Cable Net	$ 882
L-H3b	11' x 6'	3.35 m x 1.83 m	"	$1,386
L-H4a	19' x 7'	5.79 m x 2.13 m	"	$3,234
L-H4c	10' x 7'	3.05 m x 2.13 m	"	$1,995
L-H4d	7.5' x 7'	2.29 m x 2.13 m	"	$1,113
L-H4e	7.5' x 6.5'	1.98 m x 1.98 m	"	$ 903
L-HO5	10' x 8'	3.05 m x 2.44 m	"	$1,680
L-HO6	7' x 9'	2.13 m x 2.74 m	"	$1,323
L-HO7	9.5' x 7'	2.90 m x 2.13 m	"	$1,407
L-HO8	7' x 8.5'	2.13 m x 2.59 m	"	$1,260
W-67	6' x 6'	1.83 m x 1.83 m	Steel Door[8]	$ 965
W-89	4' x 4'	1.22 m x 1.22 m	"	$ 975
W-103	6' x 6'	1.83 m x 1.83 m	"	$ 975

FN-B1	10' x 6'	2.90 m x 2.44 m	Angle Iron Steel Bat Grate	$4,500
FN-B3	12' x 6'	3.66 m x 1.83 m		$5,400
FN-B4	10' x 6'	3.05 m x 1.83 m		$4,500
FN-F1	6' x 6'	1.83 m x 1.83 m	"	$3,000
FN-K1	13' x 8'	3.96 m x 2.44 m	"	$8,150
O-P1	9.5' x 8'	2.90 m x 2.44 m	"	$2,160
O-P2	6' x 9'	1.83 m x 2.74 m	"	$2,835
O-P3	8' x 6'	2.44 m x 1.83 m	"	$2,160
O-P4	9' x 7'	2.74 m x 2.13 m	"	$2,160
O-P5	6' x 8'	1.83 m x 2.44 m	"	$3,040
W-77[9]	5' x 7'	1.52 m x 2.13 m	"	$2,725
W-291	7' x 9'	2.13 m x 2.74 m	"	$4,975
S-3	3' x 2'	0.91 m x 0.61 m	Jail Bar Steel Bat Grate	$1,500
S-4	7' x 6'	2.13 m x 1.83 m		$5,250
S-38	8' x 6'	2.44 m x 1.83 m	"	$7,280
S-42	3' x 6'	0.91 m x 1.83 m	"	$2,250
S-43	4' x 6'	1.22 m x 1.83 m	"	$3,000
S-46	5' x 3'	1.52 m x 0.91 m	"	$3,640
S-52	5' x 5'	1.52 m x 1.52 m	"	$3,125
S-68	5' x 4'	1.52 m x 1.22 m	"	$3,125
S-73	6' x 5'	1.83 m x 1.52 m	"	$3,750
S-78	8' x 5'	2.44 m x 1.52 m	"	$5,000
S-79	5' x 6'	1.52 m x 1.83 m	"	$4,000
S-80	4' x 6'	1.22 m x 1.83 m	"	$3,120
S-84	4' x 2'	1.22 m x 0.61 m	"	$5,000
S-85	5' x 8'	1.52 m x 2.44 m	"	$5,970
S-105	6' x 6'	1.83 m x 1.83 m	"	$4,500
S-107a	4' x 5'	1.22 m x 1.52 m	"	$2,700
S-107b	7' x 6'	2.13 m x 1.83 m	"	$5,460

[3] Cost includes concrete stabilization of collar area and repair of headframe.
[4] Cost includes fabrication and installation without cost of access improvements or site grading.
[5] Rebar grate consists of #5 rebar on 6" centers, rebar drilled into collar without the placement of a concrete grade beam.
[6] Rebar grate consists of #5 rebar on 6" centers with the placement of a concrete grade beam.
[7] Rebar grate consists of #6 rebar on 8" centers with the placement of a concrete grade beam.
[8] Steel Door closure includes concrete block placed around the steel structure to secure the door.
[9] Angle Iron Steel Bat Grate closure includes mild steel frame allowing bat grate to be opened like a gate.

