From Gold Ore to Bat Guano: Aerial Mine Tramways in the West

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When famed mining engineer T. A. Rickard toured the San Juan Mountains in 1903, he referred to the aerial tramways near Silverton as "great spider's webs . . . spanning the intermountain spaces."[1] Indeed, visitors to many of the western mining districts at the turn of the century were impressed by the daily operation of spectacular aerial trams. Although a significant part of the mining scene, very little has been written about the history and technology of this ubiquitous method of transporting ore, supplies, and personnel. As a supplemental means of transportation, trams were considerably less glamorous than railroads, yet without them it would have been impossible to operate many of the most notable western mines. This paper presents an overview of the development and implementation of aerial mine tramways.

The concept of transporting people or materials by means of ropes spanning natural obstacles (such as rivers or canyons) dates back to the Middle Ages. During the 17th century small ropeways are known to have existed in Europe, South America, and Africa. These early efforts, which depended on hemp ropes, were unsuitable for mining purposes: they could neither carry heavy loads nor span long distances. With the development of wire rope in the early 19th century, miners finally had the technology necessary to adapt tramways to mining activities. Developed in Europe, the first wire ropes were made of a series of small wires hand woven around a hemp core. As early as 1834 a small aerial mine tramway was operating in Austria, and by 1840 wire rope factories existed in Sweden and Germany.[2]

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It is difficult to be sure when the first ropeway was constructed in the United States, although Peter Cooper claimed that honor for a small tramway he built for transporting fill-dirt near Baltimore in 1832. Two decades later the same individual constructed a two-mile ropeway to transfer iron ore, coal, and limestone to a blast furnace in New Jersey.[3] Undoubtedly, other such devices sprang up at various industrial sites prior to the Civil War, but it took the mining boom of the 1870s to create a demand for these concepts.

One of the major challenges engineers faced as western lode mining developed was the transportation of ore and supplies between the mine and reduction facilities. In many locations mine entrances were located in rugged terrain, high up in the mountains, where it was difficult if not impossible to construct processing facilities. It was indeed true, as one wag wrote, that western mines, located "on the highest tops and sides of steep and rugged mountains," belied the theory of "European geologists, viz.: that veins of the useful minerals are in nearly all cases located in the foot-hills of mountain-chains only."[4]

Andrew S. Hallidie, future developer of the San Francisco cable car system, was the first engineer to apply aerial solutions to overcome natural obstacles in the West. Born in England in 1836, Hallidie came by his interest in cable technology naturally. His father, a manufacturer of wire rope in England between 1835 and 1849, taught his son the trade. Coming to California during the Gold Rush, young Andrew first pursued the life of a miner, engaging in a number of unproductive placer ventures before turning to the construction of wire suspension bridges. He produced the first wire cable manufactured on the Pacific Coast in 1856 and a year later he opened a cable plant in San Francisco. To make his product Hallidie reportedly melted down all the horseshoes he could buy from the livery stables of San Francisco. For a decade A. S. Hallidie Co. focused on bridge construction, while its founder worked on other inventions. In 1867 he introduced the first practical aerial mine tramway.[5]

Hallidie's "Endless Wire Ropeway" included several patented features, although it is clear that he generally elaborated on ideas developed by his English contemporary, Charles Hodgson.[6] Nevertheless, Hallidie deserves credit for applying the concept to western mining operations. His tramway was of the single rope type. Basically described, the device was anchored at each end by a patented "grip-pulley," which received the rope (spliced together to form a continuous loop) and then returned it in the opposite direction. To support the cable, towers were erected at appropriate locations across intermediate terrain (usually no more than 250 feet apart). Attached to the top of the towers were grooved pulleys or rollers through which the cable ran. Thus, much like a modern ski-lift, the cable moved in an endless circle. Permanently attached to the cable of distances of about 50 feet were steel arms or clips. Suspended from these arms were the "carriers," either ore buckets or hooks to which supplies or ore bags could be attached. The moving ore carriers were loaded by means of a swivel chute. Hallidie also designed his buckets with a self-dumping feature which released the bottom and dropped ore on the fly. Since most loads moved in a downhill direction, gravity usually provided enough momentum to keep the tramway moving. In this fashion, traveling at 200 feet per minute and carrying 150 pounds of ore per bucket, 36,000 pounds per hour could be delivered to the mill at a cost of twenty to forty cents per ton mile.[7]

Exactly when and where Hallidie erected his first tramway is unclear, although a small (2,500 foot) system was under construction in Nevada's Freiberg Mining District during the summer of 1871. The mining industry quickly recognized the advantages of aerial ropeways. A June 1871 editorial in *The Engineering and Mining Journal* observed that "The wire tramway seems calculated to perform work that can scarcely be expected from any railway with two rails, no matter how narrow the gauge." Because aerial tramways were generally built above ground in a straight line, they could bypass many of the topographical obstacles that made roads and railroads so expensive. As the *Journal* editor noted, "the wire tramway forms its own road and cares nothing for spans in mountain regions of 1200 feet to 1500 feet and inclines of 1 in 3 or 4. It therefore has its special applicability, and must be made use of in a hundred instances where other means of transport are wholly inapplicable." Another writer emphasized the financial side. Although tramways were not cheap, costing

