1. NAME OF PROPERTY

Historic Name: **SHENANDOAH-DIVES MILL**

Other Name/Site Number: Mayflower Mill

2. LOCATION

Street & Number: The Shenandoah-Dives Mill is located two miles northeast of the Silverton town limits on Highway 110 and 100 feet north of the highway. Not for publication:_

City/Town: Silverton Vicinity: X

State: Colorado County: San Juan Code: 111 Zip Code: 81433

3. CLASSIFICATION

Ownership of Property		Category of Property	
Private:	X	Building(s):	X
Public-Local:	___	District:	___
Public-State:	___	Site:	___
Public-Federal:	___	Structure:	___
		Object:	___

Number of Resources within Property

Contributing	Noncontributing	
2	4	buildings
___	1	sites
2	1	structures
___	___	objects
4	6	Total

Number of Contributing Resources Previously Listed in the National Register: 4

Name of Related Multiple Property Listing:

4. STATE/FEDERAL AGENCY CERTIFICATION

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria.

Signature of Certifying Official Date

State or Federal Agency and Bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria.

Signature of Commenting or Other Official Date

State or Federal Agency and Bureau

5. NATIONAL PARK SERVICE CERTIFICATION

I hereby certify that this property is:

___ Entered in the National Register
___ Determined eligible for the National Register
___ Determined not eligible for the National Register
___ Removed from the National Register
___ Other (explain): ____________________

Signature of Keeper Date of Action

6. FUNCTION OR USE

Historic:	Industry	Sub:	Manufacturing facility
Current:	Recreation and Culture	Sub:	Museum

7. DESCRIPTION

Architectural Classification: Other: Industrial mill

Materials:

Foundation: Concrete
Walls: Wood, Aluminum
Roof: Wood, Tin, Steel
Other:

Describe Present and Historic Physical Appearance.

Summary Statement

The Shenandoah-Dives Mill, near Silverton, Colorado is located within the famous "San Juan Triangle" mining center of southwestern Colorado, which also includes the historic mining towns of Telluride and Ouray, and encompasses one of the most richly mineralized areas of North America. Fourteen thousand feet mountain peaks tower over the mill, which sits at the bottom of Arrastra Gulch in Baker's Park on the Animas River. The mill has retained an exceptional degree of historic integrity largely due to its isolation, due to its distance from major population centers, altitude, and severe winter climate. Currently, approximately 450 people reside year-round in Silverton.

The Shenandoah-Dives Mill is an exceptional example of early twentieth-century American flotation mills. The multi-level, wooden mill is 90' x 252' x 106' x 252' and in 1929 was classified as large industrial. Prominent features of the mill site include the mill, crushing plant, office/assay building, tram terminal, lime shed, and decantation ponds. The type of flotation technology used in the mill is nationally significant due to its role in diverting a crisis in the mining industry at the turn of the century.

Nearby Silverton was designated as a National Historic Landmark (NHL) in 1961. The boundary was established in 1975, and encompassed the town limits of Silverton, approximately 530 acres. The 1961 NHL designation recognized the district for its mining heritage and vernacular architecture. In 1996, in an effort to preserve Silverton's mining heritage, the Sunnyside Gold Company donated the Shenandoah-Dives Mill complex, commonly referred to as the Mayflower Mill due to its association with the Mayflower Mine; the historic Animas Power and Water Company buildings and structures; and Crooke's Polar Star Mill Office to the San Juan County Historical Society. The historical society opened the mill as an interpretative center in 1997. The integrity of the Shenandoah-Dives Mill is exceptionally high due to its historic mining location and setting reflecting the feeling and association with the mining industry in the twentieth century. The resource reflects the style, type and method of construction recognized in mining sites across the West, but more importantly the flotation technology within the mill reflects an exceptionally intact flow pattern of early twentieth-century flotation milling.

The Shenandoah-Dives Mill NHL includes four contributing resources: two buildings and two structures.

Contributing Resources

The Shenandoah-Dives Mill is nationally significant for its exceptional integrity as an early twentieth-century flotation mill reflecting America's mining heritage and the evolution of important milling practices. A 1998 National Park Service (NPS) survey of early twentieth-century, large flotation mills found that there are only four extant mills of this size remaining in the United States in a variety of conditions.[1] In the first half of the twentieth century, large mills were classified as 500-2,000 tons per day (tpd). On the contrary, the end of the century found

[1] Dawn Bunyak, *Frothers, Bubbles and Flotation: A Survey of Flotation Milling in the Twentieth-Century Metals Industry* (Washington, D.C.: Government Printing Office, 1999), 50.

large mills ranging from 2,000-60,000 tons. The NPS survey determined that the Shenandoah-Dives Mill is the only intact and functionally operational flotation mill of this size in the United States that reflects the distinctive characteristics of the hard-rock flotation milling process. The Shenandoah-Dives Mill is an outstanding representation of a hard-rock milling process and reflects the broad national pattern of American mining and milling history in the first decades of the twentieth century. Examples of extraction, production, and technological advances are reflected in the operation of the mill. The complex displays all of the buildings and processes illustrative of flotation milling, including conveyance to mill, conveyors, power source, water source, administrative and operations office, machine shop (a complete inventory of equipment), fully equipped metallurgical lab/assay office, storage buildings, employee facilities, and conveyance to smelter (rail and road), (refer to mill site plan on pg. 6). The entire complex is in exceptional condition. It is the only extant mill that contains all of its original technological components, such as flotation cells, classifiers, filters, and crushers (including one Marcy No. 86 ball mill with its GE 250 horsepower synchronous motor). The synchronous motor was one of only three made and it is the only one in existence today. This nomination includes two buildings and two structures historically associated with the Shenandoah-Dives operation. The two contributing buildings are the Shenandoah-Dives Mill and the office/assay building. The two contributing structures are the water and coal storage tanks.

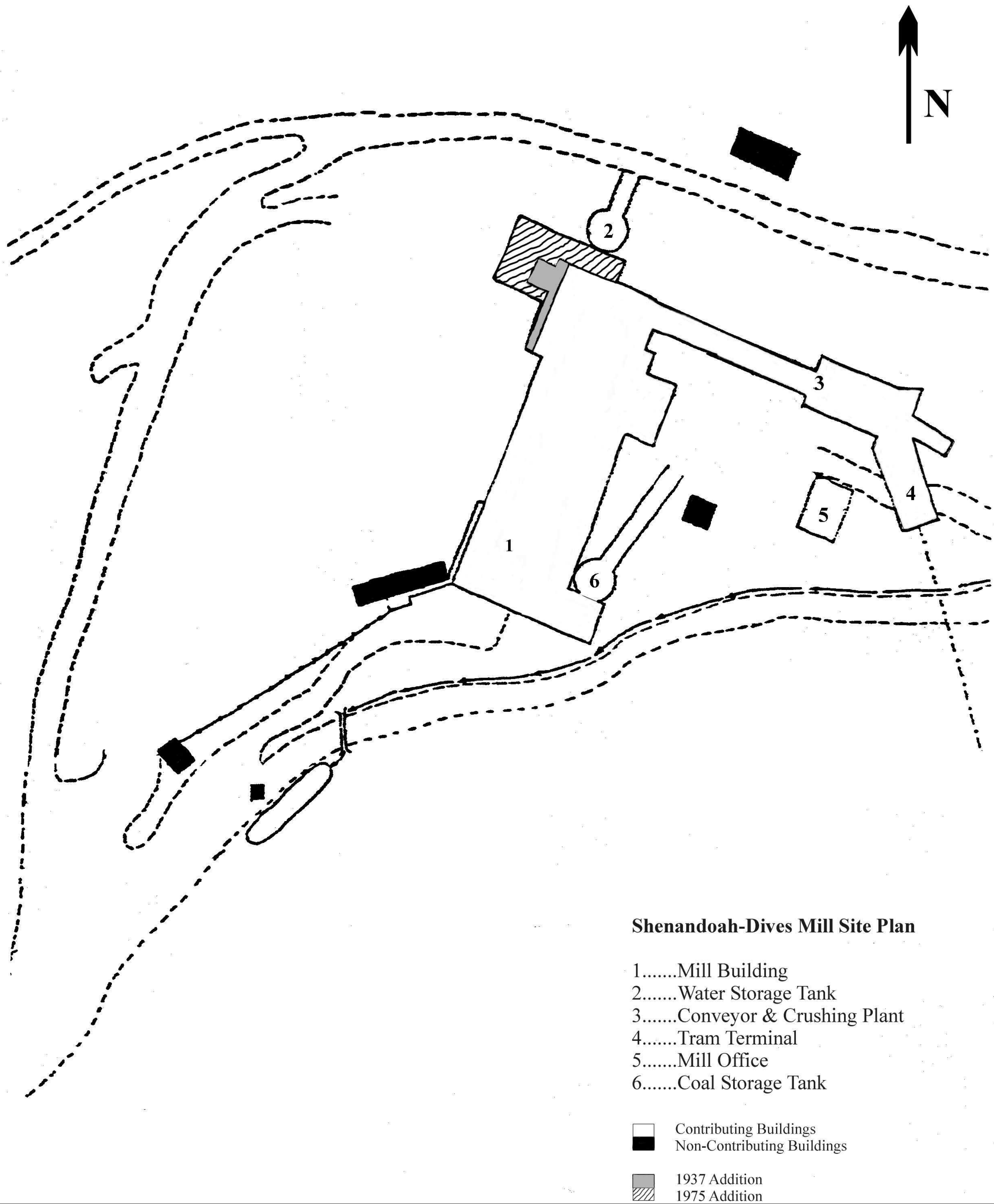
Contributing Resources
Shenandoah-Dives Mill including the equipment from period of significance (building)
Shenandoah-Dives Water Storage Tank (structure)
Shenandoah-Dives Mill Office/Assay Building (building)
Shenandoah-Dives Coal Storage Tank (structure)

Non-contributing Resources

The proposed Shenandoah-Dives Mill NHL also includes six noncontributing resources: four buildings, one site and one structure. The mill has a non-historic guard shack (building), valve house (building), lime storage building (building), trailer (building), electrical transformer (structure), and decantation/tailings ponds (site). All the noncontributing buildings were constructed outside the 1929-1945 period of significance. The electrical transformer dates to 1929 but has lost its integrity due to the construction of a new support system and enclosure of some of its equipment. The tailings ponds site has been significantly reclaimed and no longer reflects its historic appearance and integrity, other than the grass knolls next to the millsite.

Noncontributing Resources
Shenandoah-Dives Guard Shack (building)
Shenandoah-Dives Valve House (building)
Shenandoah-Dives Lime Storage (building)
Shenandoah-Dives Trailer (building)
Shenandoah-Dives Electrical Transformer (structure)
Shenandoah-Dives Tailings Ponds (site)

Shenandoah-Dives Mill Site Plan:



Summary of Contributing Resources

Constructed in 1929, the Shenandoah-Dives Mill (refer to mill site plan on pg. 6) was designed for milling metal ores from low-grade gold ore (ore that is relatively poor in the metal for which it is mined). The mill processed five metals: gold, silver, copper, lead, and zinc. In operation until 1992, the Shenandoah-Dives Mill contains virtually all of its working components enclosed within a 1,000-ton mill complex. The mill complex includes the mill building, conveyor and crushing plant, tram terminal, water and coal storage tanks, and mill office/assay building. The emphasis of this nomination is upon the technology of the flotation process.

The Shenandoah-Dives Mill complex is an excellent representation of 1920s-era American milling technology in its original processing format. Since its construction, only minor changes, in an effort to increase production capacity, have been made to the mill facility. The mill has integrity in all seven qualities: location, design, setting, materials, workmanship, feeling, and association.

The Shenandoah-Dives Mine and Mill are in the Animas Mining District of the San Juan Triangle. The mine is on the south slope of Little Giant Mountain in the section of the range referred to as King Solomon Mountain; the mine's portal is 11,200 feet above sea level (asl). The mill (9,700 asl) is two miles northwest of the mine, at the base of Arrastra Gulch near the Animas River. A 9,526-foot aerial tramway connected the mill complex with the Mayflower portal of the mine.[2] The Shenandoah-Dives Mill, which is locally referred to as the "Mayflower Mill" after the Mayflower portal of the mine, is two miles northeast of Silverton on Highway 110.

