HISTORICAL CONTEXT FOR THE CREEDE MINING DISTRICT

Eric Roy Twitty
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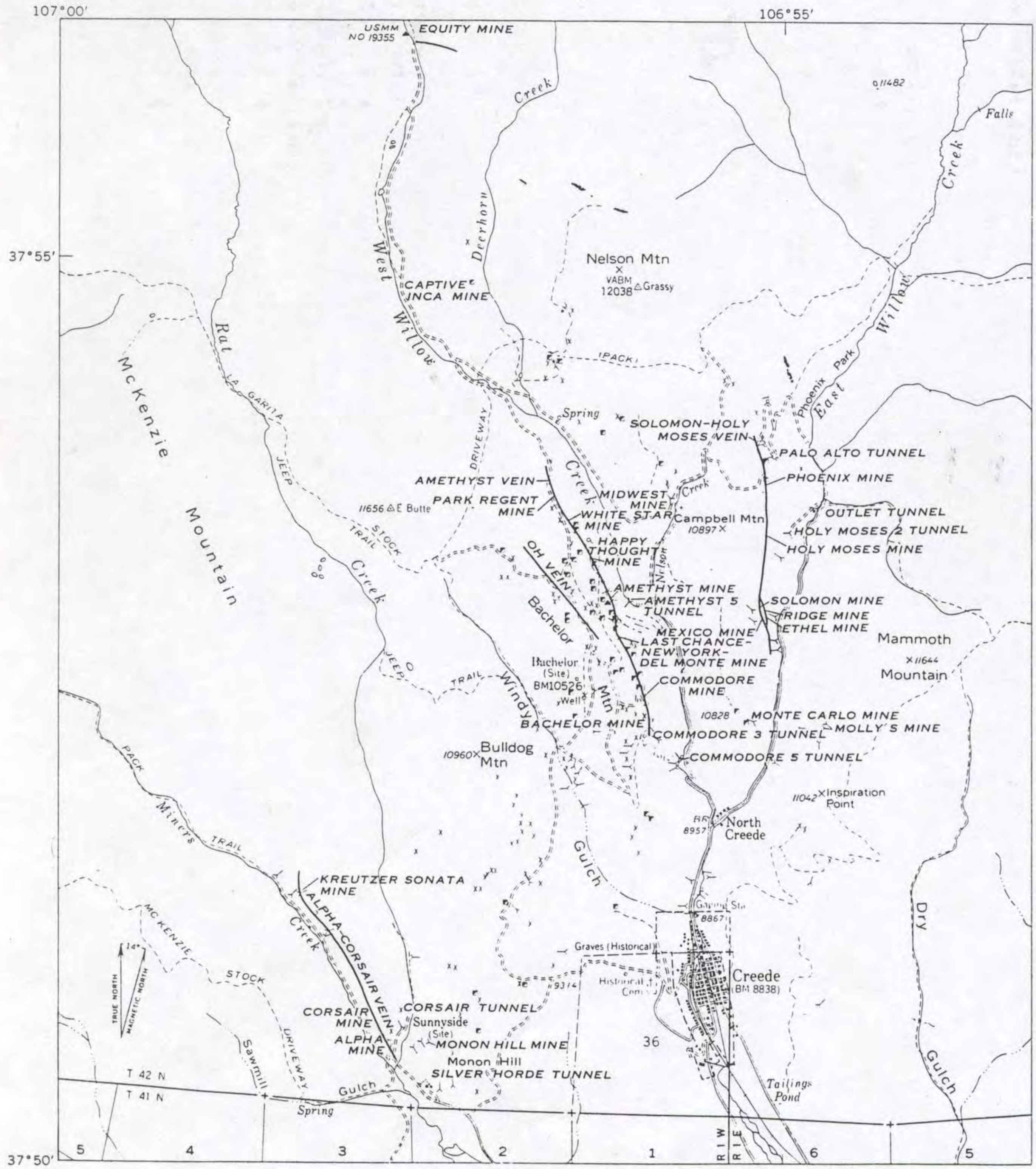