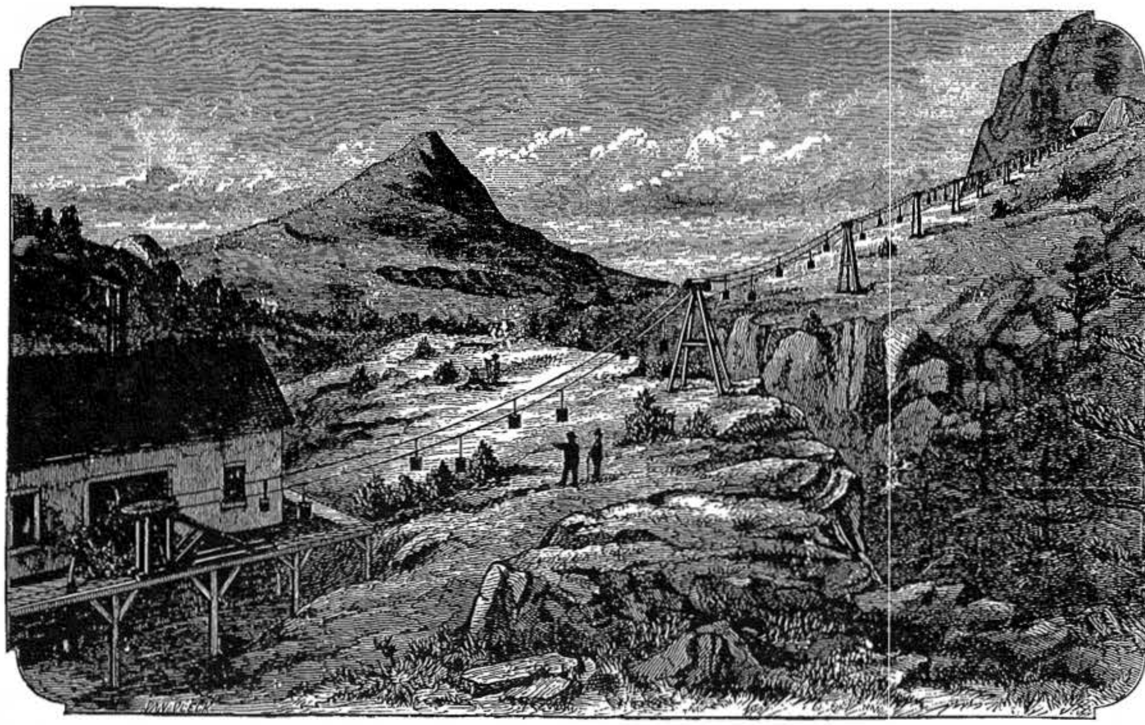
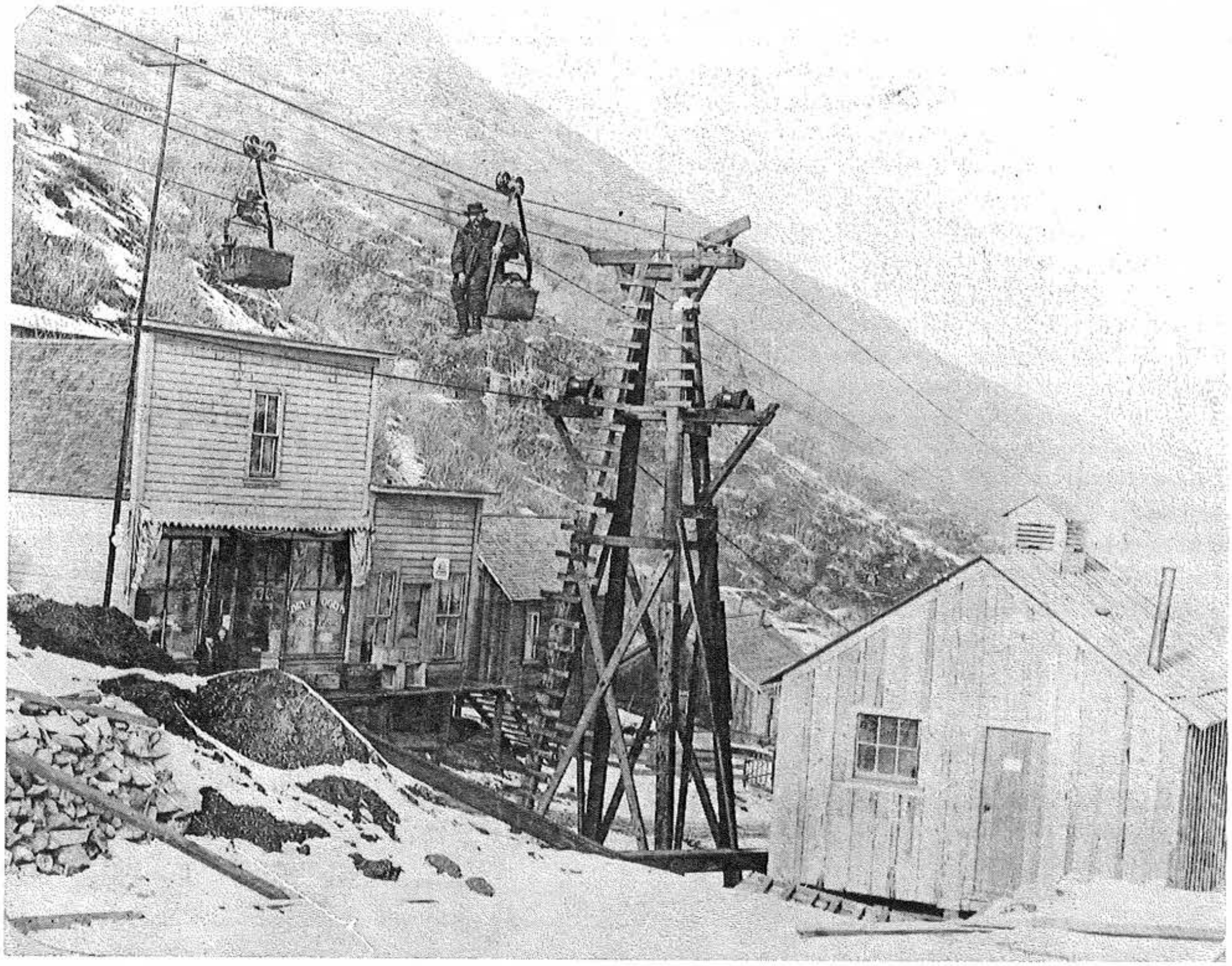


FIG. 1. GENERAL VIEW OF ROPEWAY.

Artist's rendition of the Hallidie single rope tramway taken from an 1878 promotional pamphlet published by the inventor. (Courtesy Bancroft Library)



Bleichert double rope tramway passing over Bingham Canyon, Utah. Note the man riding a loaded ore car, a common practice. (Courtesy Utah State Historical Society)

about $5,000 per mile to construct and over twenty cents per mile to operate, this was "probably much less than the cost of any method of steam transportation in regions like the Freiberg mining district of Nevada, where there is a tramway of this kind."[8]

By the mid-1870s Hallidie had built several additional tramways. Two of them were in Utah: at the Emma Hill Consolidated Mine at Little Cottonwood (built circa August 1872) and at the Chicago Silver Mine in the Ophir district (built summer 1873). As W. S. Godbe, manager of the Chicago Mine, wrote: "The line, . . . is constructed over an extremely rugged country, one and a quarter miles in length. . . . For the first half mile or so, it is down a very steep mountain side, whence it passes over the brow of another one; thence it continues down Dry Canon at an angle of fifteen to eighteen degrees." Officials of both mines expressed great satisfaction with their tramways, which were proving "to be the cheapest way to move ores on steep mountain sides."[9]

Hallidie's company, which eventually became the California Wire Works, continued to construct and improve the single-rope system. Nevertheless, the design proved to have drawbacks, the most obvious being its limited hauling capacity and another being its inability to operate effectively over lengths of more than two miles or at elevation differences of more than 2,500 feet. The permanently attached carriers also caused problems since they had to be loaded and unloaded on the fly.[10] As a consequence, by 1880 Americans were beginning to take notice of a European-designed double-rope tramway system.