The aerial tramway, which connected the mill to the Shenandoah-Dives Mine, is not included in the proposed NHL boundary. While the tramway plays an integral part in delivering the ore from the mine to the mill site, it is not an actual component of the flotation technology within the mill. The Shenandoah-Dives Mill NHL nomination is focussing upon the unique technological components inside the mill and not the architectural (design and construction) significance of the overall mill site. Aerial tramways were the norm for high altitude mines to deliver ore from the mine to the millsite, although their numbers are reduced each year due to vandalism, salvaging, or severe weather conditions. The Shenandoah-Dives mine will be capped and is not included due primarily to its lack of historical integrity. The mine buildings burned down sometime in the 1970s and the equipment removed from the mine affecting its integrity. The mine itself possesses no nationally significant associations.

The first stage of the milling process is crushing and grinding the mined ore. Machines used for crushing are generally one of three types: reduction gyratory crushers, jaw, or rolls. The ore from the Shenandoah-Dives claim was originally crushed at the mine in an underground crushing plant that housed a Telesmith 16-A gyro primary crusher and a 4-foot Symons standard cone crusher. The underground crushing plant crushed the ore to approximately ½-inch-size gravel. Unlike other crushers, the gyro primary crusher can process a large capacity of ore. Nevertheless, the

[2] "Report to the Bureau of Mines, State of Colorado for the year 1930: Metals, Mines, and Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 15 August 1930.

Symons standard cone crusher quickly became the standard in the industry after a vigorous marketing campaign.[3] Laborers loaded crushed ore into aerial tramway ore buckets at the upper terminus of the aerial tramway, and sent them down the mountain to the mill where it was unloaded into ore bins at the tram building.

Production from the mine quickly outpaced the size of the Shenandoah-Dives Mill. In addition, requests from other Silverton mining companies to process their ore prompted Charles A. Chase, General Manager of the Shenandoah-Dives Mine and Mill, to react quickly to demand. In August of 1936, five years after the construction of the mill, Chase ordered a custom ore crushing and sampling plant (non-extant) built adjacent to the mill to process ore from other mines in and around Silverton. The sampling plant was a two to three story, frame building with six bins for receiving. In the year the sampling plant was built, fourteen local mines sent their ore to the mill. Continuation of contracts generated additional revenues for the Shenandoah-Dives Company for several years.[4]

Eventually, new demands on the plant encouraged redesign of mill metallurgy from a bulk flotation product (gold-copper-lead-iron) to selective (gold, copper, lead, iron, and zinc) recovery.[5] The flotation circuits were designed for specific product change by the addition of reagents in the water bath in the flotation cells. The three products recovered were shipped to respective smelters. In order to increase tonnage to 700-725 tons per day and increase percentage of recovery, an additional ball mill (Stearns-Rodgers 6x5, No. 6 on Flow Sheet, refer to pg. 12) was added to the crushing stage in an extended portion of the building. This resulted in the plant maintaining full-production levels and running more efficiently. Despite the addition of another ball mill for a secondary grind, the integrity of the complex remains intact because the addition was minor with respect to its affect on the entire complex.

The metallurgist in the sampling plant crushed, assayed, and milled samples from the Shenandoah-Dives Mill. When metallurgists realized the proper mix of ingredients needed for highest recovery, the information was relayed from the sampling plant to the mill and incorporated in that particular bank of flotation cells. For example, if zinc was desired, the test sample was worked to recover the highest levels of zinc. The formula was then incorporated in the bank of zinc flotation cells. The same process produced formulas for copper and lead. Higher percentage of metal recovery was of utmost importance to the mill man and owners of mills. It could mean financial success or failure for a mill. The mill’s payment or settlement to the owner of the ore was dependent upon the recovery percentage of loads processed.[6]

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[3] Robert Richards, *Textbook of Ore Dressing* (New York and London: McGraw-Hill Book Co., Inc., 1940), 19-20 and A. M. Gaudin, *Principles of Mineral Dressing* (New York and London: McGraw-Hill Book Co., Inc., 1939), 35-36.

[4] William Jones, correspondence to Dawn Bunyak, 21 April 1996.

[5] William Jones, correspondence to Dawn Bunyak, 1 December 1998.

[6] William Jones, interview by Dawn Bunyak, Silverton, Colorado, 15 June 1995.

Shenandoah-Dives Mill building

The Shenandoah-Dives Mill, a four-level frame and metal building with an irregular floor plan, is a truss-timbered framed building with both gabled and shed corrugated-metal roofs on its various levels. It is located approximately 100 feet north of Colorado Highway 110, the main route between Silverton and Eureka. The massive, sprawling mill building encompassed several milling and processing operations, and the building can be divided into the main mill, tram terminal, conveyor, crushing plant, steel rod mill, and workshop. All of these operations are interconnected and under one roof.

In 1929, the Denver-based Company of Stearns-Roger Engineering designed and oversaw the erection of the gravity-flow mill and its equipment. The mill was built in eighteen weeks from a prefabricated kit.[7] Arthur J. Weinig designed the metallurgical portion of the mill. The four-level building is terraced into the mountainside, which enhances the gravitational flow within the mill. The truss-timber frame of the building is constructed of Oregon fir. Native timber is used for sheeting. The gable and shed roof covering the four levels are corrugated galvanized metal. The exterior was initially painted an aluminum color in 1932, but now has sections painted in aluminum, green, and rust-red. The foundations are concrete.[8] Its current dimensions are approximately 90 feet across the back and 106 feet across the front; the sides are approximately 252 feet. Metal and frame-sided additions reflect functional modifications made at various times; but the overall lines and shape, as well as the technology, of the plant have remained virtually unchanged since its construction in 1929.[9]

Initially, the mill had banks of windows at each of the four levels.[10] In 1981, corrugated-metal siding was placed over the windows, at which time electrical lighting systems were enhanced to supply the needed light. The top or upper level has a gabled, corrugated metal roof. The second level has a corrugated-metal shed roof. The third level has a gabled corrugated-metal roof. The lower level has an aluminum-colored, corrugated-metal, shed roof. On the north side, there are three 9/9 side-by-side stationary windows, located on the third level. The east side contains two sets of triple side-by-side windows (9/9/9), as well as one 9/9 side-by-side set of stationary windows. On the south side of the building, fifteen single-hung, 9-pane windows remain on the

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[7] William Jones, phone interview by Dawn Bunyak, 18 August 1995 and Jones, interview. Due to the evidence of archival photographs and speed in erection of the mill, it is surmised that the mill was designed and pre-cut in Denver, bundled up, and shipped to Silverton for erection by the construction crew.

[8] Jones, interview; Allen Nossaman, personal interview by Dawn Bunyak, 13-15 June 1995; "Report to the Bureau of Mines, State of Colorado for the years of 1927, 1929, 1930: Metals, Mines, and Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 8 February 1928, 28 May 1929, 6 December 1929, and 15 August 1930.

[9] Nossaman, interview; Report to the Bureau of Mines, State of Colorado for the years 1929-1930: Metals, Mines, and Mills, submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 28 May 1929, 6 December 1929, and 15 August 1930; and Colorado Historical Society Historic Building Inventory Record filed by Allen Nossaman on the Mayflower Mill, 1995.

[10] Mayflower Mill of the Shenandoah-Dives Mining Company in Silverton, San Juan County, Colorado, Photographs, 1930 and 1932, Mining Collection, Western History Department, Denver Public Library, Denver, Colorado.

third level. On the west side, there are six 9/9 double-hung windows on the third level. Over eighty windows were in the mill when it was built in 1929. Six stationary 9-pane windows are in the conveyor house that runs from the crushing plant to the mill proper.

The tram terminal is a rectangular single-story, frame and metal building with a gabled corrugated-metal roof. It was originally built as a single-story, frame building in the side of the mountain. When the crushing plant was added to the mill, the rear of the tram terminal, left intact, was enclosed inside the plant. A truss-timber frame supports the front (northeast side), which includes the lower terminus opening for arriving ore buckets. Fred Carstarphen, who designed the tramway, designed the tram terminuses. Carstarphen also directed the twelve-man crew that constructed the tram terminal. The rectangular building is approximately 28 feet x 60 feet and houses the tension equipment for the aerial tramway, the shop for tram repairs, and the loading end of the 200-foot ore conveyor to the mill. The building has corrugated metal siding. The north side retains its original set of four 6/6 double-hung windows. The roof is gabled and covered with corrugated metal.[11]

An attached frame-and-corrugated metal workshop is on the north side of the mill building. The workshop has overall dimensions of 24 feet x 44 feet with a corrugated metal shed roof and exposed rafters. The workshop was built in 1929 at the same time as the mill. It has eight 9/9 double-hung windows on the north side. The machine and welding workshop was used for maintenance on machinery within the plant, as well as fabricating engines and small locomotives for use in the mine. Flat cars on railroad lines hauled large pieces of equipment into the workshop for maintenance. The rail lines within the shop were thirty inches apart, matching the lines at the mine. The fabricated machinery was transported to the mine via the aerial tramway.

Inside the mill plant, the original milling machinery remains virtually intact, despite periodic upgrades including the addition of a rod mill and crushing plant within the mill complex. Most of the original machinery was used throughout the entire productive life of the plant and remains functional. The 1942 flow chart shown on page 12 reflects the processes that were used in the mill operations. In 1942, the War Production Board, who had closed plants processing gold or gold by-products, granted the mill permission to continue production for base metals. Typically, the plant would have processed a by-product gold concentrate, so the years before and after this flow chart would have included the gold concentrate circuit.

Milling Process: Flotation

From the ore pocket, a 24-inch-wide pan conveyor moved the ore to a 250-foot gradient belt conveyor, which transported the ore to a round, steel ore bin located within the mill. The 250-foot belt conveyor is housed in a gabled frame-and-corrugated-metal structure. From the 1200-ton ore bin (1 on the flow sheet on page 13), the rock traveled via a 24-inch-wide pan conveyor (2) to a four-foot Symons short head cone crusher (3) which dropped into the No. 86 Marcy grate ball mill (4) where the ore was ground further with steel balls in the revolving center cavity. The

[11] "Report to the Bureau of Mines, State of Colorado for the years of 1929 and 1949: Metals, Mines, and Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 6 December 1929 and 8 February 1950; Barge, "History of Shenandoah," 6; Hunt and Banks, "Operations of Shenandoah-Dives," 49 and "Shenandoah-Dives," *Mining World*, 6.

Marcy ball mill was a wet-crushing mill with water being introduced to the crushed ore at this juncture.[12] At this stage, the product was thin ore mud.[13] The mud then traveled through a distributor (5), which is another "screening" process; trommel (8); another screen; and to three Wilfley tables (10). The Wilfley tables, activated by electricity, vibrated the muddy water introduced at the upper side of the table (feedside), separating coarser material as it flowed across the grooved table. The heavier, higher-grade concentrate (lead and gold) settled along the grooves at the bottom of the table (concentrate side). From the concentrate side of the Wilfley table, the heavy concentrates rode off the table edge into two settling or dewatering device (19), such as a Dorr thickener. The thickener (19) and settling tanks (31) removed the water from the mud. The thickener was a conical, settling tank with slow moving rakes. The coarser material settled into the bottom of the cone. The rake moved through the material causing lighter minerals to rise and wash off into a launder (filter) that carried the concentrate to a settling tank where a final drying process took place. The water was then filtered and returned for mill use. From the settling tank, the dry concentrate was scraped off and moved into a bin (34), to await transport.

The oversize of the gravel material that could not pass through distributor screen then traveled by elevator to a 12-foot x 26-foot Dorr Classifier (5), where it was again washed and separated. The oversize was returned to the ball mill for further grinding, reprocessing, and screening (4, 6, 5, and 8). The overflow continued on its way to the 40-cell bulk flotation circuit (11 and 12).

In the flotation unit, the flow of mud went through three types of cells: cleaners, roughers, and scavengers. The cleaner cells had a mild concentration of reagents and short flotation time. The scavenger cells had a higher concentration of reagents and a longer flotation time. The water bath in the minerals-separation circuit was treated with an alkaline reagent. Individual reagents attracted particular minerals to the foam (froth) atop the water in the cells. Depending on the metals that were to be the end result of the process, different reagents were introduced to the process.

Each cell had an agitator and low-pressure blower that introduced a flow of air bubbles in the agitating compartment. The flow of air entered through the feed inlet. The agitator blades stirred up the mix causing the froth to overflow and coarse sand to drop to the bottom. The coarse sand either returned through the grinding process or passed out as a tailing discharge. The concentrate, buoyant on the froth, was drawn off the top of the water in the froth-separating compartment.

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[12] A. M. Gaudin, *Principles of Mineral Dressing* (New York and London: McGraw-Hill Book Co., 1939), 94-97 and Hunt and Banks, "Operations of the Shenandoah-Dives," 51.