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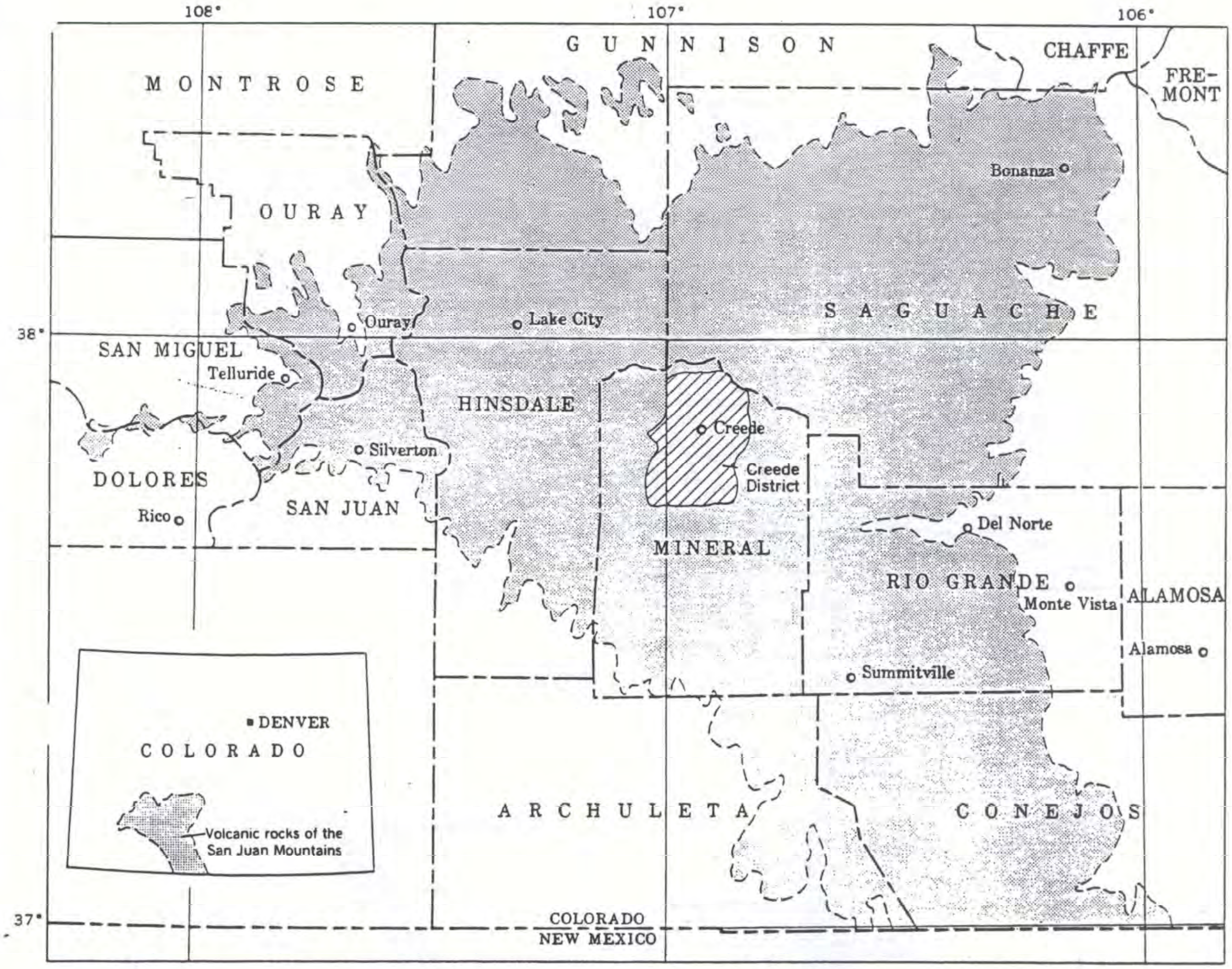
CONTENTS

CHAPTER

LIST OF TABLES

LIST OF FIGURES

Geographic location of the Creede Mining District.



CHAPTER 1

INTRODUCTION

In the early 1890s the American mining frontier began to exhibit signs of closure. The ever-hoped-for mining bonanzas and associated rushes were becoming increasingly rare, and the extant mining districts were either exhausted, or settled and industrialized. Yet two mineral strikes made during this time ignited an excitement which captured the attention of many miners, industrialists, and investors across the nation. Bob Womack made one of the strikes at what became Cripple Creek, Colorado. Parties of prospectors including Nicholas C. Creede and John C. McKenzie made the other strike at what became Creede, Colorado. For several years the two districts vied for prominence, and when legends of Creede's incredible silver wealth seemed to be eclipsing those of Cripple Creek's gold, the Silver Crash of 1893 dramatically reversed the situation. The devaluation of silver struck a significant blow to Creede, as well as silver districts throughout the West. However, Creede's ore bodies proved to be so rich that mining continued unabated for almost a century.