Figure 2. Cyclone Fence Grid closure in Bullion-Beck Project, 1985.

were bolted together with 12 mm (½") bolts. The design was made to allow the grid to be installed over shafts with uneven collar configurations. However, more grooming of the collar was required than had been anticipated. The first cyclone grid was installed in the Alta area above Salt Lake City in 1985. The grid overlapped the collar 90 cm to 120 cm (3 to 4 feet) with roof bolts installed a minimum of 30 cm (1-foot) to anchor the grid into the bedrock. A 95 mm x 5 mm (2" x 3/8") bar strap was threaded around the perimeter of the grid for attachment of the anchor.

Later in 1985 the same type of grid was used in the Bullion Beck Project with one alteration to the design. A S12 x 22.5 I-beam was installed around the perimeter and anchored to the dump material utilizing a 61 cm (24") anchor disk as a deadman placed 3 m to 5 m (10' to 15') back from the collar on all four sides of the grid. The anchor disks were secured to the grid with 12 mm (½") galvanized steel cable. The anchor disks were used to allow for possible failure of the collar without compromising the integrity of the closure. Site preparation for the grid required a relatively flat surface with the anchors placed in the dump material surrounding the collar. The perimeter I-beam was covered with dump material to blend the closure with the surrounding terrain. This design allowed for placement around the base of headframes without disturbing the integrity of the structures. None of the grids placed in 1985 have been compromised by collar failure or vandalism. Equipment was utilized to place the grid, I-beam, and excavate for the deadman anchors. Equipment access is required for this type of installation.

The grid size ranged from 4 m x 5 m (12' x 16') in the Alta Project to a maximum size of 14 m x 11 m (44' x 36') at the Bullion Beck Project. The average cost was $148.01/m^2 ($13.81/ft^2) including the fabrication. The cost of site grading and covering of the perimeter of the grate with soil materials is not included in the above costs.

Bar Grate

A bar grate design was developed as a specialized application for the Bullion Beck Project in 1985 when the cyclone fence grid design was determined to be obtrusive to the visual appearance of a historic headframe (Figure 3). The wooden collar lining of the shaft was deteriorating near the main support for a 2-post type headframe. A concrete collar support was installed with bar grating sized to approximate the original dimensions of the collar of the shaft. The final design with the skip guides attached to the wooden beams around the collar gives the appearance of the original structure while securing the collar from safety hazards. The bar grate is constructed of 12 mm (½") diameter bar on 5 cm (2") centers with 25 mm (1") square bar on 61 cm (2') centers supporting the bars.

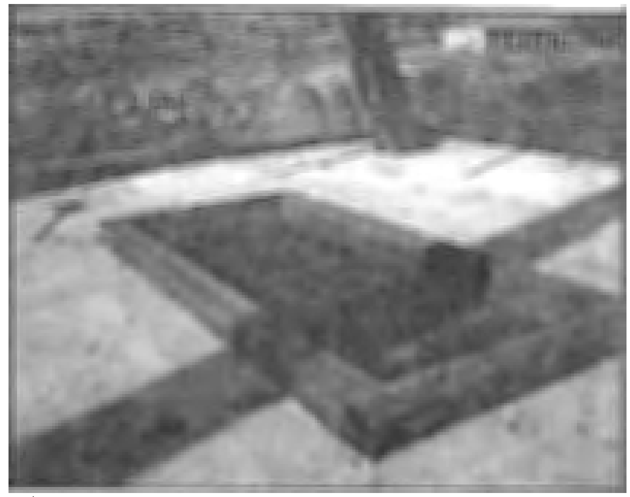

Figure 3. Bar Grate closure in Bullion-Beck Project, 1986.

The cost of the 1.5 m by 3 m (5' by 11') grate including concrete work to prepare the site and anchor the grate was $13,623.00 or an average of $2,675.37/m^2 ($247.69/ft^2). This number is high due to the amount of concrete used to stabilize the collar before installation of the grate. The cost of the installation of the bar grating would be substantially lower if a minimum of site preparation were to be required. Equipment access was required for this installation.