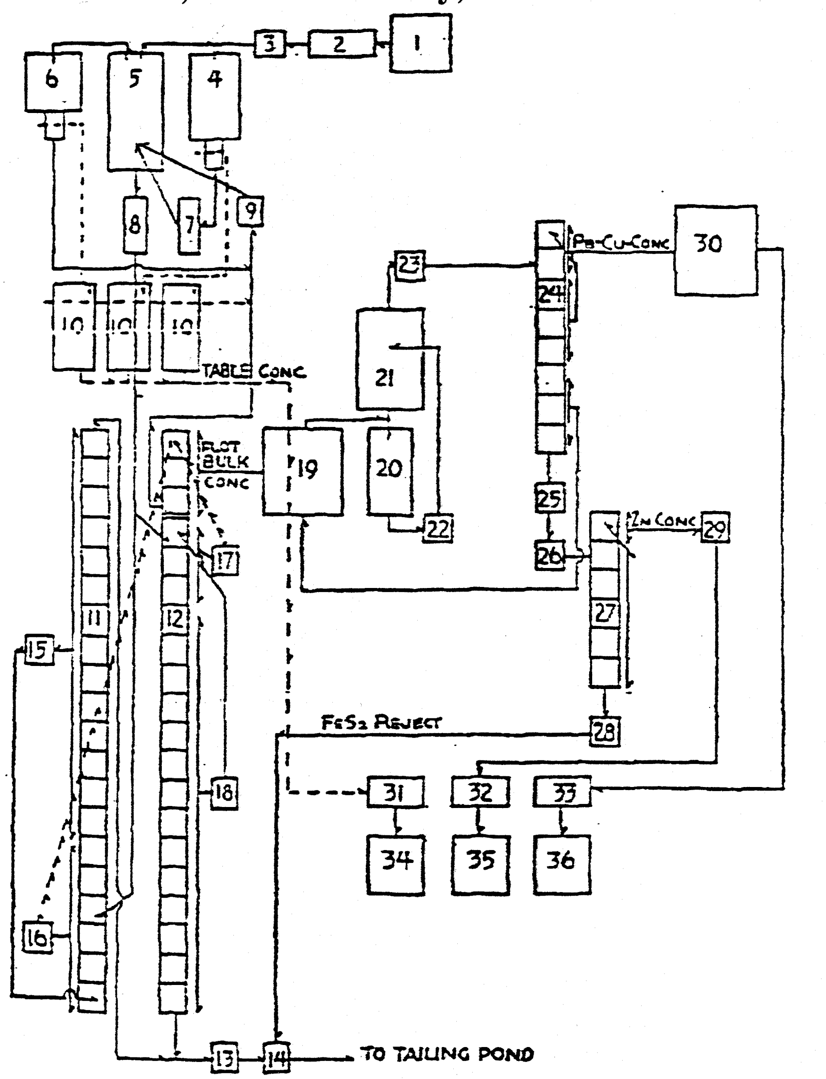
[13] Paul W. Thrush, *A Dictionary of Mining, Mineral, and Related Terms* (Washington: U. S. Dept. of Interior, 1968), 1026.

Fig. 1-**Flow Sheet of the Shenandoah-Dives Mill**

1942 Flow Sheet:

1. 1,200-ton ore bin
2. Pan conveyor, 24"
3. Symons short-head cone crusher
4. No. 86 Marcy grate ball mill
5. Dorr quadruplex classifier 12'x26'
6. No. 64 Steams-Roger ball mill
7. Bucket elevator 35'x22'
8. Trash trommel, 9-mesh, 2-1/2'x6'
9. Belt elevator 24"
10. Three No. 6 Wilfley tables
11. 20-cell No. 21 M.S. flotation
12. 20-cell No. 21 M.S. flotation
13. Liberty Bell type sampler
14. Hydroseal pump, "B" frame size
15. Wilfley pump, 2"
16. Wilfley pump, 2"
17. Wilfley pump, 2"
18. Wilfley pump, 2"
19. Dorr thickener, 35'x10'
20. Stearns-Roger ball mill, 4'x10'
21. Esperanza-type classifier, 6'x16'
22. Wilfley pump, 3"
23. Wilfley pump, 3"
24. 8-cell No. 18 Denver flotation
25. Denver conditioner, 3-1/2'x5'
26. Wilfley pump, 2"
27. 6-cell No. 18 Denver flotation
28. Liberty Bell type sampler
29. Denver 1" concentrate pump
30. Dorr thickener, 35'x10'
31. Settling box, 3'x6'x2'
32. Dorr filter 2-1/2'x6'
33. Dorr filter 5'x10'
34. Table concentrate bin
35. Zn concentrate bin
36. Pb-Cu concentrate bin

Flow Sheet
Of the Shenandoah-Dives Mining Co.
Mill, San Juan County, Colorado



The copper-lead concentrate from the first Minerals Separation flotation machine traveled to a Dorr thickener tank 35 feet in diameter (19). In the Dorr thickener, the concentrate was "de-watered" (the water returned to the mill) and sent on for crushing (20), classifying (21), and flotation (24). A thickening agent was added in the Dorr thickener to the tailing to cause overflow of water for recycling. The concentrate traveled into a 5-foot x 10-foot Dorr filter (33). The filter was a drum that revolved, forcing the water out and the mineral to attach to its sides. The minerals were then scraped from the sides of the drum and moved to an 18-foot x 18-foot x 12-foot concrete concentration bin (36) to await transport to a smelter. (The Dorr filter was later replaced with a disc filter or "canvas wheel" (same function) that took less space and processed a dryer concentrate.)

In order to gather the zinc particles, the process changed slightly. After passing through the Denver-built, Minerals Separation machine (24), the tailings were then zinc reactivated to pass through the Denver conditioner and Liberty Bell type sampler and flotation cells (25, 26, 27, 28) where the product was separated into a zinc concentrate or a reject product of waste. After the zinc concentrate was separated, it was pumped (29) to a 2-1/2 foot x 10-foot Dorr filter (32) to be separated from the water. The dry concentrate was moved into concentration bin (35) to await transport to a smelter.

The 1942 process changed over time with circuits added for processing a total of five concentrates, but it used basically the same technology and machines as listed on this flow sheet (refer to fig. 1, pg. 12). Simply stated, the ore cycled and recycled a muddy flow through grinders, sorters, separators, and dryers before ending up in concentrate bins awaiting shipments.

An inventory of the buildings in 1929 listed the mill, tram terminal with aerial tramway, sampling plant, office and assay building, electrical transformer, and two stave water storage tanks.[14] In 1937, a 6-foot x 5-foot ball mill was added, making a total of two ball mills. The plant processing capacity was then 700 tons.[15] In the 1960s, as the mill began to purchase more ore, the owners added to the technology of the main mill with the addition of a zinc circuit for processing three concentrates: lead, zinc, and copper.[16]

Mill Additions

In 1961, Standard Metals Corporation, the owners at the time, removed the mill's frame sampling plant located behind the mill and conveyer and replaced it with a new crushing plant. This plant allowed for the recovery of a smaller sample or grind (release of metals from waste rock) and increased the percentage recovered and sent to smelters. The new plant included the removal of the vintage sampling plant and construction of the currently existing metal building on the same site. The crushing plant is attached to the mill building through its 250-foot

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[14] "Report to the Bureau of Mines, State of Colorado for the year 1929: Metals, Mines, Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 28 May 1929.

[15] "Report to the Bureau of Mines, State of Colorado for the year 1937: Metals, Mines, Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 5 January 1938.

[16] Jones, correspondence, 1 and 21 April 1996.

conveyor system. The building is approximately 40 feet x 60 feet with a gabled corrugated-metal roof.

A large coarse ore bin was designed and included in the new plant. The coarse bin allowed truck-hauled ore from other mines, including the American Tunnel located in the San Juan Mountains, to be processed at the Shenandoah-Dives Mill. In addition, two short-head cone crushers were moved from the mine; as well as, one of the ball mills from the mill was moved to the new plant.[17]

Up to 1961, the mill had processed ore from the Shenandoah-Dives Mine, as well as some custom ore from mines in Silverton. Construction of the new crushing plant allowed the Shenandoah-Dives Mill to process ore from even more mining operations in the area not only the company mines, including the Silver Lake lease and small, independently-owned mines.

The new plant became strictly a crushing facility and is the same size as the vintage sampling plant. At one time, the metallurgist's sampling stage was moved to the historic Animas Power and Water Company substation, also owned by Standard Metals and used as a storage facility. Nevertheless, removal of the frame sampling plant on the Shenandoah-Dives Mill site in no way affected the product flow through the mill. The crushing plant reflects the activity of the sampling plant it replaced. Furthermore, the original footprint of the mill and mill site remains the same.

Despite these changes, the flow of the ore was only altered in the fact that the ore was now removed from the pocket ore bins, crushed in the plant, and then transported up the 250-foot conveyor to the mill. The rest of the process remained the same.

As technology advanced, Standard Metals Corporation continued to upgrade the operation. In 1975, a steel rod mill, which could grind a finer product, was added to the southwest corner of the mill (refer to Shenandoah-Dives Mill Site Plan, pg. 6). The steel rod mill, which was approximately 62-1/2 feet x 50 feet with a corrugated-metal shed roof, was added to the uppermost level of the mill in the southwest corner (where the two ball mills processed the ore). The rod mill was joined to the exterior corner of the mill plant with corrugated steel walls. An exterior stave water tank was torn down during the construction of rod mill extension. The original exterior corner of the mill remains and suitable openings were made in the walls for doors, pipes, conveyors, and lines as needed.[18] In order to feed the new rod mill extension, a short section was added to the original conveyor feeding from the bottom of the fine ore bin. No substantive change was made in the original grinding stage; it was simply a matter of re-piping the pulp flows. The rod mill addition had its own electrical substation and controls.

The rod mill was added as a component of the secondary grind stage, where a ball mill was already in place. With the addition of the steel rod mill, the ore that had been previously crushed to approximately three-fourths inch was processed further, resulting in a fine grind about 1/8 to

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[17] Jones interview.

[18] Jones, correspondence, 1 December 1998.

1/10 inch in size.[19] With a finer grind, the mill now processed 1,000 tons-per-day. In addition, the mill's stave water tank was torn down. The stave tank was located under the 1937 shed roof addition on the southwest corner where the rod mill was added. The rod mill reflects the activity of the original flow of product through the mill, in particular this stage of the recovery process

At the end of the milling process, the final tailings were pumped to tailings piles or slurried into the Animas River. In 1934, after researching methods that were believed to be environmentally sound, Mill Superintendent Charles A. Chase decided to use an innovative tailings pond method perfected and utilized by J. T. Shimmin in Butte, Montana. Altering this method to fit the Shenandoah-Dives Mill's specific needs and terrain, the Shenandoah-Dives Company began depositing its surplus into tailings ponds south of the mill. A chute or tailings flume delivered the pumped tailings to the pond area. At the time, the utilization of tailings ponds was atypical for the mining industry as a whole. Generally, environmental concerns were not at the forefront of the industry's interests; profitable veins of ore were of greater concern. As a result, the mill was one of a limited number of mining enterprises that employed environmental, as well as cost-efficient, methods in their day-to-day activities.[20] Tailings from the Shenandoah-Dives Mill were directed to the south of the plant and created four "ponds" over its years of operation.[21] During reclamation of the tailing ponds, bulldozers radically altered the landscape of the pond site into two grassy knolls to the south of the mill site.

Other Contributing Resources

Water Storage Tank

The 24 feet x 20 feet circular water storage tank built in 1929 is constructed of wooden staves; numerous steel rings hold the staves in a cylindrical shape. The conical roof is fashioned with

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[19] "Report to the Bureau of Mines, State of Colorado for the year 1962 and 1975: Metals, Mines, Mills," submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 21 January 1963 and 15 December 1975; Jones, interview; Darnall Zanoni, personal interview by Dawn Bunyak, 13-15 June 1995; Nossaman, interview; and photographs, Western History Collection of the Denver Public Library, Denver, Colorado.

[20] Duane A. Smith, *Mining America: The Industry and the Environment*, 1800-1980 (Kansas City: University of Kansas Press, 1987), 34-41.