Geologists have deemed the Creede Mining District to be one of America's most significant producers of silver. In accordance, mining at Creede was serious business, requiring capital, a highly skilled workforce, an efficient infrastructure, advanced technology and engineering, and a vibrant population. While the sun has set on Creede's mining industry today, the district retains many vestiges of this fascinating chapter of Western history. Currently, the town of Creede, the district's historic commercial and social hub, thrives as a center for ranching, tourism, and recreation in the region. Dozens of historic sites lie above the town. The sites include predominantly abandoned mines, in addition to settlements, transportation systems, and mill remnants. These sites retain importance as cultural resources and as beacons that draw thousands of tourists to Creede. The mine sites, however, face threats in the form of environmental cleanup projects and mine closure activities. Studies, recordation, and evaluations of the sites are inevitable, and for that reason this historical context, which discusses the factors important to mining in Creede, can serve as an important frame for interpreting future cultural resource work.

Specifically, this context discusses four fundamental topics useful in identifying, recording, interpreting, and evaluating Creede's historic mine and mill sites. The physical setting constitutes the first factor, and it is important because it served as the environment that Creede's residents inhabited, it presented mining operations with physical challenges that drew certain responses, and it included natural resources. The second factor consists of Creede's geology, and it is important because it governed how Creede's mining companies equipped and developed their claims, and which companies prospered. Mining technology is the third and one of the most important factors included in this historical context.

The information included in the chapter on technology can aid in the interpretation, recordation, and evaluation of Creede's historic mine and mill sites. The last factor important to Creede's mining is the district's history. These four factors need to be considered when historic mine sites in Creede are identified, recorded, interpreted, and evaluated.