Rebar Grate

Rebar grates were utilized in the Wasatch Project in 1990 and 1991 where deep shafts over 300 m (1,000') deep and a lack of available backfill material available prohibit a more permanent closure (Figures 4 and 5). A design which would require a minimum of site preparation and field fabrication was desired. The rebar grate design developed for the Wasatch Project is constructed from 16 mm (5/8") diameter rebar (#5 rebar) welded on 15 cm (6") centers. A 30 cm x 30 cm (1' x 1') concrete grade beam with two additional 16 mm (5/8") diameter rebar (#5 rebar) placed within the concrete beam was placed around the perimeter of the grate. Field fabrication and adjustments could be accomplished more easily by the contractor using rebar construction. The first rebar grate installation consisted of repair to an existing small grate by extending the rebar over the collapsing collar approximately 3 m (10'). Two of the six rebar grates were accessible only by foot and were pinned by drilling into the bedrock collars, inserting the #5 rebar and welding the rebar at all intersections of rebar. Two rebar grates were assembled in a ski resort parking lot approximately 1.8 km (1/4 mile) below the sites. The welded grates were then transported to the sites by helicopter along with concrete and water for the perimeter grade beam. The rebar grate design used in the Tintic Project, modified to withstand higher vandalism risk, is constructed from 25 mm (1") diameter rebar (#8 rebar) welded on 20 cm (8") centers. A 30 cm x 30 cm (1' x 1') concrete grade beam reinforced by two additional 19 mm (3/4") diameter rebar was placed around the perimeter of the grate.

The grate sizes within the Wasatch Project range from 1.2 m x 1.2 m (4' x 4') to a maximum size of 6 m x 7 m (18' x 24'). The average cost of $273.22/m^2$ ($25.42/ft^2) allows for variations in site access ranging from vehicle access in moderate terrain to foot only access in very steep terrain. The larger sites within the Wasatch project had an average cost of $138.88/m^2 ($12.92/ft^2) which reflects a reduced cost for volume pricing for large grates. The cost of minor site grading and revegetation of disturbed areas are not included in the above costs.

The grate sizes in the Tintic Project, utilizing the larger grate design, range from 3 m x 4 m (9' x 13') to a maximum size of 10 m x 12 m (35' x 40'). The average cost of $72.03/m^2 ($6.68/ft^2) reflects costs for sites that are equipment accessible. One site required transport of all materials by foot giving an average cost of $429.99/m^2 ($40.00/ft^2). The cost of minor site grading and revegetation of disturbed areas is not included in the above costs.

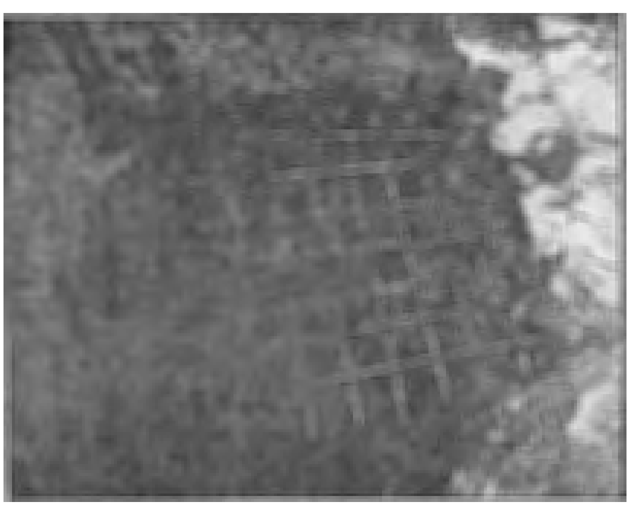

Figure 4. Pinned Rebar Grate closure in Wasatch Project, 1990.

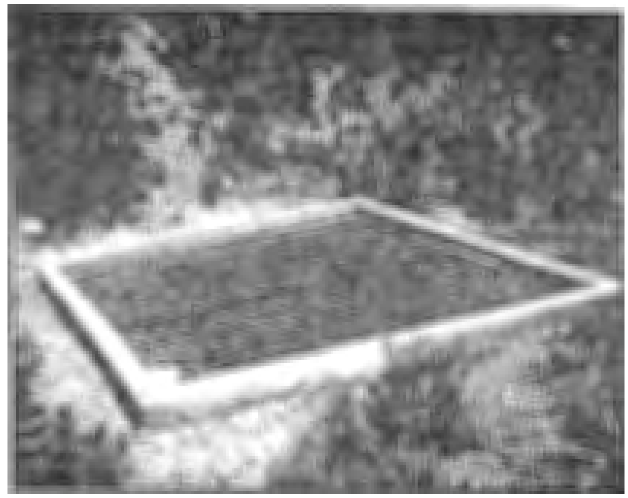

Figure 5. Rebar Grate closure in Tintic Project, 1992.