[21] A V-shaped box delivered the tailings to the pond area. The box was made of two 2-inch planks; one was twelve inches wide, the other was ten inches wide. The box was supported by a twenty-foot-high trestle that was set on gradient to initiate flow of the tailings. Upon arrival at the pond, the tailings were distributed by a grooved 20-foot-long board to form a "wall of sand" in the shape of pond. The technician would move the board periodically to retain a level top to the pond. In order to draw off water without stirring up the sediment, a wooden box was laid in a trench up the hillside prior to depositing the tailings. The top of the box had a series of holes 1-1/2 inch in diameter. As the water level rose, the lower hole was corked off to elevate the water level. As each subsequent hole was reached, a cork was placed in the hole. Once an established level of water was attained, the water was drained off through pipes into a decantation pond located on a lower plane than the tailing ponds. In practice, only a small amount of water was actually decanted or lost through evaporation. The hillside absorbed the greater volume.

[21] As each tailing pond filled to capacity, the flume was lengthened and another pond was begun. At the Shenandoah-Dives Mill, the ponds filled a triangular shape, following the mill's property lines. Four ponds are located within the triangle. The two oldest ponds, #1 and #2, are from the 1930s to 1950s; while #3 and #4 ponds were created from 1970 to 1990.

timber supports and sheeting, which is covered with asphalt shingles applied in a circular fashion. The tank is located on the west side of the mill near the steel rod mill. A wooden, timbered ramp runs from ground level to the roof of the tank. An opening, approximately two feet square, is at the end of the ramp. Several steel pipes run from the tank into the steel rod mill. Although only one water tank remains, a 1929 mining report notes that there were two stave water storage tanks. Based on historic photographs, the second tank, which was approximately 20 feet in diameter, was located where the steel rod mill was added in 1975.[22]

Coal Storage Tank

The circular coal storage tank is built of wooden staves and steel rings with a conical roof fashioned from timber supports and sheeting covered by asphalt shingles. It is located on the north side of the mill. The tank, built in 1929, is on the lower (or fourth) level and is placed under the truck ramp. A chute is located near the pinnacle of the conical roof. Trucks used the loading ramp leading to the top of the storage tank to unload coal.

Office/Assay Building

The Shenandoah-Dives Mill office/assay building is a rectangular, two-story frame building with a slightly gabled roof covered in tarpaper shingles. It was completed in the summer of 1929. It has three floors and is 24 feet x 30 feet; the lower floor is terraced into the side of the hill. According to inspector reports, the building has insulex walls and ceilings. The exterior walls are made of Oregon fir timber, native timber sheeting, and tarpaper shingles. The lower floor has an office, three rooms, and a concrete vault. The upper floor contains six rooms and a drafting area. A 1950s report notes that the lower floor was the assay office, and the upper floor held the superintendent's office and sleeping quarters.

On the north side of the building, two upper floors and a partially exposed lower level are visible. The lower level has a covered porch. The next level has three 4-pane, double-hung windows. The top floor has three sets of windows: one set of side-by-side windows, one double-hung window, and a set of double-hung windows. All double-hung windows are 4-paned and covered with screens.

Because of the terraced design of the building, only the two upper levels of the office/assay building are visible on the south side. The ground level has two wooden doors, one solid and one glazed. A set of boarded-up windows is between the glazed door and the stairs to the upper level of the building. There are exterior, wooden steps leading to the glazed door. On this level, there are four 2/2 double-hung windows. A chimney pipe runs up the side of the building.

A road to the workshop and lower levels of the mill runs along side the western side of the office/assay building. Only two levels are apparent on this side of the building. There are three windows visible with two 2/2 double-hung on the upper level. The window on the lower level has a vent protruding from the top half and the bottom is a 2/2.

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[22] Report to the Bureau of Mines, State of Colorado for the year 1929: Metals, mines, Mills, submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 28 May 1929 and 6 December 1929.

Summary of Non-Contributing Resources

The Shenandoah-Dives Mill complex includes four noncontributing buildings, one noncontributing site, and one noncontributing structure. The buildings (guard shack, trailer, valve house, and lime storage building) were built in the 1960s and 1970s and fall outside the period of significance. The tailings ponds, which are counted as one site, are noncontributing due to a lack of historic integrity since reclamation. The electrical transformer, a noncontributing structure, supplied electrical power to the mill and mine. The transformer, installed circa 1929, consists of three 250-kva General Electric transformers on an elevated steel structural support which is fenced and locked.[23] The transformer was initially constructed upon a wooden trestle similar to the coal ramp trestle. Deteriorated supports were replaced with an elevated steel structure in 1978. A small white metal building was added to house some of the electrical components. In the 1970s, Federal Safety Standards required warning signs and yellow handrails around the transformer.

The guard shack, a rectangular frame structure with a gabled corrugated-metal roof, is located at the entrance to the fenced-in mill facilities. The entrance is on the east side, which has two glazed doors with a 1/1 window. Wooden steps lead to each door. The north side has a picture window and glazed door. The west side contains a side-by-side window and glazed door. The southern side has two windows.

The pre-fabricated building is a rectangular, wooden, modular unit with a gabled corrugated-metal that is located on the mill's lower level on its eastern comer. It was installed in 1986 as a shower room for mill workers. A porch was added to the center entryway. One solid door is located to the rear, and one in the center front.

The valve house, a rectangular, corrugated metal building inside the fenced property of the mill, about 30 feet from the guard shack. The valve house shelters the valve to the mill's water system from the harsh winter weather. It is situated on the slope above the decantation pond. The door on the eastern side has a bracketed hood.

The rectangular lime storage building is approximately 50 feet x 40 feet and is principally made of corrugated metal over a wooden frame with a gabled metal roof. The building has a garage door on the northern end. A solid door with a warning sign is next to the garage door.

The Shenandoah-Dives' four man-made tailings ponds cover approximately eighty-five acres, and encompass nearly ten million tons (or approximately five million cubic yards) of tailings residue. The ponds, which are gently sloped and in a truncated conical shape, were designed to enclose water and residue from the processing of ore in the milling process.[24] The four tailings

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[23] Report to the Bureau of Mines, State of Colorado for the year 1929: Metals, Mines, Mills, submitted by Shenandoah-Dives Syndicate for the Mayflower Mine, (County: San Juan; Dist.: Animas), 28 May 1929 and 6 December 1929; and Field Survey, 14 June 1995.

[24] William Jones, phone interview by Dawn Bunyak, 7 January 1997. Jones reviewed maps of the mill site and estimated that the approximate acreage of the tailings ponds as: Pone 1: 33 acres; Pond 2: 23 acres; Pond 3: 4 acres; and Pond 4: 25 acres.

ponds are southwest of the mill site. Although the tailings ponds were an important component of the Shenandoah-Dives Mill, they have been reclaimed and, as a result, have lost their historic integrity. The flat top and gently sloped sides of the tailings ponds have been reseeded with grass to better contain loose material. The decantation pond is located between the tailings ponds and Highway 110.

8. STATEMENT OF SIGNIFICANCE

Certifying official has considered the significance of this property in relation to other properties:
Nationally: X Statewide:_ Locally:_

Applicable National Register Criteria:	A X B__ C X D__
Criteria Considerations (Exceptions):	A_ B_ C_ D_ E_ F_ G_
NHL Criteria:	1
NHL Theme(s):	V. Developing the American Economy 1. Extraction and production VI. Expanding Science and Technology 1. Technological Applications
Areas of Significance:	Engineering Industry
Period(s) of Significance:	1929-1945
Significant Dates:	1929 and 1938
Significant Person(s):	N/A
Cultural Affiliation:	N/A
Architect/Builder:	Metallurgy of mill: Weinig, Arthur J. Mill Design: Stearns-Roger Engineering
Historic Contexts:	XVIII. Technology (Engineering and Invention) F. Extraction and Conversion of Industrial Raw Materials G. Industrial Production Processes XII. Business A. Extractive or Mining Industries

State Significance of Property, and Justify Criteria, Criteria Considerations, and Areas and Periods of Significance Noted Above.

Introduction

With the imminent depletion of the quantity of the world's rich ore supply at the end of the nineteenth century, the mining industry faced a severe crisis. An innovative process known as flotation diverted the crisis. In 1912, flotation was introduced to the American mining industry in a Butte and Superior Mill in Butte, Montana (non-extant). The evolution of the flotation process significantly impacted the industry when flotation efficiently and economically concentrated complex minerals that were practically impossible to treat by earlier methods.

As a result, flotation and its evolution prompted a major shift from costly, underground mines with 500-2,000 tons of ore per day (tpd) mills to the modern open-pit mines and enormous, 60,000 tpd mills operating in the mining industry in the American West. The numbers of employees and miners needed shifted when large mechanized equipment took over human roles. Open-pit mines in turn have had significant environmental impact on the western mining landscape with the removal of tons of ore and surface deposits.

In 1998, a survey of industrial mills from the early flotation era found only four extant 500-2,000 tpd, flotation mills in the United States. During the first half of the twentieth century, industrial mills ranged from 25 tpd to 2,000 tpd range and large mills defined as 500-2,000 tpd. Currently, large mills range from 2,000 to 60,000 tpd. The Shenandoah-Dives Mill is the finest example of a selective flotation mill reflecting the distinctive characteristics of the hard-rock milling process in the early twentieth century. Its technology demonstrates the evolution of the twentieth-century mining and milling industry and the products it made available to manufacturing in the era of American industrialization into the militarism of the United States during the World Wars era. Thus the Shenandoah-Dives Mill and its technology demonstrates the evolution of flotation and its impact on the twentieth-century mining and milling industry.

The Shenandoah-Dives Mill NHL nomination underscores the intent and true nature of the historic mining district of Silverton, Colorado in which the mill is located. The Shenandoah-Dives Mill nomination will: 1) explain why flotation is nationally important, 2) describe the historical aspects of the flotation process and how the mill represents this, and 3) discuss the integrity and representation of the process in the mill.

Period of Significance

The period of significance for the Shenandoah-Dives Mill is 1929-1945. The mill was constructed in 1929 and utilized the latest in flotation technology and manufactured milling equipment at that time. The period ends in 1945 with the conclusion of WWII and the U. S. government's influence on the metals mining industry. After the war, demand dropped drastically for U. S. base metal production causing a slump in the mining industry. After 1945, the history of the Shenandoah-Dives Mill operations reflected sporadic periods of operation and several changes in ownership.

Criteria

The Shenandoah-Dives Mill is nationally significant under Criteria 1. The mill is an extraordinary example of a selective flotation mill reflecting the distinctive characteristics of the hard-rock milling process in the twentieth-century. The Shenandoah-Dives Mill technology demonstrates the evolution of the twentieth-century mining and milling industry and the products it made available to manufacturing in the era of American industrialization into the militarism of the United States during the World Wars era. Demand for minerals prompted the creation of the Shenandoah-Dives Mill in 1929 and mining busts caused its obsolescence in 1992. The Shenandoah-Dives Mill is one of two 500-2,000 tpd mills that possess the highest degree of historic integrity required for NHL eligibility. It is an intact and fully functional mill and includes all of its original equipment from the early twentieth century.[25]

Background

Silverton represents the distinguishing architectural, settlement, and industrial characteristics of a mining community in the Rocky Mountain West. It contributed to the mining and milling industry in the United States and its impact on the expansion and settlement of the American West. Mining in the region began as early as 1765 when the Spaniard Rivera and his men entered the San Juan Mountains searching for minerals. His excursions were the beginning of many that prompted westward expansion and development of the mineral and mining industry in the Rocky Mountain region into the next century. Gold and silver rushes from the 1860s to the 1880s brought miners and speculators into the western frontier and settlement to the region. Base metal mining began during the same period as the silver and gold rushes, when non-precious metals such as lead, zinc, and copper were found in proximity to the gold and silver veins. Eventually, technological advancements and high investment in the hard-rock mining industry replaced the temporary gold fever. Placer gold mining brought transients; hard-rock mining encouraged habitation. Mines were patented and mills erected. New industrial technology was instituted in mines and mills alike. When it was built in 1929, the Shenandoah-Dives Mill became a leader in the region with the latest technology in the industry. Its operation significantly affected the economy of Silverton and the San Juan Triangle.

More importantly, the Shenandoah-Dives Mill documents the transformation of flotation milling in the first half of the twentieth century. Mining history as reflected in the NHL program has been primarily focused upon westward expansion and settlement in the nineteenth century as found in historic districts such as Cripple Creek, Leadville, and Telluride, Colorado. A common factor in each of these districts is a lack of illustrative features of its mining history. The only other twentieth century mining NHL districts are in the Calumet & Hecla Industrial District, which includes the NHL historic districts of the Calumet and Quincy Mining Company located in the Keweenaw Peninsula in Michigan. The dates of significance for these districts cover the period from 1846 to 1930. The Shenandoah-Dives Mill represents the period 1929-1945 and offers an opportunity to expand the NHL representation of twentieth-century mining history.

[25] Bunyak, *Frothers, Bubbles and Flotation*.