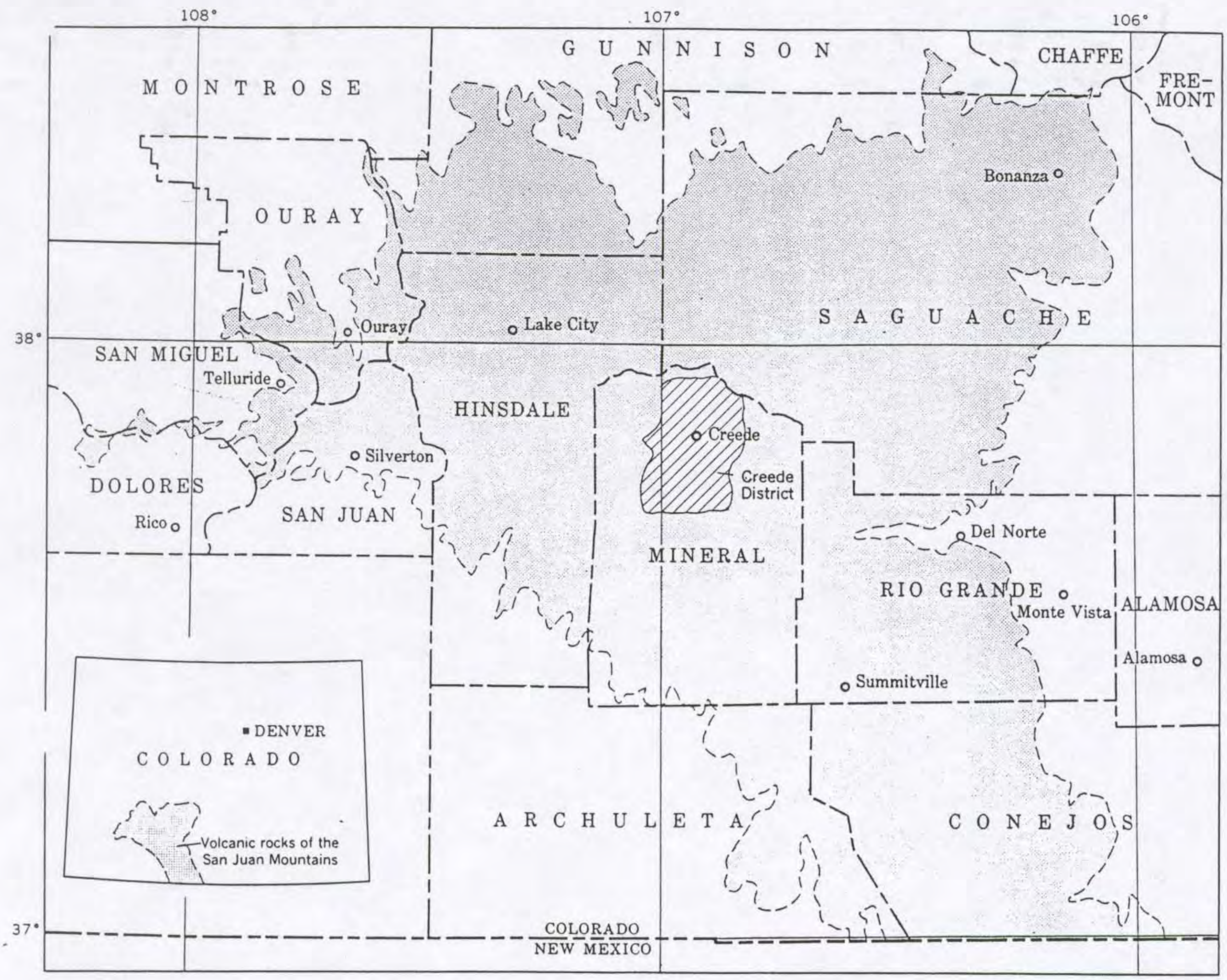


Figure 1.1 The geographic location of the Creede Mining District.

CHAPTER 2

THE PHYSICAL SETTING

The Creede Mining District covers an area of approximately 47 square miles in Mineral County near the upper Rio Grande River in the east San Juan Mountains. The district encompasses much of the Willow Creek drainage system, Miners Creek, and land along the Rio Grande River's north side. The region's topography is predominantly mountainous. Extremely rugged terrain rises along the north side of the Rio Grande River Valley and culminates in a series of 12,000-13,000 foot high peaks, which form the Continental Divide. Both the Divide and the Rio Grande valley extend east-west in the vicinity of the mining district. East and West Willow creeks, their tributaries, and Rat and Miners creeks dissect the mountainous area within the district. East and West Willow creeks join to form Willow Creek, Rat Creek drains into Miners Creek, and they flow south into the Rio Grande. Most of the activity in the Creede Mining District occurred in the lower portions of the Willow Creek drainage, while some prospecting and limited mining occurred near Rat and Miners creeks.

The terrain within the district is typical of that resultant from volcanic activity. Gently sloped terraces and the summits of table top mountains lie between approximately 10,000 and 11,000 feet, and the topography below is steep and rocky. Further, volcanic rock formations manifest as cliffs and pinnacles in the lower, eroded portions of the East and West Willow creek valleys.

Because the Creede Mining District is located in the eastern San Juan Mountains, it lies within rain shadow, and as a result, the ecological communities adapted to dry conditions. The Rio Grande River Valley features stands of juniper-pinion trees and areas of grassland, while the mountain slopes bounding the valley support subalpine fir and spruce forests. Lodgepole pines and fir trees predominate the dry lower slopes, and spruce trees replace the pines with increase in elevation. In addition, stands of aspen trees thrive on flat areas above 8,500 feet. Some of the groves are natural, while many others grew in logged clear-cuts. Because the soil within the district is well-drained, ground cover in the forests is limited to woody, drought-tolerant species such as mountain juniper, holly, and kinnikinnick. Subalpine meadows thrive in open areas between forests, and arctic willows line most of the area's stream channels.