Cable Net

The cable net closure was utilized in the Lathrop Canyon Project in Canyonlands National Park in 1990 where the National Park Service (NPS) requested this type of closure (Figure 6). The cable nets used are fashioned after the design pioneered by the NPS in Death Valley National Monument in California. The design incorporates the use of a single length of preformed 7 x 19 construction (7 strands of 19 wires each) 64 mm (1/4 inch) diameter galvanized aircraft cable to form the grid. A perimeter cable of 79 mm (5/16 inch) of the same type construction is threaded around the grid and through rings secured to the portal wall by 46 cm (18") resin bolts. A lock box was bolted to the rib to allow access into the portals by the NPS. The contractor fabricated the nets at his facility from a jig of his own design. This design allows for small discrepancies in measurements of the portal and allows for irregularities in the ribs to be easily secured. Equipment access is preferred for installation of the nets due to the requirement of drilling the collar for placement of the resin bolts. However, no equipment access was allowed on this project by the NPS resulting in all materials and equipment transported to the sites by foot.

The net sizes within the Lathrop Project range from 2 m x 2 m (7' x 6') to a maximum size of 6 m x 2 m (19' x 7'). The average cost of \$238.88/m^2 (\$22.17^2/ft) included transporting all materials to the site by foot. The cost of revegetation of disturbed areas is not included in the above costs.

Steel Door

Steel doors have been used to a minor degree by the Utah AMRP. These doors were installed in the Wasatch Project in the Wasatch Mountains above Salt Lake City in 1990 and 1991 (Figure 7). Steel doors have only been used in non-coal applications. The doors were installed at the request of landowners for access for probable mineral development or access to water supplies. The steel door construction includes the installation of a solid concrete block wall to secure the door to the portal configuration. A 15 cm x 10 cm (6" x 4") angle iron is mounted to the block wall with a steel gate of 38 mm (1-1/2") diameter pipe frame. A 25 mm x 25 mm (1" x 1") sheet of expanded metal was welded at 15 cm (6") intervals over the pipe

Figure 6. Cable Net closure in Laythrop Canyon Project, 1990.

Figure 7. Steel Door closure in Wasatch Project, 1990.

frame and secured to the angle iron with heavy duty hinges. The purpose of using an expanded metal cover rather than a solid metal closure was to allow for ventilation of the adit. A lock box installed on the gate allows for access to the adit.

The steel door sizes used in the Wasatch Project range from one small door 1.2 m 1.2 m (4' x 4') installed with foot access over an inclined shaft to larger doors 2 m x 2 m (6' x 6'). The cost of the small door with foot access was \$655.07/m^2 (\$60.94/ft^2) and is high due to the single site located in steep terrain. The cost of the larger door with equipment access was lower at \$289.65/m^2 (\$26.95/ft^2) due to vehicle access and a larger size. The cost of revegetation of disturbed areas is not included in the above costs.

Angle Iron Steel Bat Grate

Angle iron steel bat grates were used in the Ferron North Project in 1992, the Oyler Project in 1993, and the Wasatch Project in 1994 (Figure 8). The angle iron steel bat grate design used by the Utah AMRP is a combination of designs pioneered by Roy Powers of Mountain Empire Community College, Virginia, and is presently being used by eastern and western states. Modifications of early designs included hanging the angle iron in front of vertical supports rather than butting the angle iron into the vertical supports. The bat grates are constructed of 12 mm x 12 mm x 79 mm (4" x 4" x 5/16") angle iron with two 38 mm x 38 mm x 64 mm (1-1/2" x 1-1/2" x 1/4") angle iron stiffeners welded inside of the horizontal bars. The horizontal bars are either welded or bolted with 12 cm (½") carriage bolts to 10 cm x 10 cm x 79 mm (4" x 4" x 5/16") square steel tubing posts. The steel posts are anchored to the roof of the adit by 16 mm (5/8") resin roof bolts placed a minimum of 20 cm (8"). The horizontal bars and base of the posts are anchored to the ribs and floor of the adit by concrete grout. The design of bolting the bars to the post simplifies field installation and allows one or two of the bars to be secured with lock boxes to allow entry into the adit. The 15 cm (6") spacing between bars allows bats to enter and exit freely while restricting public access.