Mining in the American West

The 1849 California gold rush launched the United States into a period of western exploration, expansion, and settlement. Early miners used "low tech" methods: hand tools, such as pans, rockers, sluices and water. The gold rush in California was succeeded by gold rushes in many of the Rocky Mountain States. By the 1860s, mining spurred settlement from the Rocky Mountains to the shores of the Pacific. After the Civil War, explosive growth in big business, fueled by eastern entrepreneurs, changed the face of mining in the West. By the late nineteenth century, mining evolved from the single miner with his packhorse to entrepreneurs and syndicates backing large-scale mining entities. Most precious metals, e.g. gold and silver, are buried deep within the mountains and valleys of the West. Excavation and extraction involved drilling, blasting, hoisting, and hauling from open mine shafts and tunnels to bring up the ore. Benefication (the ore processing stage) includes crushing, concentrating (e.g. gravity, flotation, amalgamation, leaching), and smelting. Railroads crisscrossed the western region allowing movement of ore to smelters in industrial centers throughout the United States. Miners and mine owners continued to be affected by the ever-constant rise and fall of the economic market, which was affected by depressions, wars, monetary standards, and supply and demand for metals.

In the nineteenth century, the mining industry realized they were nearing an eventual depletion of the world's supply of high-grade ores, ore bodies with a high percentage of a single metal. Rapid growth in industry accompanied by an increase in use of natural resources was depleting the world's high-grade metals supply. Compounding the problem were the types of ores remaining. Historian Jeremy Mouat maintains "the crisis with which the mining industry had to deal with in the 1890s resulted from the pattern developing in many of the newly opened mines: the deeper they went [searching for high-grade ore], the more complex and consequently more difficult to treat the ore became." The cyanidation process treated low-grade gold ores economically, but it wasn't until the flotation process was discovered that low-grade and complex ores could be treated efficiently and readily supply the world with base metals. "Flotation enabled the mining industry to exploit complex ores that were virtually impossible to treat profitably by earlier methods," Mouat asserts.[26]

Initially, miners and the mining industry focused upon the highly valuable precious metals, gold and silver. Historians Michael Malone and Richard Etulain contend that "in the wake of the Panic of 1893, precious metals faced a dreary future: the best high-grade veins had, for the most part, been mined out, and silver had lost its primary market when the U.S. government stopped coining dollars."[27] Nevertheless, growing electrical and telephone industries in the nineteenth century created a huge demand for copper. As the American manufacturing industry's demand

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[26] Jeremy Mouat, "The Development of the Flotation Process: Technological Change and the Genesis of Modern Mining, 1898-1911," *Australian Economic History Review* 36, No. 1 (March 1996): 4 and 6.

[27] Michael Malone and Richard Etulain, *The American West:: A Twentieth-century History* (Lincoln & London: University of Nebraska Press, 1989), 23. For more information, refer to Frank R. Milliken's Introduction and Charles W. Merrill and James W. Pennington, "The Magnitude and Significance of Flotation in the Mineral Industries of the United States," *Froth Flotation: 50th Anniversary*, ed. D. W. Furstenau (New York: American Institute of Mining, Metallurgical and Petroleum Engineering Inc., 1962), 1-3 and 55-56, and Mouat, "The Development of the Flotation Process," 3-5.

for base metals developed, miners and mining operations sought base metal sources in the United States and around the world.

Thus, the mining industry turned to ores formerly considered sub-marginal: complex ores, low-grade, off-grade materials, and waste products. (In the United States these types of ore are largely found in the western, mountainous region.) The industry realized that materials they once considered worthless, because it was too expensive to profitably separate the metals from the waste, would be the only available deposits for mining. The question was how to find a more efficient means of concentration to process these products. And it had to be found quickly. Simultaneously, the world market struggled with this problem and historians note that this crisis and experimentation with flotation facilitated significant developments in grinding and classifying methods in mining and milling in the world's principal mining regions.[28]

At the time, there were principally two ore processing methods available, heat and non-heat. Smelting used heat to "melt" the metals out of waste. Alternative concentration methods did not use heat and were based upon the principle of gravity and harsh chemicals; they include gravity concentration, chlorination, amalgamation, and later cyanide heap leaching.[29] However, these simple concentration methods could not be used cost-efficiently on low-grade or complex base-metal ores. While relatively high-grade ores can be smelted directly, smelting is quite costly per ton of material treated. So companies found it was more economical to concentrate low-grade ores first and then smelt the concentrate.

Inventors in Australia, Great Britain, and the United States developed through a series of experiments the process of flotation that could concentrate low-grade ore. The process included crushing ore to a fine powder, mixing it with chemically laden water, introducing bubbles to a water bath, and minerals adhering to bubbles, which float to the surface. The mineral-laden froth is scraped off and dried. In 1905, an Australian mill unlocked the economical concentration process for minerals (metallic and non-metallic) through flotation.[30] The process, as well as mill design, made flotation commercially viable. By 1912, flotation was in use in the United States.

The first two decades of the twentieth century mark a period of growth and development in the mining industry and with it the revolutionary application of new technologies. Inventors in Australia, Great Britain, and later, the United States designed and perfected extractive processes, crushing technology, and milling operations. Mouat points out that flotation "allowed vast underground areas to be sent to the surface for treatment or, alternatively, mechanized excavation to be carried out in huge open pits."[31] Malone and Etulain note that whereas the concentration of copper ores by the new flotation method made it easier and cheaper to reduce lower-grade ores,

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[28] Mouat, "The Development of the Flotation Process," 3; A. M. Gaudin, *Flotation* (New York & London: McGraw-Hill, 1932), 53; Milliken, "Introduction," 1-3; and Malone and Etulain, *The American West*, 23-24.

[29] Don L. Hardesty, *The Archaeology of Mining and Miners: A View from the Silver State* (Ann Arbor, MI: The Society for Historical Archaeology, 1988): 39-51. In addition, it is important to recognize that cyanide is used on low-grade ore for the recovery of gold, but not for base metals as it is an efficient means of recovery.

[30] In addition, the paper production industry found flotation useful.

[31] Mouat, "The Development of the Flotation Process," 25.

open pit mines proved a dramatic new way of mining. Secondly, flotation made new resources commercially available that could not be treated by older metallurgical methods and took over the benefication field formerly occupied by gravity methods. Flotation marks the passing of the stamp battery and vanner and it decreased the importance of the Wilfley table and jigs.[32] However, it marks the beginning of grinding circuits with balls, rods, and tube mills that made flotation possible.

Mining professionals and historians agree that mineral technology advanced more during the first decades of the twentieth century than ever before in its history.[33] Historian Mouat asserts that although "patented inventions and complex machinery" were part of the reorganization of the mining industry, "the development of flotation was the greatest single metallurgical improvement of the modern era."[34] In addition, Mouat declared,

> As a result the exhaustion of high-grade ores no longer appeared to signal the end of the mining industry: flotation guaranteed that low-grade and complex ore deposits could be tapped successfully and thus the industrialized world's considerable appetite for base and precious metals could be satisfied. It is not overstating the case to claim that flotation's development was of central importance to the smooth functioning of the global economy, for without it metals such as copper, lead, and zinc would have become increasingly difficult to produce and their price would have risen as a consequence.[35]

The president of a mining company announced without flotation "there would be no mining industry as we know it today, because virtually the entire world supply of copper, lead, zinc, and gold is first collected in the flotation process."[36] Those in the mining industry pointed out flotation made the concentration process easier, cheaper, and improved the purity of the

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[32] Malone and Etulain, *The American West*, 23-24; Milliken, "Introduction," 9; Mouat, "The Development of the Flotation Process," 35; and Merrill and Pennington's "The Magnitude and Significance of Flotation in the Mineral Industries of the United States," 56.

[33] In 1962, Frank Milliken, President of Kennecott Copper Corporation exuberantly offered in his introduction for the *Froth Flotation* that mineral technology "advanced more during the short space of the last fifty years than in the five thousand years or more since the invention of smelting (3). Malone and Etulain and others, less exuberantly, acknowledge that the twentieth century technological advances employed in mining and milling operations forever changed the mining industry. See Merrill and Pennington's "The Magnitude and Significance of Flotation in the Mineral Industries of the United States" and Mouat's "The Development of the Flotation Process."

[34] Mouat, "The Development of the Flotation Process," 25; Michael Malone, *The Battle for Butte: Mining and Politics on the Northern Frontier, 1864-1906* (Helena, Montana: Montana Historical Society Press, 1981), 202; and "The Trend of Flotation," *Colorado School of Mines Magazine* 25 (January 1930): 20.

[35] Mouat, "The Development of the Flotation Process," 4.

[36] Milliken, "Introduction," 1.

concentrate.[37] More importantly, one historian declared "it was the time when custom and tradition were replaced by technical knowledge and technical control."[38]

The minerals market took off and remained relatively constant until the depression of the 1930s. However, World War II created a demand for metals in manufacturing armament. Market demands caused base-metals production (copper, lead, zinc, iron, and molybdenum) to literally take over the mining industry. During the war years, the U.S. government set controls limiting the extraction of precious metals. Metals for armament was the cry! Government-influenced scrap drives for metal and rubber products initiated destruction of the earliest historic mining structures. After WWII, while other industries flourished, base-metal mining in the West languished under high costs of labor and diminishing markets. Foreign mining companies flooded the U.S. market with low-priced metals in the 1950s, prompting industry-wide closures of mines and mills. By the 1960s and 1970s, heavy equipment, open-pit mines, and mammoth mills and smelters became the norm of the American industry. Currently, these giants in the minerals industry remain its leaders.

Importance of Metals in Society

Our highly technical society generally takes metals for granted. With the flip of a switch or the turn of a knob, electricity flows throw a number of systems. Metals are used in the building of homes, offices, and plants. Metals make up the infrastructure of electrical networks, including communication, lighting, and power. Metals are used in the manufacture of cars, trains, and planes. Rubber production is dependent upon zinc, which became critically important with the introduction of the automobile. In many ways, the infrastructure of society is dependent upon base metals.

Base metals such as copper, lead, nickel, silver, and zinc are found naturally together in ore bodies. Copper is widely used as a pure metal and as an alloy. The most important characteristic of copper is its conductive characteristics. Historically copper's electrical properties were recognized in the eighteenth century. The importance of copper and other base metals (lead, nickel, and zinc) was realized with the discovery of the magnetic field and electromagnetic energy early in the nineteenth century. The introduction of battery-operated power, telegraphs and cables, as well as generators quickly followed the introduction of electric energy. An 1866 generator required over 500 pounds of copper strip and wire, while a modern generator contains about fourteen tons of copper for its internal components.[39] During the industrial revolution, copper's conductivity inspired a new field of science, electrical engineering, which led to urban power and light networks.

[37] Malone and Etulain, *The American West*, 23-24, and Merrill and Pennington's "The Magnitude and Significance of Flotation in the Mineral Industries of the United States," 56.

[38] Pierre R. Hines, "Before Flotation," *Froth Flotation*, 9.

[39] B. Webster Smith, "The Development of the Dynamo" in Chapter "Copper in Electrical Engineering," in *Sixty Centuries of Copper*, [book on-line] (London: UK Copper Development Association, 1965, accessed 25 January 1999); available from http://60centuries.copper.org/modern2_a.htm, Internet.

These developments led to a tremendous demand for electricity in a growing nation and the development of its infrastructure. Advances in technology introduced power distribution installed a web of electrical lines, and used electric traction for trains and trolleys.[40] By 1920, one third of all households were wired; and in 1930, eighty per cent of U.S. homes were wired under the rural electrification program.[41] Clearly, as the world's infrastructures were burgeoning, so were its demands for metals.

Concentration Methods

As explained earlier, in the nineteenth century, there were principally two ore processing methods available, heat (pyrometallurgy) and non-heat (hydrometallurgy), which produced two products, concentrate and waste. Why use one method over the other? The choice of method varied with the type of ore and the most efficient metal recovery method; costs dictated the mining company's choice.

Some metals require concentration prior to smelting, while others can go directly to smelting. Smelting, a heat process uses furnaces raging at 2500 degrees that literally melt metals away from waste. U.S. smelters tend to be built at low-altitude locations, because altitude affects the melting point of metals. Many mines were located in mountainous terrain making transportation of ore costs prohibitive.

Non-heat processes used water baths and chemicals to separate minerals. Mill processes included gravity concentration, amalgamation (1858), chlorination (1860), and later cyanide leaching (1891). Historically, the Greeks and Romans used gravity concentration in their mining operations. The specific gravity of metals causes heavier metals in water to drop to the bottom and the lighter waste to be "washed" away. Effective for thousands of years, gravity concentration eventually declined after the development of flotation, amalgamation, and leaching, although its principles remain in use in each process.