The climate in the district is typical of that in the drier, deep Rocky Mountains. The summers tend to be warm, however the temperatures during the day rarely exceed 85 degrees Fahrenheit, and the nights cool down to the 40s and 50s. The months of June and September are often dry, while thunderstorms punctuate the afternoons July through August. The Fall also tends to be dry, yet the weather has an element of unpredictability. At the least, the temperatures during both day and night are cooler than during the summer. Cold snaps, snow, and prolonged warm weather are possible during September through November. Winter usually commences during November and lasts until late April. During wet years, periodic storms can deposit up to several feet of snow at a time and send temperatures plummeting below zero degrees. The San Juans occasionally experience dry years in which little snow accumulates and temperatures rise into the 30s and 40s. Because the air is very dry, cold temperatures are often tolerable with proper clothing. Because cold air tends to sink, during the winter the mountain canyons channel streams of frigid air, while the areas on the slopes above tend to be much warmer. The prevailing winds in the area blow from the west, and they may carry in storm systems. Occasionally, summer storms creep up from the south, and winter storms may descend from the north. In all, the climate in the Creede Mining District is hospitable for much of the year, however winter storms and wet summers presented the early settlers with a formidable challenge.

CHAPTER 3

ECONOMIC GEOLOGY

To gain a full comprehension and appreciation of mining in Creede, a brief account of the district's geological history and fabulous ore bodies is important. The San Juan Mountains began to rise approximately 100 million years ago, during the Cretaceous Period, when powerful forces in the earth's mantle forced the region up out of an ancient sea floor. A dome of magma intruded the Earth's crust and the heat and pressure caused the overlying sedimentary rocks to metamorphose, fracture, and dome upward. This intense activity abated and the Ancestral San Juan Mountains were eroded almost totally flat, resorting back to a sea floor. The importance of these geological events lay not in the creation of lasting topography, but in the deposition of the minerals sought by miners during the nineteenth century. As the magma body intruded into the overlying sedimentary formations when the Ancestral San Juans formed, the rock strata became fractured and superheated fluids, mostly water, deposited metal ores in the form of veins and chimneys in the cracks and areas of weakness. These ores were not the bodies worked by Creede's miners, but their impact on Creede was crucial, because they initially drew the prospectors who eventually located Creede's rich deposits. Several million years would pass before the ore systems at Creede formed.[i]

After the Ancestral San Juans had been uplifted and eroded to their base, the area became the focus of intense volcanic activity which created the mountains that exist today. The first eruptive period deposited thousands of feet of andesitic and conglomerate rock strata that geologists have termed the San Juan Formation. When the volcanic activity abated, natural forces make significant headway eroding the strata. Two more violent eruptive periods subsequently occurred, in which the Silverton Volcanic Group formed, followed by the Potosi Volcanic Group. Andesite tuff comprised the Silverton Group and rhyolite comprised the Potosi Group. The portion of the Potosi Series in our area of study is known as the Creede Formation. After the explosive volcanic activity, the San Juan region subsided, creating expansive fault systems. Further, subsidence of the many caulderas associated with the volcanic activity resulted in localized radial faulting. The Creede area was subjected to both types of faulting, laying the groundwork for the formation of the fabulous ore bodies mined during the nineteenth century.[ii]

Even though the volcanic activity largely ceased, the San Juan region was by no means geologically quiet. The area experienced periodic upheavals followed by settling, and superheated fluids began infiltrating the fault systems. In many areas the fluids deposited veins of silicic rocks such as gabbro, diorite, quartz, monzonite, and pegmatite in the fractures. In the Creede area, the fluids deposited silver, lead, zinc, and minor amounts of other metals in some of the fractures. Over thousands of years, great fluctuations in the region’s groundwater redeposited the metalliferous materials, enriching the zones near the water table.

This factor was the primary reason that Creede's ores were located relatively close to ground surface.[iii]

The Creede district became host to four principal vein systems resulting from the millions of years of geological processes. The veins were oriented primarily north-south, and they dipped steeply eastward. The eastern-most vein system, termed the Mammoth Vein, lay under Mammoth Mountain on the east side of East Willow Creek. Unfortunately for some of Creede's prospectors and mining companies, the Mammoth Vein proved to contain only limited quantities of economic ore. The Soloman-Holy Moses Vein, the second principal system, lay underneath Campbell Mountain on the west side of East Willow Creek. The Soloman-Holy Moses proved to one of the district's richest ore bodies, and its discovery by Nicholas Creede and associates in 1889 stimulated greater exploration for Creede's mineral wealth. The Last Chance-Amethyst Vein, the district's third important vein system, proved to be an unequaled bonanza for mining companies. The system consisted of one main vein flanked by minor stringers, and it extended uninterrupted for over two miles along the west side of West Willow Creek. The Amethyst Vein proved to be the district's richest ore system, and it experienced activity for almost 100 years. The district's last significant ore system, the Alpha-Corsair Vein, lay along the east side of Miners Creek. The Alpha-Corsair Vein was the first to be discovered in the district and it ranked third in importance.[iv]