The angle iron steel bat grate sizes in the Ferron North Project range from 2 m x 2 m (6' x 6') to a maximum of 4 m x 3 m (13' x 8'). The cost of $831.60/m² ($77.34/ft²) is high due to helicopter access required to deliver the materials to the sites. The sites in the Oyler Project located within Capitol Reef National Park range in size from 2 m x 2 m (6' x 8') to a maximum of 3 m x 2 m (9.5' x 8') with an average cost of $481.06/m² ($44.71/ft²). The sites in the Wasatch Project range in size from 1.5 m x 2 m (5' x 7') to a maximum of 2 m x 3 m (7' x 9') with an average cost of $844.66/m² ($78.50/ft²). The cost of revegetation of disturbed areas are not included in the above costs.

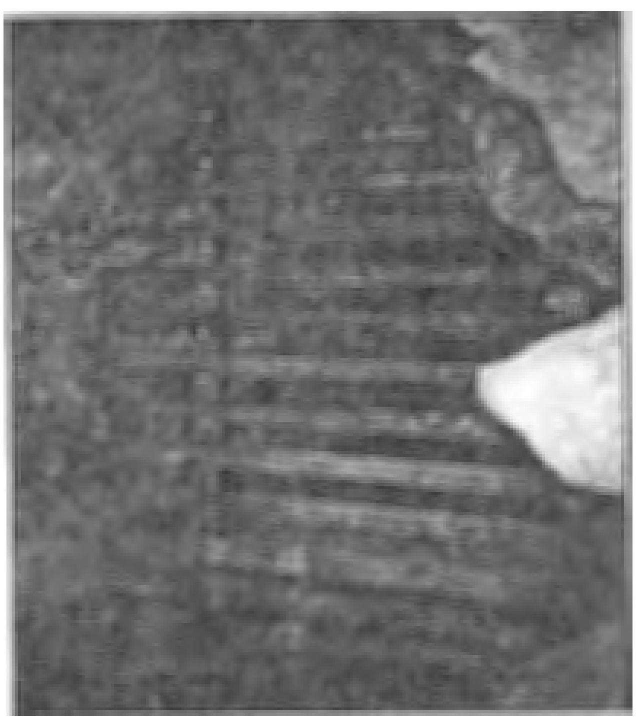

Figure 8. Angle Iron Steel Bat Grate closure in Wasatch Project, 1994.

During the late summer of 1994, one of the angle iron steel bat grate installed in the Wasatch Project was vandalized by cutting of the horizontal angle iron steel support with a hacksaw. The site located in Big Cottonwood Canyon to the east of Salt Lake City, was repaired by hard-facing all angle points exposed on the outby side of the bat grate. In the summer of 1995, the site was again vandalized by the removal of a portion of the lock-box mechanism on the grate. This vandalism was accomplished by reaching through a 64 mm (¼-inch) space between the lock box and frame with a hacksaw blade. The mild steel used in the angle iron steel bat grate is easily breached by vandals armed with hacksaws and time.

<u>"Jail Bar" Steel Bat Grate</u>

Jail bar steel bat grates were been used in the Summit Project in 1995 (Figure 9). The "jail bar" steel bat grate design used by the Utah AMRP is an attempt to thwart the vandalism of the mild steel angle iron bat grates utilized in previous projects. The bat grates are constructed of 25 mm (1") diameter solid manganese steel bar with two or more 12 mm x 10 cm (½" x 4") manganese steel strap vertical supports. All components are made of 12-14% manganese steel. The vertical supports have 25 mm (1") diameter holes cut on 16 cm (6-1/2") centers with the horizontal bars either electric welded or brazed to the vertical support. The vertical supports are anchored to the roof of the adit by 25 mm (1") diameter 12-14% manganese bars placed a minimum of 20 cm (8") and anchored with resin. The base of the vertical supports are anchored to the floor of the adit by concrete grout. The design and installation of a lock box to the vertical support allows one of the bars to be removed allowing entry into the adit. The manganese steel may be rough cut off-site and cut to fit onsite utilizing a cutting torch. The 14 cm (5-1/2") spacing between bars allows bats to enter and exit freely while restricting public access. Modifications of this design were warranted when a small child (6 years old) was observed crawling between the lower bars of the closure. The modification consists of reducing the spacing of the bars to 11 cm (4-1/2") on bars located below 1.5 m (60") from the floor of the adit. The spacing of 14 cm (5-1/2") is maintained above the 1.5 m (60") threshold. This allows for one or two spacings of 14 cm (5-1/2") for the average adit. After the 1995 construction season, bats were observed in adits known to have no bat use prior to the installation of the bat grates. The design of the jail bar steel bat grate will be modified to a 10 cm (4") spacing below 1.2 m (48") threshold for all grates after the 1995 season. This change is in response to a change in the national building code standards for constructed gates in public areas.