The double-rope system was perfected by two German engineers, Theodore Otto and Adolph Bleichert, who integrated ideas developed earlier. Their first successful tramway went into operation in

1874. Known as the Bleichert system, the double-rope tramway was significantly different from Hallidie's system. The carriers ran on heavy stationary cables clamped in place and stretched between terminals that essentially formed a track over which the carrier pulleys rolled. Motive power was provided by a second, lighter, rope--the traction cable--which ran in an endless closed loop. The traction cable was attached to the carriers by means of a grip. As described in *The Mining Engineers Handbook*: "In operation, each load is placed in a carrier while standing on a track in the loading terminal; the carrier is then fastened to the traction rope, and is hauled along track cable to discharge terminal; there it is released from traction rope and contents are discharged." Among the major advantages of this system was a higher carrying capacity, the ability to operate over greater distances, and less wear and tear on the cable.[11]

Again, the American mining community took notice of the new technology, especially since the Bleichert system, though more expensive to construct, reduced ore transportation costs by nearly half. In 1880 representatives of the Bleichert Company visited New York, hoping to license their design in America. By 1888 the Cooper, Hewett & Company of New York, and the Trenton Iron Company had acquired patents on the Bleichert system. In the meantime, a number of double-rope tramways had been erected, mostly in the East.[12]

Aerial tramways reached the peak of their popularity in the western mining districts between 1890 and 1920. During this period a number of other manufacturing firms entered the field, using variations of the original two designs. Theodore Otto, for example, went into business for himself, offering the "Otto Aerial Tramway" to U.S. customers through the Chicago firm of Fraser & Chalmers.[13] As tramways proliferated, numerous mechanical improvements were introduced by manufacturers competing for business. Indeed, both single- and double-rope tramways saw various advances. Manufacturers of the Hallidie system developed improved rope clips to assure smooth running, invented a way of releasing the bucket from a moving cable in order to facilitate loading, and found ways to extend the line.[14] Many of the improvements on the Bleichert system focused on better methods for gripping the traction cable. By the turn of the century simple mechanisms for automatically coupling and releasing carriers were in general use, all of which reduced wear on the cables.[15]

Despite an effort to improve single-rope tramways, they continued to decline in popularity. Still, Hallidie's California Wire Works managed to secure contracts until well after the turn of the century. During the summer of 1895, for example, the company built six ropeway systems, although most were rather small. The system installed at the Silver King mine in the Kootenay district of British Columbia was notable for a length of four and a half miles, which earned it the title of "the longest unbroken line built under the Hallidie system." Even so, the limit of 100 pounds of ore per bucket presented an obvious drawback.[16]

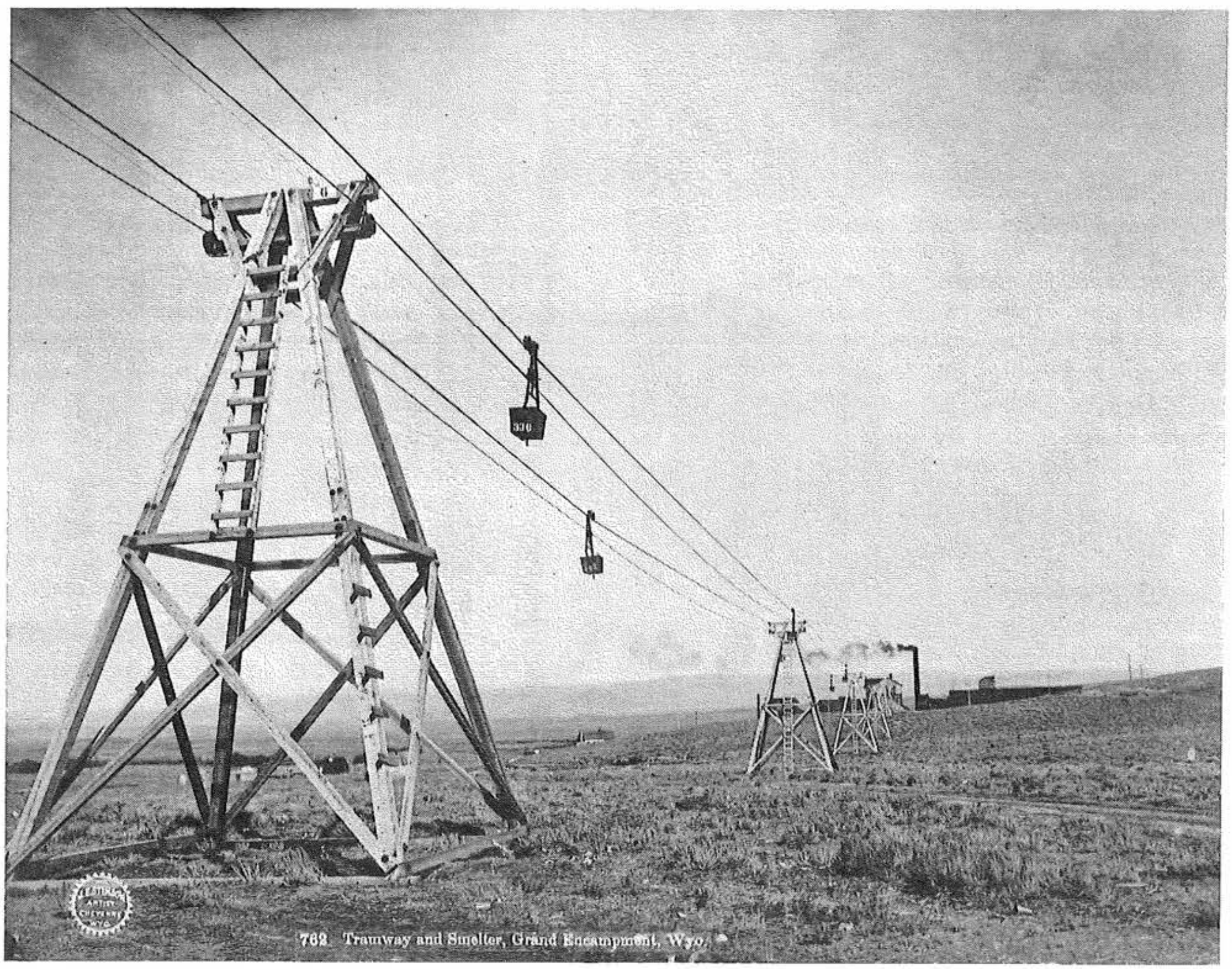
By 1903 T. A. Rickard could pronounce the Hallidie system "nearly obsolete." "Experience," he said, "now favors the double ropeway system in spite of a cost of installation which is 30 to 50 per cent greater than the single rope, because this difference in first cost is soon wiped out by the cost of maintenance, which is nearly double that demanded by the Bleichert; moreover, in the matter of capacity, it may be said that the former is limited to say, 75 tons per day of 10 hours, while the substantial construction and larger scale of the latter permits a capacity that ordinarily reaches from 250 to 400 tons per day of 10 hours." The same advantages were touted at the Trenton Iron Company's exhibit at the Columbian Exposition a decade earlier.[17]