Miners found the ores in these veins to be quite favorable for extraction and milling. Most of the ores consisted of zinc compounds, galena, pyrites, argentite, native silver, and gold in a matrix of plain and amethyst quartz, chlorite, barite, fluorite, and additional sulphates. This mineral blend filled the voids created by faulting in the hard volcanic country rock. Alteration to the country rock abutting the veins was minimal, and as a result the ore broke away easily and cleanly. In addition, the ores tended to be soft, making drilling and blasting easy, and in some places it was so soft that miners extracted it with pick and shovel. In many places the country rock maintained integrity, resulting in sound hanging and footwalls. Several mines on the Amethyst Vein experienced catastrophic cave-ins, which were probably a result of poor engineering and oversight, rather than inherently unstable geology.[v]

The shallow natures of Creede's vein systems lent themselves well to initial exploration through adits. However, as mining companies developed the ore at depth, they realized that shafts were necessary to profitably extract the payrock. Hence the mine workings in the district tend to include both adits and shafts, and most of the workings on each vein system tend to be interconnected. Engineers joined mine workings for three main reasons. First, it allowed for thorough exploration of consolidated mineral claims. Second, interconnected workings provided access and escape routes in the event of danger. However, the most important factor proved to be ventilation. Like other mining districts in volcanic geology, Creede's miners encountered gases such as nitrous compounds at depth. The gases displaced breathable air, which impeded the extraction of ore. As a result, mining companies were forced to link workings to stimulate the movement of natural air currents where possible, and to employ ventilation fans where necessary.[vi]

The ore systems at Creede presented a curious variety of opportunities and obstacles for mining companies. The Soloman-Holy Moses and the Amethyst veins contained huge quantities of silver-rich compounds which produced up to $80 to $100 per ton. Once mining companies exhausted the shallow ores in the principal veins by the end of the Gilded Age, mining engineers and geologists pooled their knowledge and searched for additional veins, which they periodically encountered from the 1920s to the 1960s during underground exploration. In addition to new discoveries, mining companies found that Creede's seemingly exhausted principle veins offered low-grade ores left by early operations as unprofitable. By working new and old veins, mining companies in Creede and their workers profited from 1891 until the early 1980s.

End Notes

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CHAPTER 4

MINING TECHNOLOGY DURING THE GILDED AGE AND GREAT DEPRESSION

When the miners of Creede began to pursue silver underground in the early 1890s, the American hardrock mining industry had attained a high state of development. Capital, a willing workforce, transportation systems, technology, and engineering shared the symbiotic relationship necessary to win mineral wealth from a rugged wilderness. The topics of technology and engineering are of considerable importance to the history of Creede in two ways. First, without advanced technology and engineering, mining there would have failed. Second, most of Creede's historic mine and mill sites feature archaeological remains and standing structures representative of mining during the Gilded Age and the Great Depression. A discussion of conventional mining methods employed during those eras lends important context for the examination and interpretation of Creede's historic mine sites.

Prospecting: The Search for Ore

Mining in the West has been popularized in the form of vignettes in which individual or pairs of prospectors arbitrary hacked holes into the earth with pick and shovel in hopes of "striking it rich". Few things were farther from reality. During mineral rushes prospectors rarely worked alone for the sake of survival, economy, efficiency, and the likelihood of finding ore. They also practiced planned, systematic approaches for finding ore bodies in a group effort. Over several decades of mining in the West prospectors learned to identify geological and topographical features suggestive of ore bodies. They often examined visible portions of bedrock for seams and joints, for outcrops of quartz veins and dykes, unusual mineral formations, and minerals heavy in iron. In many regions where vegetation, sod, and soil obscured visibility of bedrock, prospectors also scanned the landscape for anomalous features. Water seeps, abrupt changes in vegetation and topography, and changes in soil character also hinted at the underlying geology.[i]

Seasoned prospectors understood that the lands of the West were vast and a person could have spent a lifetime examining bedrock outcrops and puzzling over landscape form. Instead, they employed sampling strategies as a primary means of exploration in areas they felt held promise. One of oldest and simplest sampling strategies, popularized during the California Gold Rush, consisted of testing steam gravels for gold. The premise was that the natural process of erosion freed gold from bedrock sources and deposited it in a stream. Water action moved the gravel and the heavy gold slowly sifted to the bottom of the stream channel, where it awaited the prospector's shovel and pan. By periodically panning samples of stream gravel, a prospector could track the gold upstream, and when he encountered the precious metal no more, he knew he was near the point of entry.