The jail bar steel bat grate sizes in the Summit Project range from 1 m x 0.6 m (3' x 2') to a maximum of 2.4 m x 1.8 m (8' x 6') with an average cost of $\$1,582.37/m^2$ ($\$147.06/ft^2$). The average cost is increased to $\$1,884.90/m^2$ ($\$175.18/ft^2$) when including a small site (S-84) requiring helicopter access to deliver the materials. The cost of revegetation of disturbed areas is not included in the above costs.

Conclusions

Over the last twelve years the Utah AMRP has used a variety of metal closures with varying degrees of success. The AMRP closure process has been a dynamic evolution as different closure methods are tried and tested.

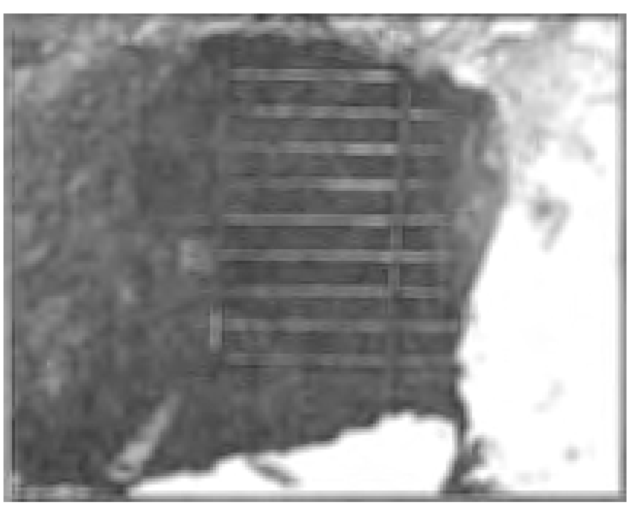

Figure 9. "Jail Bar" Steel Bat Grate closure in Summit Project, 1995.

The A-frame bird cage was the first attempt for the AMRP to find a closure method which would be both cost effective to secure the opening and withstand minor vandalism. With this design, the custom fit, offsite fabrication, difficult installation, and transport to high elevations drove the cost up. The cage is susceptible to failure under snow loads, collar failure, and vandalism.

The large cyclone fencing gives protection for minor collar failure while allowing ventilation, visibility for shaft inspection, and snow loading. The fencing does require moderate site preparation, offsite fabrication and transport to the site. A specialized jig is required to turn the bar stock for fabrication of the fencing design. To date vandalism of the fencing has not been a problem. For large sites with unstable collar configurations the cyclone fencing closure would be the best fit to provide maximum security.

The bar grate provides site ventilation, security, and high loading capacity. Equipment, offsite fabrication, large volume of concrete reinforcing of the collar, and a high amount of site preparation for the single use by the AMRP gave the bar closure an inflated cost for the project. The bar grate provides a secure closure with a high visual compatibility to the historic headframe above the shaft.

The rebar grate gives a secure closure while allowing ventilation, high loading, and visual inspection of the shaft. Minimal site preparation is required allowing the grate to be placed on slopes and uneven collar configurations. The grate is constructed of widely available rebar with onsite fabrication and modifications easily made during assembly without compromising the integrity of the structure. Equipment access to the site reduces the cost significantly due to the volume of rebar and concrete required for the installation. A relatively competent collar configuration is required to anchor the structure while the configuration and flexibility of the grate would allow for minor collar failure. For large, deep shafts with equipment access the grid is a very cost effective way to achieve security. Though configured differently than bat grates, there is anecdotal evidence suggesting bat utilization of this design in the Tintic Project area in the spring of 1993.