During their heyday some truly impressive aerial tramways were constructed in the mountainous West, each one seemingly more sophisticated. In all, several hundred were built between 1890 and 1920. The ropeway built in 1901 for the Silver King Mine at Park City, Utah, was more than 7,000 feet in length, had a fall of 1,000 feet, and operated at a speed of 150 feet per minute. It rolled downhill over a 1 1/8 inch cable and uphill (empty) on a one inch cable, the traction rope being 3/4 inch in diameter. One of its distinguishing features was the use of steel towers, which reached as high as 75 feet above the ground.[18] At Silver Lake, near Silverton, Colorado, the combined tramways of the Iowa and Royal Tiger mines constituted the "longest straight tramway in the San Juan[s] and one of the most spectacular." This Bleichert design operated over a total distance of 14,600 feet, with one span clearing a distance of 2,200 feet. The upper portion of the tramway dropped 2,100 feet over a distance of 8,400 feet. Located nearby was the tramway of the Silver Lake Mine, which featured a four story loading terminal capable of storing 1200 tons of ore.[19] Another notable operation was that of the Spring Canon Coal Co. near Helper, Utah. Although only 3,000 feet long with a drop of 321 feet, the terrain was so rugged that one of the towers had to be cantilevered over the edge of a rock precipice to accommodate a change in grade. The tramway buckets were also unique, holding 2,000 pounds each and designed to fit on wheels so they could be "run into the mine and otherwise handled exactly as an ordinary mine car."[20]

Among the other unique turn-of-the-century tramways, the line connecting the Gold Prince mine and mill stands out. Built in 1906 to connect the ill-fated 100-stamp mill at Animas Forks, Colorado, with the mine entrance two and half miles distant, this Bleichert tramway possessed several unique features. Because the line followed the contour of the mountains, going up and down, it was necessary to construct an automatic tension station near the midway point and to make a 30 degree turn. This was carried out with the help of 33 substantial wooden towers, which were also equipped to carry electric (or telephone) lines from mill to mine.[21]

The longest system of the era--16 miles--was built by A. Leschen & Sons in 1904 for the North American Copper Company at Grand Encampment, Wyoming. Because of steep grades and excessive strains, the line actually consisted of four separate systems, each operating independently, but connected by overhead rails, so that "the buckets upon arriving at the end of the first section are transferred to the second section." The line also featured a fully automated terminal, which unloaded 40 tons of ore per hour, and double tension stations located every mile, "the first of this kind used in tramway construction."[22]

Without question one of the most spectacular tramways in the West was constructed in 1909-1910 to connect the Highland Boy Copper Mine at Bingham Canyon, Utah, with the International Smelting and Refining Company's mill at Tooele. Everything about this operation was on a grand scale. Capable of handling 100 tons per hour, this double-rope system was built in three connecting sections, with control stations at each junction. This enabled the tramway to

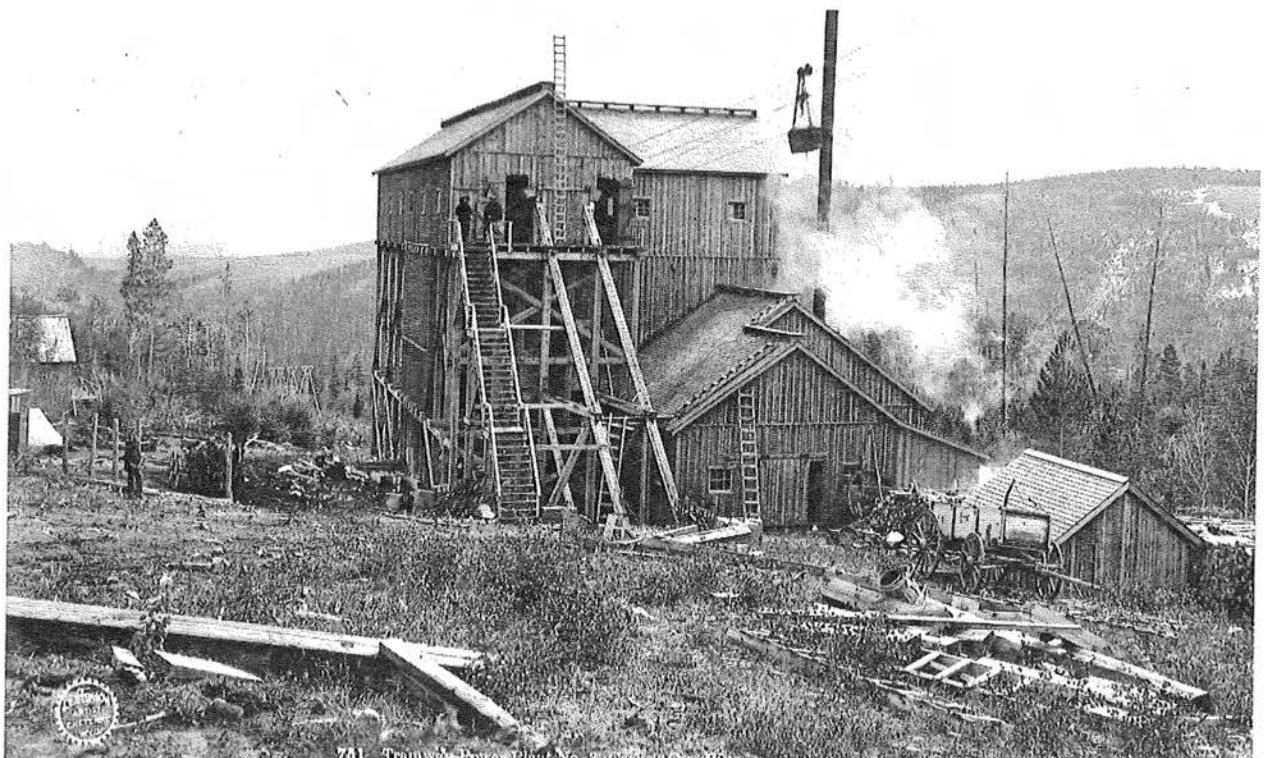


Nearing the end of a 16 mile journey, loads of ore approach the smelter terminal at Grand Encampment, Wyoming. Built in 1904 by A. Leschen & Sons, this tramway was one of the longest in the United States. (Courtesy State of Wyoming, Cultural Resources Division).