Nineteenth-century stamp mills used an amalgamation process in their mills. A pulp of ground ore was passed over copper plates covered with mercury, which attracted gold and silver.[42] This was not an economical process for copper, lead, and zinc.

Chlorination, a complex concentration process, relied upon chemicals to separate the minerals. Although it was effective, it was extremely expensive. Chlorine separated metals from waste through a leaching process. Less popular in the twentieth century, it was replaced by cyanide heap leaching.[43]

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[40] Smith, "The Development of the Dynamo."

[41] American Public Works Association, *History of Public Works in the U.S., 1776-1976*, ed. Ellis L. Armstrong (Chicago, IL: APWA, 1976): 152-3.

[42] Hardesty, *Archeology of Mining*: 43.

[43] Hardesty, *Archeology of Mining*: 47-48.

However, prior concentration methods could not be used effectively on the small percentages of metal found in low-grade, base metal ores. Particles were washed away in gravitation and amalgamation and leaching did not "capture" copper, lead, and zinc particles. Prior methods were dependent upon the specific gravity of metals. It would take a departure from earlier principles of concentration for inventors, metallurgists, and engineers to find a process to concentrate low-grade, base metal ores.

History of the Development of Flotation

> The flotation process is undoubtedly the most important development in the recovery of metals from ores that has taken place during the present century. No other method of ore treatment has ever effected such great changes in metallurgical practice in so short a time…In point of tonnage treated, flotation is at present leading all other methods of ore concentration.[44]—Arthur J. Weinig and Irving A. Palmer

The most important development of the twentieth-century for the mining industry was flotation, an innovative concentration process separating valuable minerals from complex ores.[45] In order to meet twentieth century industry's market demands, American mining companies opened mines in the West's hard rock regions, abandoned earlier principles of concentration, and used flotation, making it the most widely used concentration process in the United States. In 1929, mining engineers Arthur J. Weinig and Irving A. Palmer argued flotation is the "most important development" of the century. This was the same year the Shenandoah-Dives Mill was erected. Seventy years later, there has been little change to the flotation process, except for machine technology and size, and modern mining engineers support Weinig and Palmer's 1929 findings.[46]

By the 1860s, the mining industry realized that they would soon exhaust the world's supply of high-grade ore (rock with an extremely high metal content). Meanwhile, the industrial age was in full swing. Industry's demand for metals was increasing exponentially each day. Engineers and inventors worked at a feverish pitch to 1) create a concentration method to economically process the world's abundant supply of low-grade (low metal content) and complex ores and 2) to sell their process to the commercial market. Low-grade ore had been regarded as worthless, because it was difficult to economically extract metals from waste rock. In many situations ninety-nine per cent of low-grade ore is waste, with the remaining one percent metal.[47] Inventors from England, Australia, and the United States triumphed near the end of the nineteenth century in finding an economical process called flotation to use in their concentration mills. In 1905, the world's first commercially successful flotation mill was established at Broken Hill, Australia. Soon, experimental plants in Australia, Great Britain and the United States also spread the news

[44] "The Trend of Flotation," *Colorado School of Mines Magazine* 25 (January 1930): 20.

[45] Previously metallurgists used ore treatments relying entirely upon specific gravity methods.

[46] Richard Graeme, phone interview with Dawn Bunyak, 28 March 1997; Merrill and Pennington, "The Magnitude and Significance of Flotation," 1-3 and 55-56; and Crabtree and Vincent, "Historical Outline," 39.

[47] B. Webster Smith, "The Flotation Process."

of their success with flotation. Almost overnight, the mining industry shifted from exploiting diminishing high-grade ores to an abundant supply of low-grade ores.

The development of flotation allowed for the most efficient and economical means of mineral recovery to date. While earlier concentration methods, such as gravity followed by cyanidation, were effective in processing gold ore, flotation opened the base-metals market. The mining and milling industry found a way to exploit complex minerals that were practically impossible to treat by earlier gravity methods. Without flotation, base metals (such as copper, lead and zinc) would have become increasingly costly and difficult to produce causing a direct impact on the global economy. Instead flotation unlocked many metallic (e.g. copper, lead, zinc, gold, silver) and non-metallic minerals (e.g. clay, phosphate, coal). Now the most widely used process in the world for extracting minerals, flotation separates several metals (from a single ore body) stage by stage by allowing different chemicals to "sort" two or more concentrated products from a chemical, water bath. A survey conducted in 1864 listed three metal concentrates; in 1895, mills processed 14 concentrates; and in 1945, due to flotation, the list had leaped to 43 products.[48] Flotation diverted a crisis in the mining industry, as well as allowing increased minerals production in the twentieth century. Thus, it can be argued that flotation is the beginning of modern mining and the base-metals industry.

Development of Flotation

Flotation is a method for concentrating valuable metals from finely ground ores in a water bath, with either the ore pulp or water chemically altered with reagents and frothers to encourage separation of minerals. The term flotation has been loosely used for all concentration processes in which heavier mineral particles have been separated from lighter waste particles in water by "floating" the mineral away from the waste. Today the term is generally used to describe froth flotation, but it is necessary to understand that flotation evolved through three principal stages of development: bulk oil flotation, skin flotation and froth flotation.

Bulk Oil Flotation

An Englishman, William Haynes, began experimenting with the idea of flotation in 1860. Haynes found, when mixing powdered ores, oil and water, some minerals had a tendency to attach to certain oils.[49] By the end of the century, many others experimented with such variables as: additives (oils, acids, or salts), agitation, and heat. Several individuals patented their findings in the late 1800s. Carrie Everson's patents (1886 and 1891) included a two-step process, 1) thoroughly mixing pulverized ore, oil, and an acid or salt together creating a pulp and 2) agitating the pulp on an irregular work surface. The metals rose to the top of the work surface and the waste settled to the recessed areas of the surface. The Wilfley table, developed in 1896, works on the same principal as Everson's irregular work surface. In her patents, Everson listed the

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[48] Bunyak, *Frothers, Bubbles and Flotation*, 21.

[49] Robert Richards, *Textbook of Ore Dressing* (New York & London: McGraw-Hill Book Co., Inc., 1932), 233 and E. H. Crabtree and J. D. Vincent, "Historical Outline of Major Flotation Developments," in *Froth Flotation*, 39.

minerals she successfully recovered.[50] By 1894, George Robson and Samuel Crowder, working at a mine in Wales, developed a mixture balance with oil, which resulted in the oil lifting fine mineral particles to the surface. Their process was the forerunner of the Elmore bulk oil process developed in England in 1898 by two brothers, Francis and Alexander Elmore.[51] Although the Elmore process and its mills eventually failed, due to excessive amounts of oil, the process was the first to introduce bubbles. Frances Elmore and the Minerals Separation Company patented it in 1904. But Italian Alcide Froment laid claim to the first patent (1902) to mention the use of gas in creating bubbles, which increased buoyancy of metallic particles. Meanwhile, A. E. Cattermole's patent in England in 1903 used less oil, introduced soap and alkali into the pulp stream, and agitated the pulp in a water bath through a continuous stream of gas bubbles. Although a commercial failure, Cattermole's process is considered the forerunner to modern flotation methods used today.[52]

Skin Flotation

Another type of flotation under consideration was skin flotation. In June of 1885, Hezekiah Bradford patented a process for separating sulfide ore based upon the principle of surface tension on water.[53] (Sulfide ores can contain copper, lead, zinc, iron, molybdenum, cobalt, nickel, and arsenic.) Bradford's process stipulated that dry ore be sprinkled, without agitation, onto the surface of a body of water. The heavier materials sank to the bottom, while the surface tension caused the lighter metals or minerals to float on the surface. Subsequent developments by de Bavay and Elmore in 1905 made this process commercially successful. Their process used a small amount of oil (a fraction of 1 per cent) mixed with one ton of mineral pulp. The mixture was then poured onto a water bath and agitated to encourage frothing.[54]

Froth Flotation

The first successful commercial mill using froth flotation was built in 1905 at Broken Hill, Australia, which today is recognized as the home of flotation. Independent experimentation, based upon early patents, at Mineral Separation's Broken Hill mines and mills resulted in the froth flotation process and the Minerals Separation Machine. In 1905, Mineral Separation engineers, E. L. Sulman, H. F. K. Picard, and John Ballot, filed a patent for their process that

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[50] Thomas Rickard, a leading engineer in twentieth-century mining, disputed Carrie Everson's stature as an innovator in the milling world. He did not disclaim her findings, but was distressed that the findings were attributed to a woman, Carrie Everson. Rickard wrote several articles discussing the topic including an article called "Everson Myth" in the January 15, 1916 issue of the *Mining and Scientific Press*. Rickard was editor of the journal. No one else disclaimed Everson's patents nor did they try to dispute her recognition as an inventor as did Rickard.

[51] Crabtree and Vincent, *Froth Flotation*, 40.

[52] Thomas Rickard, *Concentration by Flotation* (New York: John Wiley and Sons, Inc., 1921), 8; C. Terry Durell, "Universal Flotation Theory," *Colorado School of Mines Magazine* 6 (February 1916): 27; and Crabtree and Vincent, *Froth Flotation*, 42.

[53] Theodore J. Hoover, *Concentrating Ores by Flotation* (San Francisco: Mining and Scientific Press, 1914), 20.

[54] Crabtree and Vincent, *Froth Flotation*, 40.

separated froth flotation experiments from skin and bulk-oil flotation. Their froth flotation process (based on Froment's and Cattermole's earlier patents) used less oil in the ore pulp and added agitation by a rising stream of air bubbles. In another Minerals Separation mill, Theodore J. Hoover, brother of American President Herbert Hoover, devised a new innovation, which he called the Minerals Separation Standard Machine, that principally consisted of a spitz box. The pulp passed over the spitz box causing the mineral-laden bubbles to rise to the surface. This in turn allowed the collection of mineral-laden froth from the water. The machine consisted of a series of cells divided into agitation and frothing compartments. Although it was eventually superseded as improvements were made to the machine, Hoover's Separation Machine significantly advanced mechanization of the milling industry.

New technology in crushing and separation of ground ore further advanced the development of flotation. While mechanical classifiers, separation machines, and the Wilfley table assist in the separation phase of the flotation process, selective flotation requires finely ground ore to allow metals to be recovered on the froth of a water bath. Without improved grinding treatment in ball and rod mills, flotation would not have been possible. Inventors continued to experiment with soluble frothing agents (commonly referred to as reagents) and patented several combinations used at the Broken Hill mills. Aware that many minerals react differently to reagents in the water bath, experimentation continued to create formulas necessary for the separation of various minerals. The isolation of desired metals would depend upon the delicate balance of acid and alkaline agents in the flotation process. However, Minerals Separation's first froth flotation plant at Broken Hill was a success and flotation found its way around the world.

Commercial Mills

The first American flotation mill was at the Butte and Superior Copper Company in Basin, Montana. James M. Hyde, engineer for the Butte and Superior, designed a 50 ton-per-day pilot plant and operated it successfully in August 1911. The first, large commercial mill to use flotation in one bank of cells was the Timber Butte Mill built in 1913 at a Butte, Montana mine.[55] Neither of these mills is extant.

By 1914, there were 42 American mining companies using froth flotation in their mills.[56] Skin and bulk-oil flotation soon became obsolete. The first mill to use only the flotation process in its concentration process was the Engels Mine and Mill in Plumas County, California in 1914 (non-extant).[57] Mills continued to experiment with reagent use in froth flotation process on a variety of ores. Chemical agents, acid or alkaline, in the flotation process affected metal recovery in various ore bodies. The Sunnyside Mill at Eureka, San Juan County, Colorado was credited with perfecting the flotation of two minerals (lead-zinc) from a complex ore in 1918.[58] C. H. Keller

[55] Richard O. Burt and Chris Mills, *Gravity Concentration Techniques* (Amsterdam: Elsevier, 1984) 17; and Crabtree and Vincent, *Froth Flotation*, 43.

[56] Hines and Vincent, "Early Days of Froth Flotation," 29, citing G. A. Roush, *The Mineral Industry, 1914* (McGraw-Hill Book Co., New York, 1915).

[57] Hines and Vincent, "Early Days of Froth Flotation," 28.