Gold veins usually cropped out at some distance from watercourses, necessitating that prospectors extend their sampling system. After following traces of gold up a stream channel, they turned toward one of the stream banks and began excavating test pits and panning the soil immediately overlying bedrock. They tested soil samples horizontally back and forth across the hillslope in attempts to define the lateral boundaries of the gold flecks. Afterward, the party of prospectors employed a similar sampling strategy to find the upslope deposit boundary, under which should have hypothetically been the hardrock gold source. Employing such a sampling strategy occasionally paid off, but the party of prospectors had to undertake considerable work in the form of digging prospect pits with pick and shovel, hauling soil samples to a body of water over rough terrain, and panning in cold streams.[ii]

One of the greatest drawbacks to systematic panning was that it only detected gold, while areas such as Creede abounded with other precious and semiprecious metals. In addition to searching stream gravels, prospectors scanned the ground surface for what they termed *float*, which consisted of isolated fragments of ore-bearing rock. As with free-gold, over centuries natural weathering processes fractured ore bodies and erosion transported the pieces downslope. Metalliferous ore was heavy and it sank below the soil in rainy regions, complicating the search. Greenhorn prospectors may have shambled around an area in disorder searching for float, while experienced prospectors targeted drainage floors where heavy material was likely to accumulate. If the prospectors encountered ore specimens, they then walked transects back and forth across a hillslope, narrowing the boundaries of the float scatter until they reached the apex. With high hopes they sank several prospect pits down to bedrock and chipped away at the material to expose fresh minerals. Locating a source of float was an unsure undertaking at best, and in the process of narrowing the search area, parties of prospectors excavated many worthless pits and trenches. Yet, this method had proven itself successful many time over, as it did at Creede.[iii]

Modern legends highlight the few examples of prospectors who traced scatters of float directly to glorious ore veins in bedrock outcrops, and those individuals who literally stumbled across gold or silver-bearing rocks in search of lost burros and the like. In reality prospecting was hard, laborious, dirty work requiring excavation of numerous pits two to fifteen feet deep over the span of many days. Digging pit after pit in pursuit of subtle hints of ore only to find the promising lead vanished soured greenhorns with get-rich-quick expectations, and the reality of repeated failures at striking ore proved enough to completely discourage even experienced prospectors. The landscapes of many Western mining districts, including that around Creede, are dotted with hundreds to thousands of prospect pits for every successful mine.

On rare occasion parties of prospectors dug pits and struck mineral deposits worthy of further investigation. The next step in subsurface exploration involved driving either a small shaft or adit with the intent of sampling the mineral deposit at depth in hopes of confirming its continuation. After clearing away as much fractured, loose bedrock as possible with pick and shovel, a pair of prospectors began boring blast-holes with a hammer and drill-steels. The drilling team made between 12 and 18 holes, 18 to 24 inches deep, in a special pattern designed to maximize the force of the explosive charges they loaded. Prior to the 1880s prospecting parties often used blasting powder, and most had converted to stronger but more expensive dynamite by the 1890s.

Within approximately 30 days the party of prospectors had driven their tunnel or shaft deep enough to confirm the presence or absence of ore at depth. Yet, in many cases shallow adits or shafts failed to prove or disprove economic quantities of ore, in which cases parties of prospectors often elected to drive *drifts*, horizontal internal tunnels, along the suspected mineral body. In most cases such exhausting efforts proved, in fact, that the mineral claim was worthless, but in a few exceptions the party of prospectors uncovered enough ore to warrant the development of a proper *mine*. Until economic ore had been proven, the operation could have been classified as merely a glorified *prospect adit* or *prospect shaft*. At this point the need for capital, equipment, organization, and a labor force became apparent, and the party of prospectors either sold their holdings to a capitalist, or formed their own company.