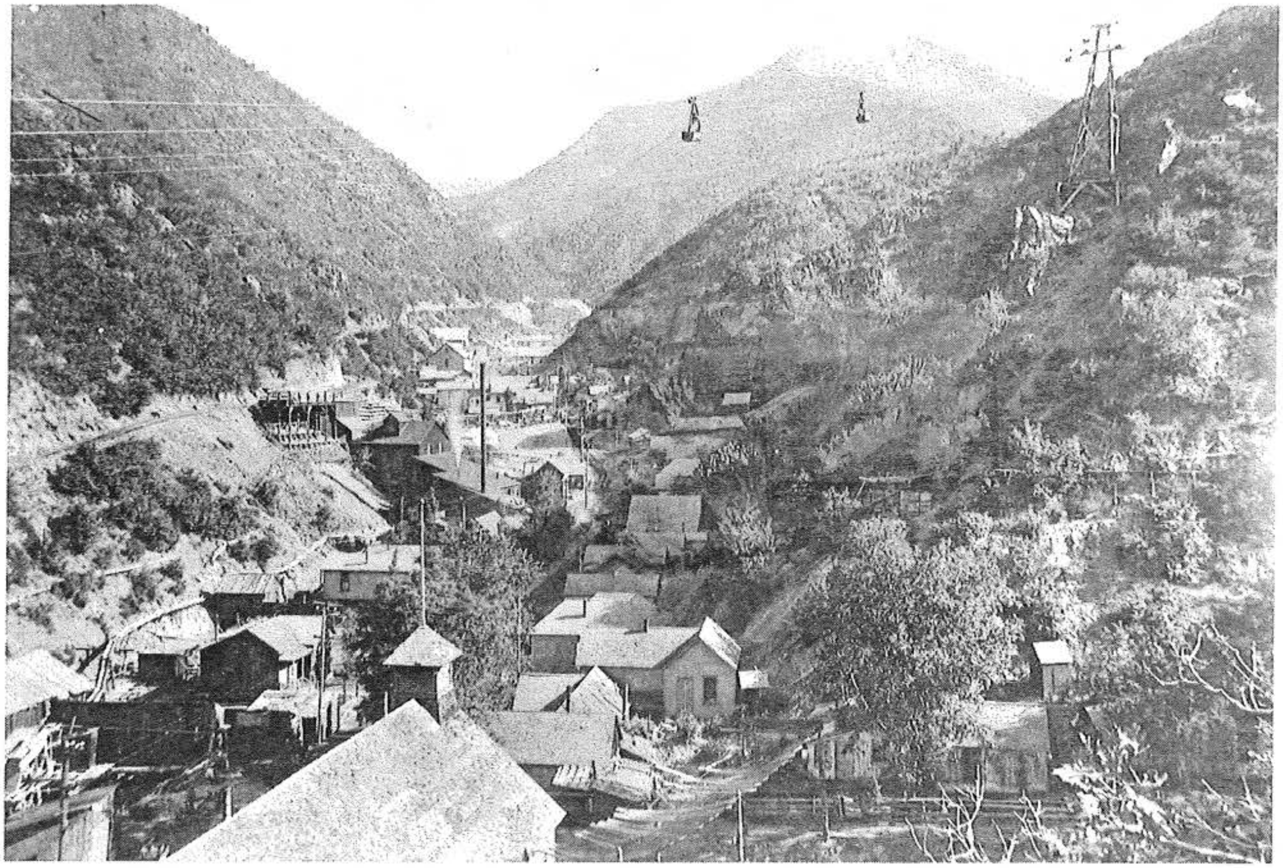
cover a total distance of 20,975 feet, or nearly four miles on a total of eighty towers. The greatest span between towers covered 1,040 feet. Because of the up and down topography of the line, 100 horsepower motors were installed at each control station to start the buckets moving. Once in motion, however, no additional power was required, and one of the motors was used as a generator to produce electricity for mine use. Operating at a normal speed of 600 feet per minute, the Highland Boy tramway required a crew of fourteen. It cost a total of $190,000, or $47,500 per mile, to construct.[23]

Aerial tramways were popular because of their operating economy. In difficult terrain they offered considerable savings. In the Black Hills, for instance, five mines owners in the Bald Mountain area proposed building a seven mile tramway to carry ore to the mills at Deadwood. Although the cost of construction was estimated at $150,000, the ropeway promised to reduce by half the costs currently (1907) being paid for rail transportation.[24] A report prepared by the superintendent of the Blue Bell Copper Mine near Humboldt, Arizona, calculated that it cost only 5.6 cents per ton, including repairs and labor, to move ore over its 3.3 mile tramway. By comparison, the total cost of delivering Blue Bell ore to the Humboldt smelter, which included, extraction, transportation, sorting, and taxes, came to $3.56 per ton in 1916.[25] Mining engineer R. D. Seymour of Denver, pointed out another saving. This involved back traffic, the transporting of supplies to the mine in return carriers. The cost of conveying these materials on mountain trails by mule train would obviously have been much more expensive.[26]

The contours of the terrain made construction of tramways exceedingly difficult, even though the systems were fairly simple. Not only did construction crews have to scale steep mountains to build the



Because of its great length, the Grand Encampment tramway needed several transfer points. These stations also provided power for tram operations. (Courtesy State of Wyoming, Cultural Resources Division)



An aerial tramway spanning the canyon and residential areas of Bingham Canyon, Utah, in the early 20th century. (Courtesy Utah State Historical Society)

terminals and towers, but they also had to move thousands of pounds of cable into place. One account of this herculean task appeared in the June 15, 1907, issue of *The Engineering and Mining Journal*. This involved the Silver Dollar Mine near Camborne, British Columbia, which was located in terrain so rugged that the mine could only be reached by pack horse. As a consequence, horses were used to move lengths of cable to the terminals. Over a span of seven days pack trains of increasing size hauled long lengths of cable to the construction site. These efforts culminated when a "team of 31 horses conveyed 3600 feet of 1 1/8 in. cable, weighing 7,600 lbs., to the upper terminal," without a single kink.[27]