[58] Hines and Vincent, "Early Days of Froth Flotation," citing Editorial, *Engineering and Mining Journal* 125 (Feb. 4, 1928): 195.

introduced xanthates (water-soluble froth collectors) into water baths in flotation circuits in 1925.[59] In 1932, G. K. Williams introduced the first continuous refining process.[60] However, the end of the 1920s had established the fundamentals of flotation.
By the 1930s, froth flotation provided several commercial concentrates. Arrival of poly-metallic mills allowed separation of more than one metal in a series of flotation circuits. Single circuit plants continued to be useful in many regions. New poly-metallic mills were larger in size, generally processing 750 to 2,000 tons per day, to accommodate multiple circuits and ore bins. Financially stronger companies in the industry moved to consolidate mineral patents. Mills and their equipment also expanded in size and processing capability. In the 1940s, mining companies also increased their use of open pit mines, which greatly increased the amount of ore extracted. As a result of increased ore extraction, the size of mills grew exponentially to accommodate ore delivered to the mills. The new mills with multiple buildings in a complex covered acres of land.

Mill expansion resulted in the replacement of obsolete or exhausted operations. By the 1960s, larger electrical capacity generators were designed, which allowed for variable speed drives in mills. Even larger sizes of mill equipment could be built and operated on this increased horsepower. New equipment allowed for the addition of automatic controls and instrumentation. Whereas small mills were not capable of developing adequately to keep up with large mine operations, new plants were constructed on old mill sites.

Development of Flotation Circuits and Mills

Flotation Circuits

Flotation plants operate through a series of flotation circuits. Finely crushed and ground ore is introduced into a water bath in the flotation circuit. In order to achieve separation, an optimum point has to be met. There are several variables that need to be considered: particle size, reagent additions, pulp density, flotation time, temperature of the pulp, type of the circuit, and water. Next the ore itself must be considered: uniformity of the ore, settling and filtration data, corrosion and erosion, and finally, the mineralogy of the ore.[61] Once all these variables are tested in pilot plants, the concentrator flotation circuits are designed.

Generally, there are two types of separation circuits, a simple or a complex circuit. Simple separation circuits are generally described as one-product separations. A single circuit separates the ore pulp into a concentrated product and tailings. In order to process more than one concentrate, the one circuit mill and its workings are periodically adjusted to recycle the ore pulp through the system. After chemically altering the bath or pulp, the process can be repeated as many times as necessary to float off all desired metals. The Timber Butte Mill is an example of a simple circuit mill (refer to Fig. 2).

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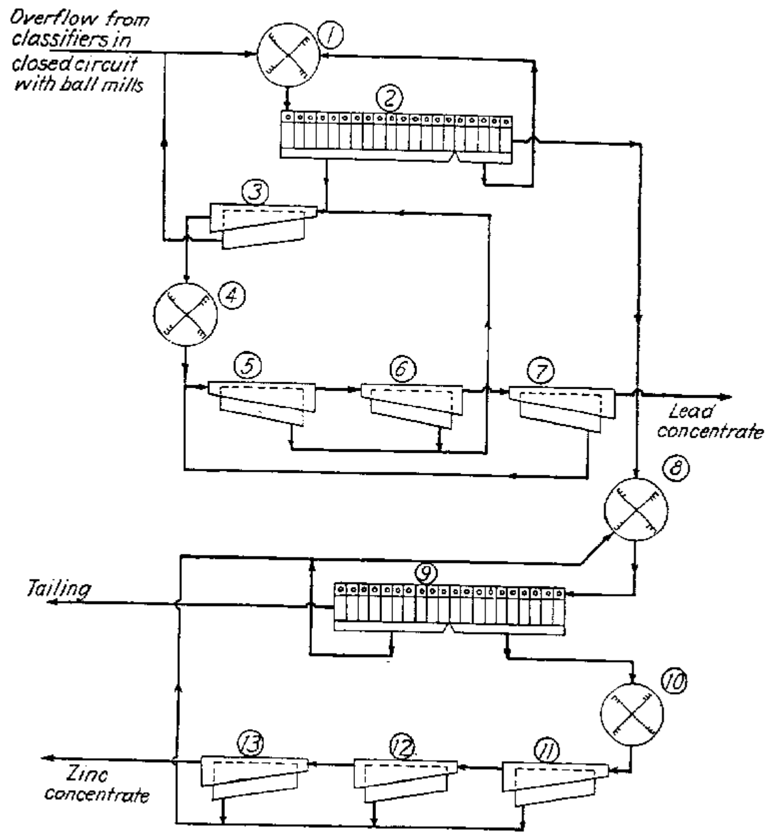
[59] Crabtree and Vincent, "Historical Outline," 45.

[60] Cedric E. Gregory, *A Concise History of Mining* (New York: Pergamon Press, 1980), 140.

[61] Adrian C. Dorenfeld, "Flotation Circuit Design," *Froth Flotation 50th Anniversary*, 365.



(1) classifier "surge tank"
(2) 20-cell minerals separation flotation machine
(3) callow cell (flotation machine)
(4) conditioning tank
(5)(6)(7) callow cells "roughing", "cleaning" & "recleaning"
(8) conditioning tank - reagents added
(9) minerals separation flotation machine
(10) surge tank
(11)(12)(13) callow cells

Fig. 2—Flotation Division, Timber Butte Mill (Gaudin 1932: 231)

A complex flotation circuit separates several concentrates from the ore pulp. Valuable metals are floated together to form a bulk product. The bulk product continues its course through a series of flotation cells where metals are "selectively" separated into concentrates. The waste is sent off to the tailings pond. The complex or selective flotation circuits are essentially several cells in a series. The first circuit of cells may separate lead and copper, the second zinc, and the third, an iron reject. Yet the flow of the pulp through the flotation circuit is continuous. Additional operations in the mill may include roasting, steaming, thickening, filtering, leaching, and regrinding of the ore pulp in the flotation circuit.[62] The Shenandoah-Dives Mill is an example of a complex circuit (refer to Page 12).

Plants designed similar to the Shenandoah-Dives did not necessarily produce the same concentrate, even on the same ore. Adjustments were made during the process to allow concentration of different grades of ore. Ore testing is an ongoing process. It is important to note that a circuit can separate zinc one day and be adjusted to separate copper the next day, depending on the needs of the mill and the mineralogy of the ore it was processing. Flexibility of the concentrator (mill) to simultaneously treat various grades of ore improved the mill's ability to stay viable in fluctuating markets.

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[62] Dorenfeld, "Flotation Circuit Design," 370-371.

Equipment found in a complex circuit may include: roughers, flotation cells (in many sizes), launders, thickener tanks, regrinders, reagent or frother machines, tubes for roasting or heating pulps, pumps, samplers, settling boxes, filters, and concentrate bins.

Historic Flotation Mills

There are several property types that may be found in twentieth-century flotation mills. Milling landscapes are reflective of a particular region's terrain and ore body. Sites can consist of interlocking buildings perched on the sides of steep mountain slopes in the Rocky Mountain West to taller, compact mill buildings found in dry desert regions of Arizona and New Mexico. Mills are often found in remote locations of the United States, but increased population has brought them into close proximity to some towns and cities. Butte, Montana is an example of a community (eventually a city) that almost encapsulates the mines and mills that fueled its economy. In Utah, the burgeoning population of nearby Salt Lake City surrounded the Midvale Plant. Eventually, the mill was removed due to community concerns of mineral contamination.

In the first decades of the century, most mills (also referred to as concentrators, concentration plants, or reduction plants) were generally located in or near remote mining districts. Twentieth-century milling districts were chosen for their mineral wealth (mine), proximity to a water source for mine and mill use, and their potential accessibility to transportation (railroad or road systems). A mill built close to the mine and/or smelter kept the cost of transportation of ore and concentrates to a minimum. A labor supply or available property for a community for employees was also of utmost need to the mill. In addition, a large site for disposal of tailings was essential if a mill was to operate for years or even decades.

Mill Building Designs

Many twentieth-century flotation mills were engineer-designed complexes. Mill buildings came in a variety of sizes, from the size of a small warehouse (50-100 tons-per-day production) to the modern industrial size covering many acres (60,000 tons-per-day production). As the National Park Service's publication *Guidelines for Identifying, Evaluating, and Registering Historic Mining Properties* states, "They [mills] were intricate industrial operations with every component ideally working in harmony to reduce costs, increase production, and maximize profits."[63] Cost efficiency and profit margins were of utmost importance to milling companies and their shareholders.

In an essay discussing the trends in mill design up to the 1960s, Norman Weiss and John Cheavens noted wooden structures from the nineteenth and early twentieth century were able to accommodate flow sheet (refer to pg. 12) changes with little alterations. By the 1930s, mills used steel and concrete to encompass a fireproof structure. As the milling industry expanded in the 1950s and 1960s, old structures were removed and replaced with numerous steel and concrete buildings for crushing, grinding, flotation, roughing, and thickening processes.[64] While this was

[63] U.S. Department of Interior, National Park Service, Interagency Resources Division, *Guidelines for Identifying, Evaluating, and Registering Historic Mining Properties*, by Bruce J. Noble and Robert Spude, National Register Bulletin 42 (Washington, D.C.: Government Printing Office, 1992), 13.

[64] Norman Weiss and John Cheavens, “Present Trends in Mill Design,” *Milling Methods in the Americas*, ed. Nathaniel Arbiter (New York: Gordon and Breach Science Publishers, 1964), 12.

the trend, smaller operations tended to be frame buildings, with newer buildings often using a combination of frame, steel, and/or concrete.

Two factors that impacted mill design were terrain (location) and the type of mineral to be processed (machinery necessary). An ore's mineral content affects the milling process used, whether it is flotation, leaching, or chlorination. Only after the mill process was chosen and a review of the necessary equipment completed was the mill building designed. Allowances were generally made for additional space for new equipment (to replace old or allow for new technology), enlargement of flotation circuits, or other mill needs. After the foundation was constructed at the mill site, the processing equipment was delivered and installed. A single piece of equipment could weigh several tons with individual parts weighing almost one ton. Then the exterior walls of the building were built around the equipment and foundation.

Natural Features of Mill Sites

Mining engineers designed mill complexes for sloping ground, flat ground, or partly inclined and flat properties:

- In mountainous regions, sloping-ground mills were built as multi-level buildings on the side of the mountain (See Fig. 3, Page 35). The step pattern of the building used gravity to move the ore, which saved power costs. Gravity caused the ore to fall from a crushing machine into a trough that led to a conveyor that carried the ground ore to the mill where it fell into secondary crushers and so on. The gravity flow of the watered ore pulp carried it from classifiers to flotation machines and so on. Thus, there was less need for pumps, elevators and launders.
- Flat-ground mills were generally taller and more compact buildings (See Fig. 4, Page 35). These facilities used more electrical or steam power than their mountainous counterparts to pump the ore through a series of launders and elevators to the various stages in concentration.
- Partly inclined and flat-ground mills were designed to benefit from both gravity and flotation. The slope was used for the grinding stage and the flat section housed the flotation cells.