The cable nets offer security while allowing ventilation of adits with a minimum of site preparation. Equipment access to the site significantly reduces costs and the cable net's light weight and capability to be rolled increases the ease of transport. The nets are less durable than the other closures requiring some maintenance to guarantee the security of the closure. The lock is still the weak link in the system with the closure only as secure as the lock. Offsite fabrication, difficult field alterations, and possible vandalism lower the effectiveness of this closure method. The National Park Service applications of this closure technique provide low visibility and minimal impact to the surrounding area. Where the closure can be monitored, this method works well.

Steel doors offer moderate security while allowing controlled access to workings. The steel doors constructed of expanded steel are susceptible to vandalism. The doors must be sized for the opening and then secured to the walls and roof of the mine with block and grout. As with the cable net closure, the lock placed on the door is the weak link in the system. Equipment access to the site significantly reduces the cost of the closure method. In Utah, the doors have only been installed at the request of landowners. This method works well and is cost effective in locations where the doors can be monitored.

The angle iron steel bat grate design offers ventilation of the working along with controlled entry. The bars are fabricated offsite but can be transported in manageable pieces and assembled onsite. Some designs require detailed cutting and welding for installation. This design has minimal effect on the ventilation and a maximum flyway for bats. The grate also gives a secure closure with a higher cost than other methods with equipment access. This method may be acceptable in locations of bat sightings where infants or small children would not be present. In Utah, footprints and other indications of visitation by small children are found in even the most remote locations.

The "jail bar" steel bat grate design also offers ventilation of the working along with controlled entry and vandalism resistance. The bars may be cut offsite with final fit onsite. This allows for the transport of the grate in manageable pieces to be assembled onsite. This design allows for welding by electric or gas with detailed cutting and welding onsite. The grate has a minimal effect on the ventilation and a maximum flyway for bats. The grate also gives a secure closure with a lower cost than angle iron steel bat grates. This method is the preferred closure in locations of bat sightings where infants or small children may be present.

Table 2 summarizes the closures by type, cost, advantages, and disadvantages

Of the eight fabricated metal closures used by the AMRP, the most successful in terms of cost, effectiveness and closure security have been the jail bar steel bat grates.

References

Fjeldsted, B.L. and Hachman, F. C. 1991. Results of the 1990-1991 Utah Skier Survey. Utah Economic and Business Review, Vol. 51, 16 P, August/ September 1991.

Table 2 - Fabricated Metal Closures by Type

TYPE OF CLOSURE	COST $/ft²	COST $/m²	ADVANTAGES	DISADVANTAGES
A-Frame "Bird Cage"	$46.63	$483.76	Ventilation, possible re-entry	Custom fit, easily vandalized, low snow loads, offsite fabrication, no protection if collar fails
Large Cyclone Fencing	$13.81	$148.01	Ventilation, secures shaft, high loads, bar stock widely available, shaft visible for inspection, collar failure not a problem	Equipment required, offsite fabrication, specialized jig required, site preparation
Rebar Grates	$ 6.68[10] $40.00[11]	$ 72.03[10] $429.99[11]	Ventilation, secures shaft, high loads, minimal site preparation, fabrication onsite, rebar available and inexpensive, field alterations easy	Equipment required, cut with hacksaw
Bar Grates	$247.69	$2,675.37	Ventilation, secures shaft, high loads	Equipment required, offsite fabrication, site preparation
Cable Nets	$22.17	$238.88	Ventilation, secures shaft/adit, minimal site preparation, light weight, transport ease	Custom fit, offsite fabrication, less durable than others, field alterations difficult
Steel Doors	$26.95[10] $60.94[11]	$289.65[10] $655.07[11]	Ventilation, controlled entry, minimal wildlife use	Offsite fabrication, vandalism
Angle Iron Steel Bat Grates	$44.71	$481.06	Ventilation, controlled entry, stock materials, allows bat and other wildlife use, onsite assembly	Offsite fabrication, equipment required, some detailed cutting and welding, cut with hacksaw

"Jail Bar" Steel Bat Grates	\$147.06[12] \$175.18[13]	\$1,582.37[12] \$1,884.90[13]	Ventilation, controlled entry, stock materials, allows bat and other wildlife use, onsite assembly	Limited availability of material, gas and/or electric welder required, some detailed cutting and welding

[10] Average site cost for equipment accessible.
[11] Average site cost for single site or foot access to site only.
[12] Average site cost for closure.
[13] Average site cost increased by helicopter access to remote site (S-84).