Other natural obstacles could hamper tramway operation once the engineers passed the first test of constructing the systems in formidable mountain settings. Bad weather, particularly snow and wind storms, created numerous difficulties. Often located in severe high altitude climates, the tramways were regularly showered with heavy snowstorms. Snow became more than just an inconvenience. Heavy snow often accumulated in buckets and froze the ore, especially if the line had to be stopped for any length of time. Avalanches also threatened operations, and it was not uncommon for towers to be downed by snowslides several times a year. At the Sunnyside Mine near Eureka, Colorado, miners lost one of their towers so frequently that the company eventually built a 50 foot tunnel into the mountain to store an emergency spare tower. When a snowslide carried one tower away, "the reserve tower is taken from the tunnel and erected at the site of the one carried away." Other means of contending with snowslides included building masonry snow breaks, angling towers, and using extra heavy timber or steel towers.[28]

High winds also caused trouble. Suspended on long segments of cable, buckets tended to sway in the wind. To cope with swinging buckets in areas particularly susceptible to high winds, engineers built towers that separated the lines by ten feet or more. Yet even this adjustment could not deal with extraordinary situations. The Bleichert tram at the Baker Mines in Oregon, for example, began to malfunction after a severe wind storm in March 1916. On examination, inspectors found a tangle of wire and buckets. At one point two buckets (one loaded, the other empty) had collided and locked together. At another location, the downhill track cable had blown across the parallel line, then attached itself to an empty bucket. Elsewhere, the traction cable whipped across an adjacent bucket and was resting on the grip lever. To repair this mess, mine superintendent Hamilton W. Baker rigged a platform to lower three men down the line. In a tricky and delicate operation that required 27 hours, the tramway cables were finally straightened. After the work was completed, Baker remarked that the wind had been so strong that the "traction cable rubbed a tree 40 ft. to one side of the line of travel."[29]

Cable-wear created different problems. Early operators discovered that cable could wear out in as little as three months. And if the wear was not detected, a cable might snap, dumping buckets loads of valuable ore the ground. Single-rope tramways of the Hallidie design, which had permanently attached buckets, were particularly troublesome because they could not be rotated to assure even wear and thus were prone to frequent failures. The Bleichert tramways, on the other hand, were designed so that operators could regularly turn the track cable to produce an even wear pattern. Trial and error taught mechanics to rotate the cable one-eighth of a turn with special wrenches every two weeks. The trick was to keep the cable in its new position despite a "tendency on the part of the cable to return to its former position." As a consequence, it was preferable to release tension on the cable before turning and then clamping it into place. In general, track cables experienced greatest wear in the vicinity of the towers. Nevertheless, with proper turning and regular oiling track cables were known to last up to seven years. Although traction cables possessed a shorter life, they were relatively easy to replace.[30] Well run and profitable operations tended to guard against wear and replace cable well before they presented a danger.

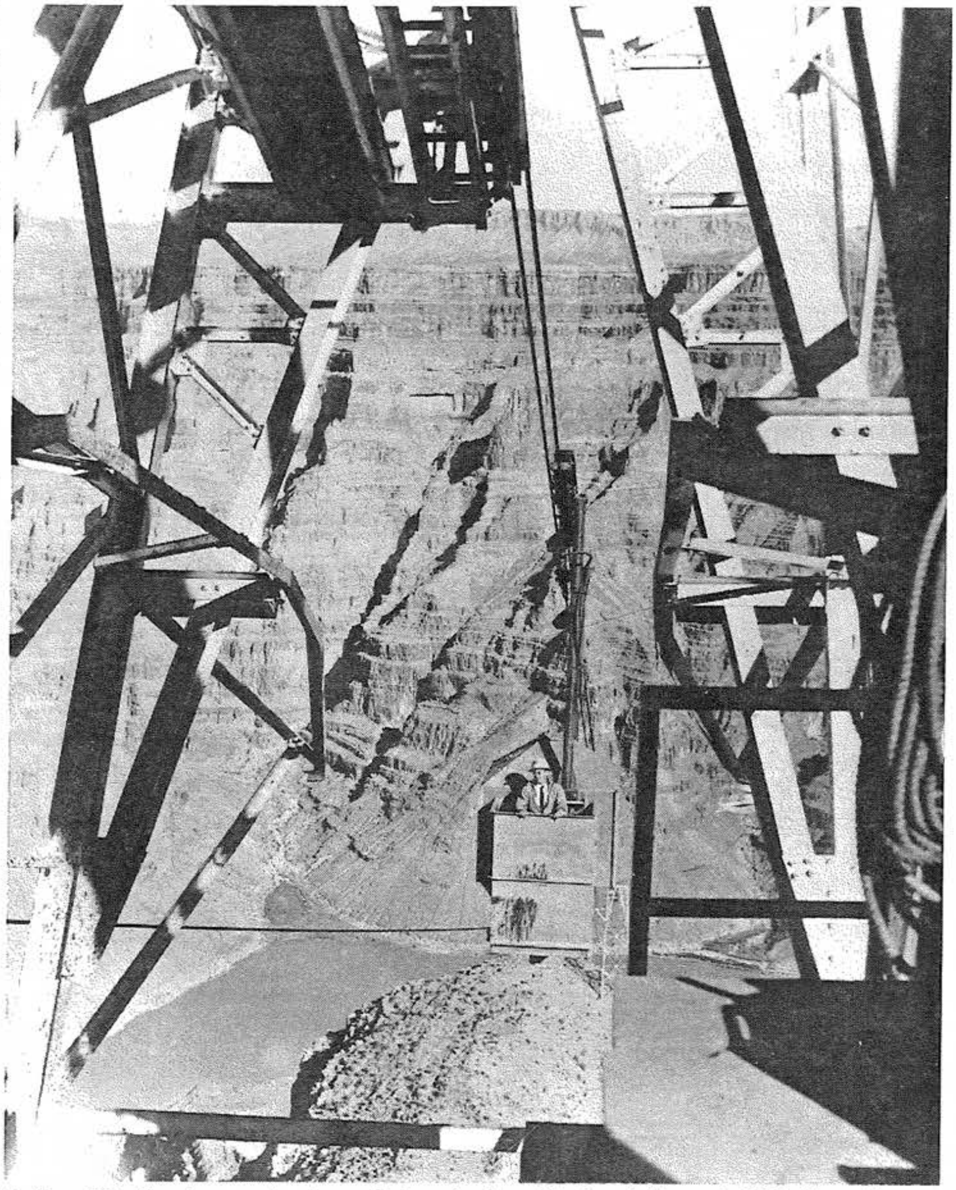
Tramways also served a variety of purposes in addition to the movement of ore. The famed Shenandoah Dives tramway near Silverton, Colorado, ran a particularly diverse operation. Built in 1929 to connect a mine in the remote Arastra Basin with a mill along the Animas River, the 10,000 foot tramway, noted for its rugged steel towers, carried significant freight and passenger traffic. Nearly two miles of tram was needed to maintain the company's timber yard, its various shops and warehouses, and its bunk houses near the otherwise unaccessible mine entrance. A considerable freight of about 2,500 tons per year was sent up the tramway, onto a spur tram, and then to the freight yard. Also, because many of the miners lived in Silverton, the tramway carried passengers (two per bucket). By some accounts, as many as 250,000 passenger trips per annum were made over the line.[31]