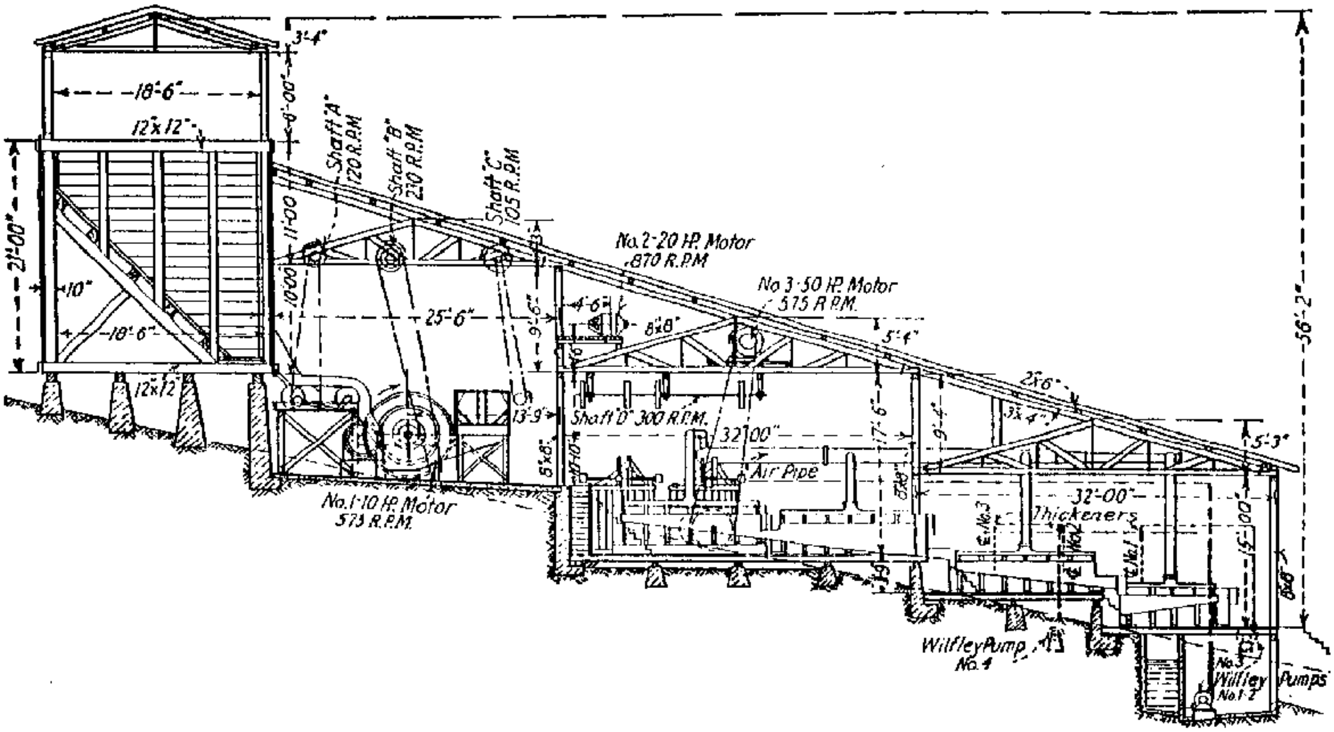

Fig. 3—Multi-level design for small lead-zinc plant on a hillside. Typical design for fine-grinding & flotation divisions to handle 100 tons of lead-zinc ore per day. (Gaudin 1932: 431)

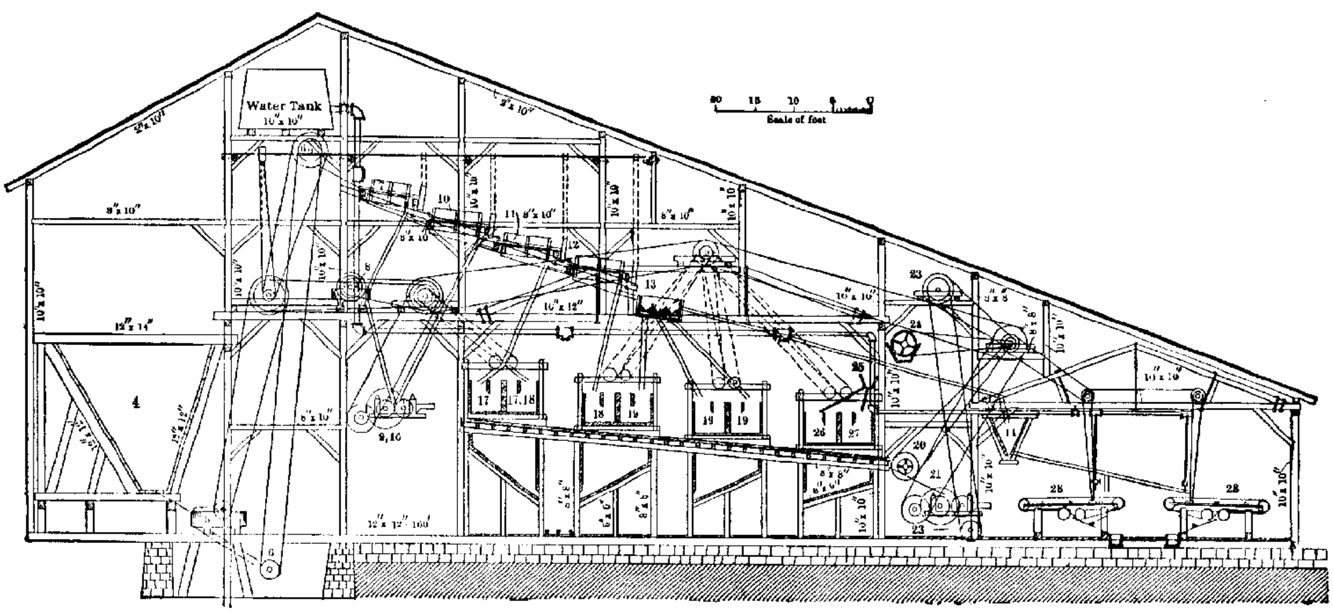

Fig. 4—Section of a mill on level site. (Richards 1940: 647)

Historic mill properties can be found perched on the sides of mountains, in the rolling hills of the Midwest, and the flat deserts of western states. Over time, many of these abandoned historic mill properties have been altered by several factors, including humans and weather.

Shenandoah-Dives Mill

The Shenandoah-Dives Mill provides an extraordinary vision of the development of mills in the first half of this century. Building, technology, and collection of equipment have scarcely been changed since the turn of the century, presenting a striking and rare case of an early twentieth-century flotation mill.

Constructed in 1929, the Shenandoah-Dives Mill processed ore for the Shenandoah-Dives Mining Company mines in the Silverton area. The mill was designed for milling metals from low-grade gold ore using alkaline reagents in separation processes. Charles A. Chase's vision establishing the most modern and up-to-date mining and milling operation in the business was financially funded by a investors from Kansas City who hired Chase as general manager in 1925.[65] In addition to the mill complex, the Shenandoah-Dives Company developed the mine site, which was located on King Solomon Mountain. Here the company built a boarding house for single miners, as well as those workers who did not live in Silverton. The four-story boarding house included an underground entrance to the mine enabling men to go in and out of the mine without leaving the building in treacherous winter storms. A 9,526 feet long, steel aerial tramway connected the mine to the mill. At its peak, the mill processed from 750-1,000 tons of ore per day in a multiple circuit plant that milled five metals: copper, lead, zinc, gold, and silver. In operation until 1992, the Shenandoah-Dives Mill contains virtually all of its working components enclosed within a 1,000-ton complex.

The Shenandoah-Dives Mill was one of many mills that flourished in the first half of the century. While not unique at its inception, the Shenandoah-Dives Mill is now an exceptional surviving milling property. In a 1998 survey of 500-2,000 tpd mills[66], the Shenandoah-Dives Mill was one of four extant flotation mills in the United States: the Shenandoah-Dives Mill; the Ely Valley Pioche Mill in Pioche, Nevada; the Combined Metals Smelter and Mill in Castleton, Nevada; and the Idarado Mill near Telluride, Colorado.

Other Flotation Mills

In the past decades, early flotation mills have disappeared. Natural and social factors have drastically affected historic properties. Equipment and materials were salvaged. Increasing market demands in foreign countries for out-dated or mothballed American milling and concentration equipment have resulted in the loss of a large segment of American historic mining and milling technology. In other cases, metal shortages, as in the 1940s, led to scrap drives, which resulted in the destruction and dismantling of mills to obtain valuable metal equipment. For example, the Combined Metals Smelter and Mill in Castleton, Nevada has lost the majority

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[65] Jones, interview; and Barge, "History of Shenandoah," 3-6.

[66] The survey was conducted to locate early twentieth-century mills in the range of 500-2,000 tpd, that were recognize as large mills of the period. In addition, the survey was conducted to determine the national significance of the Shenandoah-Dives Mill.

of its equipment for these reasons. It was constructed (about 1939-41) as a 1,500-ton, partially inclined and flat mill. Active during the Second World War, the mill processed five mineral concentrates. Intermittent openings and closures led to its final closure in the 1980s and dismantling of its machinery.

The Smuggler Union Mining Company built the Idarado Mill near Telluride, Colorado in the 1920s. Subsequent operations have drastically altered the flotation circuits of the mill. Technological advancements and upgrading of facilities have resulted in changes to the original equipment and process flow. In many facilities, one can easily detect the overlay of several technologies. As one ore body was depleted or markets fluctuated with demands for various metals, different processing facilities were needed. Mills originally designed for cyanidation might convert to flotation. Nevertheless, the Idarado Mill's technology has been substantially altered. In extreme cases, modernization has led to the bulldozing of earlier concentration plants and mills for the construction of new plants, which is the case in several locales in New Mexico and Arizona.

The Ely Valley Pioche Mill in Pioche, Nevada is a 500-1,000 ton-per-day, selective-flotation mill. When an early 1920s mill burned down, a second plant was built in the late 1920s and early 1930s on the partially inclined site above town. First powered by steam, the stack for the current mill is visible from the nearby town of Pioche. Electricity was run to the mill site at a later date. The ore (lead-zinc, gold, silver, and minimum copper amounts) from the Pioche Mine was hauled from the mine to the tram terminal by a small steam locomotive. Once loaded into the tram's ore buckets, the ore traversed approximately one and one-half miles to the mill at the upper end of the town. After the ore was processed in the mill, the concentrate was transported by the Union Pacific Railroad to Salt Lake City, Utah. The mill ran from the 1930s into the 1950s when it was eventually mothballed. It was briefly reopened in the 1980s. Currently, the mill is mothballed with much of its equipment intact. However, in order to run the plant, manipulation of the machinery would need to be addressed before beginning operation. One can view the ball mills, agitators, float cells, redwood tanks, and classifier. The tailings are piled nearby. Ore buckets are still visible, hanging from the tramline.

While the Ely Valley Pioche Mill's integrity is very strong, it differs from the Shenandoah-Dives Mill in several key elements. The Pioche Mill does not possess the intact and functioning technological system that the Shenandoah-Dives Mill illustrates. The Pioche Mill houses an incomplete and altered collection of equipment that is not entirely its original components. The Pioche Mill is a fine example of a partially inclined mill representative of desert mining locales. However, the Shenandoah-Dives Mill equipment is in working order as outlined on its flow sheet (refer to pg. 12) and only awaits the flipping of an electrical switch. In addition, there are examples of additional pieces of early equipment in storage at the Shenandoah-Dives Mill.

There are two extant mining mills listed on the National Register: 1) the Shenandoah-Dives Mill in San Juan County, Colorado and 2) Kennecott Mill (ammonia-leaching mill) in Valdez County, Alaska. There is only one extant (mining) mill designated as a NHL and that is the Kennecott Mill in Valdez County, Alaska. This mill is a twentieth-century, ammonia-leaching plant. As described earlier, leaching plants are one of several earlier methods of concentration.
The Shenandoah-Dives Mill is an extraordinary example of early twentieth-century flotation mills found in the mountains of the American West. Charles A. Chase, founding general manager of the Shenandoah-Dives Mining Company, took the newest innovations in milling and

incorporated them in his plant. Working with some of the best engineers and mill men in the West, Chase created a plant and facility that would remain viable throughout the twentieth century. Chase's era ended in 1953, but operation of the mill continued intermittently until its final closure in 1992. At that time, the mill property was donated to the San Juan County Historical Society to be operated as an interpretative center. With the closure of the mill, the resident population of Silverton declined by one half, as miners and their families moved to other mining regions. As a result, San Juan County's tax base reduced by one-third. Today, similar to other former mining towns in the Rocky Mountain West, the economy of Silverton is now based upon government activities and tourism. The town of Silverton and the Silverton Historic District NHL is well known for its nineteenth-century mining history. The proposed Shenandoah-Dives Mill NHL illustrates Silverton's twentieth-century mining history and its economic impact on the community, the region, and the nation. With its intact technology (including instruction manuals for equipment), the Shenandoah-Dives Mill illustrates the evolution of flotation and presents a twentieth-century view of man and industry.

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Previous documentation on file (NPS):

__ Preliminary Determination of Individual Listing (36 CFR 67) has been requested.
_X_ Previously Listed in the National Register.
__ Previously Determined Eligible by the National Register.
__ Designated a National Historic Landmark.
__ Recorded by Historic American Buildings Survey: #
__ Recorded by Historic American Engineering Record: #

Primary Location of Additional Data:

_X_ State Historic Preservation Office
__ Other State Agency
_X_ Federal Agency
__ Local Government
__ University
_X_ Other (Specify Repository): San Juan County Historical Archives, Silverton, Colorado

10. GEOGRAPHICAL DATA

Acreage of Property: 5 acres

UTM References:	Zone	Easting	Northing
Mill	13	268780	418860.

Verbal Boundary Description: Mineral Survey Number 20407 Patented Claim: "S" Mill Site

Boundary Justification:

The Shenandoah-Dives Mill is located two miles northeast of Silverton, Colorado, 100 feet north of Highway 110. The nominated property includes the five-acre parcel historically associated with the Mineral Survey Patent Claim No. 20407 shown on the attached sheet entitled "S" Mill Site. The office building, the small dot below mill on the attached USGS map, was used as the UTM marker.

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