By World War I aerial tramways had become a standard part of mine technology. At least a half dozen American companies competed for the business. Some firms, like the American Steel and Wire Company, kept tramway engineers on staff to design lines specifically suited to customer needs. Although systems in the United States rarely exceeded three or four miles in length, continued advances in technology by European manufacturers permitted tramways of much greater distance. In 1910, for example, the Pohlig Company of Germany claimed to have constructed nearly 2,000 tramways, including ones of 22 and 27 miles. About the same time, the Bleichert Company built a 21.5 mile tramway (divided into eight sections) in Argentina. This line featured spans as long as 3,000 feet with a 500 foot tunnel. As the quality of wire rope improved, it eventually became feasible to build 60-mile lines, although it is doubtful that any this size were ever constructed.[32]

Although western mining activities declined somewhat in the 1920s, new tramways were still being built. In 1926, for example, the Park-Utah Consolidated Mines at Park City opened a sophisticated fully automated system capable of simultaneously (and separately) handling lead-zinc ores as well as zinc and lead concentrates. All incoming supplies, such as coal, lumber, and timbers went to the mine on cables. Coal was transferred from railroad cars to the tramway terminal on a bucket conveyor, then forwarded to the mine in returning ore buckets. The loads were then "automatically tripped a short distance from the upper terminal and the coal dropped through a pipe to the boiler-room bins." During the 1920s other versions of the basic design were introduced. By mid-decade the Interstate Equipment Corporation was marketing its "Automatic Aerial Tramway." This system featured cars (much like mine cars) mounted with grooved wheels which rode on two parallel tracks, pulled by a traction cable attached directly to the bottom of the ore car. The ore car discharged its contents at the terminal and returned to the mine upside down on a second line which ran below the first one. Interstate promoted this as a one-man operation. "He pushes a button at the bunker," said one advertisement, "and the tram cars at the mine are automatically loaded, sent on their long overhead journey, discharged at the bunker and returned." This system was employed on the 9,500 foot long Nephi gypsum system in Utah,[33] but apparently never became common.

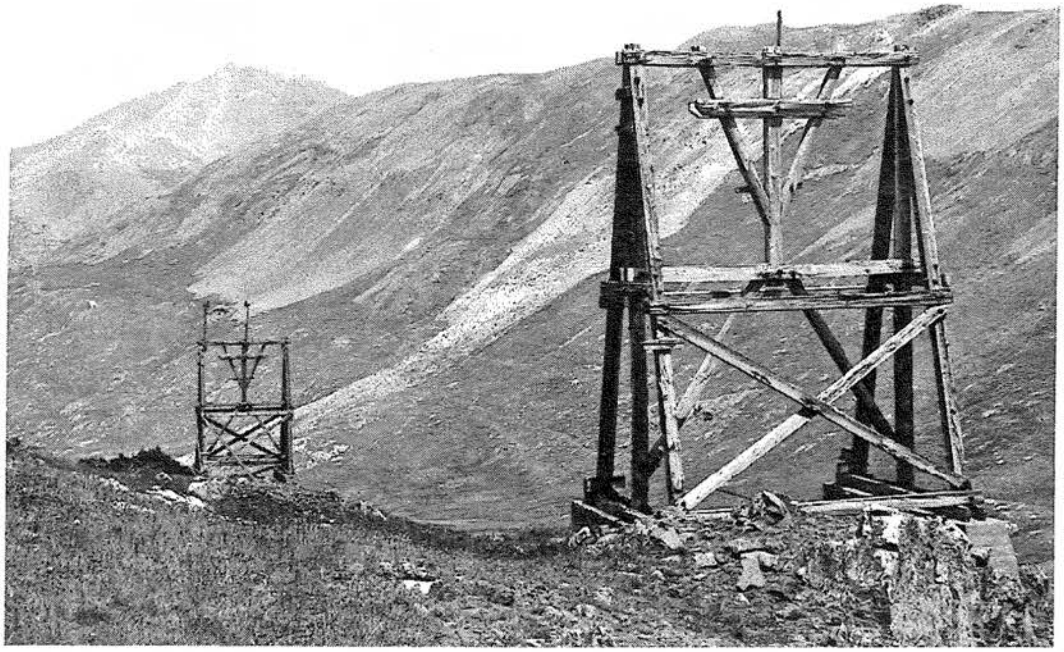
A significant decline in aerial mine tram operations began in the 1930s. The Depression caused many western mines to close. In most cases, the tramways were simply abandoned, left in place with the expectation that some day mining operations would resume. In a few cases the cables and machinery were salvaged and used at other locations.[34] After World War II, mine tramways became obsolete with the development of open pit mining, huge trucks, and modern road building techniques.

Yet the trams did not bow out without some fanfare. One of the last aerial mine tramways built in the West became known as the Grand Canyon "boondoggle." It revolved around the "Bat Cave," discovered in the 1930s in a remote western section of the Grand Canyon. The cave got its name from deposits of bat guano, then in demand as a natural plant fertilizer. In 1958 the U.S. Guano Company leased the cave, planning to "mine" the estimated 200,000 tons of guano accumulated over the centuries. To reach the cave, an aerial tramway was essential. But this would be no average cableway. The Western Steel Division of U.S. Steel won a contract to construct the 10,000 foot modernized double-rope system. The longest span covered a mile and a half, giving the tramway by far the longest span across a canyon in the United States. Nevertheless, trouble plagued the "Bat Cable" from the beginning. During the first year cables snapped twice, falling into the Canyon. Once operations began, it was discovered that the cave contained only 1,000 tons of guano. Within a year the mine had played out. As one writer observed: "The Company had spent $3.5 million to salvage 1000 tons of guano which sold for 69 cents a pound." Shortly after the mine closed a U.S. Air Force jet severed one of the lines, which fell to the Canyon floor. The remaining cable was used one final time to make the 1959 film *Edge of Eternity*, featuring Cornell Wilde and the tramway. Although a costly failure, U.S. Steel considered the project worthwhile because "we got a million dollars worth of free advertising doing this job."[35]

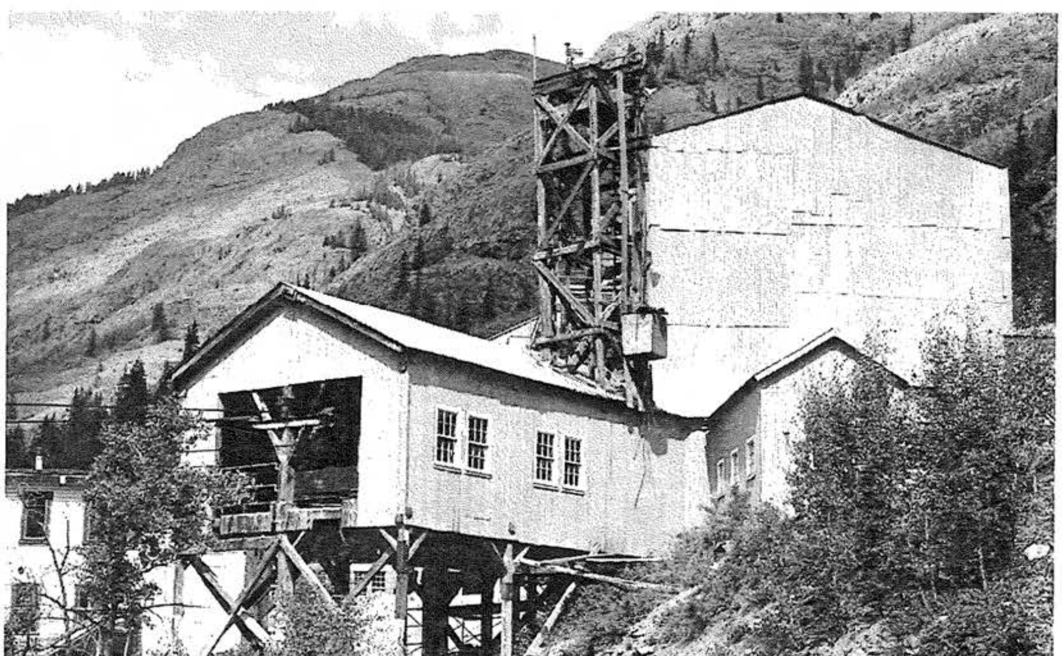


The famed "Bat Tram" approaches its terminal on the rim of the Grand Canyon in 1958. The cable swung down into the canyon to a tower, then stretched a mile and a half to the guano cave. This tramway, which lasted only a year, was one of the last mining tramways constructed in the U.S. (Courtesy Mohave County Historical Society)

Even though many of the old tram systems have collapsed over the years, some of them are still visible at mine and mill ruins throughout the West. Historic preservationists have even begun to rehabilitate some



Stark reminders of the great aerials tramways are still visible across the west. Above Animas Forks in Colorado several deteriorating towers remain on the alignment of the 1906 Gold Prince Mine Tramway. (Bob Trennert photo)



One of the best remaining examples of an aerial tramway can be found just outside Silverton, Colorado. The 10,000 foot tramway, constructed in 1929 by the Shenandoah Mining Company, remains largely intact and may be visited at the preserved Mayflower Mill. The above picture shows the tram terminal and unloading facility. The wooden tower supports some of the weights used to keep the line under tension. (Bob Trennert photo) of the surviving systems, reminding us of an important part of America's mining past. Examples of such tramways are the 1929 Shenandoah Dives Line near Silverton, the Keane Wonder in Death Valley, California, and the 1920s aerial tramway at Pioche, Nevada. These existing systems illustrate the mining industry's ability to adapt to difficult natural conditions and tell us of an unheard and little known part of our mining heritage.

NOTES

1. T. A. Rickard, "Across the San Juan Mountains," *The Engineering and Mining Journal* (hereafter *E&MJ*) (August 22, 1903): 269.
2. Zbignieu Schneigert, *Aerial Tramways and Funicular Railways* (Warsaw, Poland: Pergamon Press, 1966), 1-4.
3. "Wire Tramways," *E&MJ* (June 20, 1871): 385; "Endless Wire Rope Tramways," *E&MJ* (July 9, 1872): 26.
4. "Hallidie's Endless Wire Rope Tramways," *E&MJ* (July 2, 1872): 2.
5. Edgar M. Kahn, *Andrew Smith Hallidie: A Tribute to a Pioneer California Industrialist* (San Francisco: privately published, 1953), 1-13.
6. Schneigert, *Aerial Tramways*, 4-5.
7. The best description of Hallidie's cable system is provided in his own words. See Andrew S. Hallidie, *Transportation of Ore and Other Material by Means of Endless Travelling Wire Ropes* (San Francisco: C. A. Murdock & Co., 1878), 1-25. Also see "Hallidie's Endless Wire Rope Tramways," 26; Edward B. Durham, "Aerial Tramways and Cableways," in Robert Peele, ed., *Mining Engineer's Handbook* (John Wiley & Sons, 1927), Vol. II, 1787-1788; and O. H. Metzger, "Aerial Tramways in the Metal-Mining Industry, Part I," U.S. Bureau of Mines, Information Circular #6948 (September 1937), 3-4. Hallidie's patent for the "Improved Grip-Pulley" (No. 100,400), was issued on February 22, 1870.
8. "Wire Tramways:" 385; "Air Transportation," *E&MJ* (August 20, 1972): 122.
9. L. V. Colbath to Thomas M. Martin, September 28, 1872, Colbath to Hallidie, December 17, 1874, and W. S. Godbe to Hallidie, December 1, 1874, printed in Hallidie, *Transportation of Ore*, 6-7. Other Hallidie systems known to have been built in the 1870s include a mile and a half line at the Harley Mine in Kernville, California (1878), the Blue Jacket Mine at Elko, Nevada (1878), and a ropeway for the Standard Gold Mining Company in California (1877).
10. Stephen De Zouidovia, "Aerial Tramways," *The Iron Age* (September 24, 1903): 30; Durham, "Aerial Tramways and Cableways:" II, 1787.
11. Schneigert, *Aerial Tramways*, 5-6; J. Pohlig, "Aerial Wire Ropeways," *Transactions of the American Institute of Mining Engineers*, 19 (1891): 761; Durham, "Aerial Tramways and Cableways:" II, 1753.
12. "Relative Economy of Different Systems of Wire-Rope Conveyance," *E&MJ* (February 14, 1880): 115-116; "The Bleichert System of Wire Rope Tramways," *E&MJ* (May 19, 1888): 361-362; "Contracting Notes," *E&MJ* (June 30, 1888): 478; Advertising Supplement, *E&MJ* (December 29, 1888): 20.
13. *Fraser & Chalmers Catalog*, 3rd ed. (Chicago: June 1898). Among the companies entering the market around the turn of the century was the J. H. Montgomery Machinery Company of Denver and the Vulcan Iron Works of San Francisco.
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