Deep Exploration and the Development of Ore Bodies

The methods by which engineers and miners searched for and extracted ore and equipped their mines to do so were universal throughout the West. The mines and prospects in Creede were no exception, and they fell into several common patterns. A *prospect* differed greatly from a *mine*. A prospect was an operation in which prospectors sought ore. The associated workings ranged from shallow pits to adits or shafts with hundreds of feet of horizontal and vertical workings. A mine, on the other hand, consisted of at least hundreds of feet of workings and a proven ore body. All mines began as prospect operations. Most prospect operations, on the other hand, failed to prove the presence of ore and died early deaths. Once prospectors determined the existence of ore, the activity at the mineral claim shifted at first to quantifying how much ore existed, then to profitable extraction.

In efforts to address the above two ore production issues, mining companies hired crews of miners who proceeded to enlarge the small adit or shaft and systematically block out the mineral body. Generally ore bodies tended to take one of two forms; miners and engineers recognized the first form as a *vein*, and they defined the other as being massive and globular. Typically, free gold, telluride gold, and tungsten tended to be deposited in veins while industrial metals such as copper and iron were deposited in massive form. The silver and industrial metals in Creede formed as a vein. At the point where a tunnel or shaft penetrated the mineral body, miners *developed* the body with internal workings consisting of drifts, *crosscuts* extending off the drifts, internal shafts known as *winzes* which dropped down from the tunnel floor, and internal shafts known as *raises* which drove up. Drifts and crosscuts explored the length and width of the ore, and raises and winzes explored its height and depth.

Miners and prospectors consciously sank a shaft or drove an adit in response to fundamental criteria. First, a shaft was easiest and less costly to keep open against fractured and weak ground. Second, a shaft permitted miners to stay in close contact with an ore body as they pursued it to depth, and they were able to sample the ore periodically. Third, in cases where miners sank a shaft on profitable ore, the payrock they extracted provided the company with almost instant income, which pleased stockholders and greased the skids of mine promotion. Last, a shaft lent itself well to driving a latticework of drifts, crosscuts, raises, and winzes to explore and block out an ore body.

Mining engineers discerned between the purposes of sinking vertical versus inclined shafts. One contingent of engineers preferred inclined shafts because, as they correctly pointed out, mineral bodies, especially veins, were rarely vertical, and instead descended at an angle. As a result vertical shafts were ineffectual for intimate tracking and immediate extraction of ore. In addition, inclined shafts needed smaller, less expensive hoists than those used for vertical shafts. The other camp of engineers, however, claimed that vertical shafts were in fact best because maintenance and upkeep on them cost less. Vertical shafts had to be timbered merely to resist swelling of the walls, while timbering in inclines had to also support the ceiling, which was more expensive, especially when the passage penetrated weak ground. Inclined shafts also required a weight-bearing track for the hoist vehicle, which, including maintenance such as replacing rotten timbers and corroded rails, consumed money.

In light of the collective experience gained during five decades of mining in the West, by the 1900s most mining engineers recommended that vertical shafts be sunk in the footwalls of ore veins. Experience had taught the mining industry, often through expensive and dangerous lessons, that the hanging wall overlying the vein was likely to settle and shift after ore was extracted, throwing the shaft out of plumb.[iv]

Despite the hypothetical advantages of sinking a shaft over an incline or adit, several factors beyond miners' or engineers' control governed the actual choice of shaft versus adit. In many cases geology proved to be a deciding criterion; steep hillsides, deep canyons, and gently pitching ore bodies lent themselves well to exploration and extraction through adits. In many cases prospectors who had located an outcrop of ore high on a hillside elected to drive an adit from a point considerably downslope to intersect the formation at depth. If the ore body proved economical, then the mining company carried out extraction through the adit. One of the most problematic aspects of driving an adit was that miners had to labor at considerable dead work, drilling and blasting through barren ground, with no guarantee that they would locate the ore body where they had anticipated striking it. In many cases veins cropping out high on mountainsides disappeared at depth, or natural faulting broke them up and shifted the pieces around. In addition, adits were not as well suited as

Figure 4.1 The cut-away view illustrates the typical mine workings associated with a shaft operation. Miners sank the shaft in the footwall underlying the vein, and drove drifts at regular intervals to intersect the ore body. They may have also driven raises through the ore to link the drifts. After miners had completed this development work, they began stoping out the ore upward.

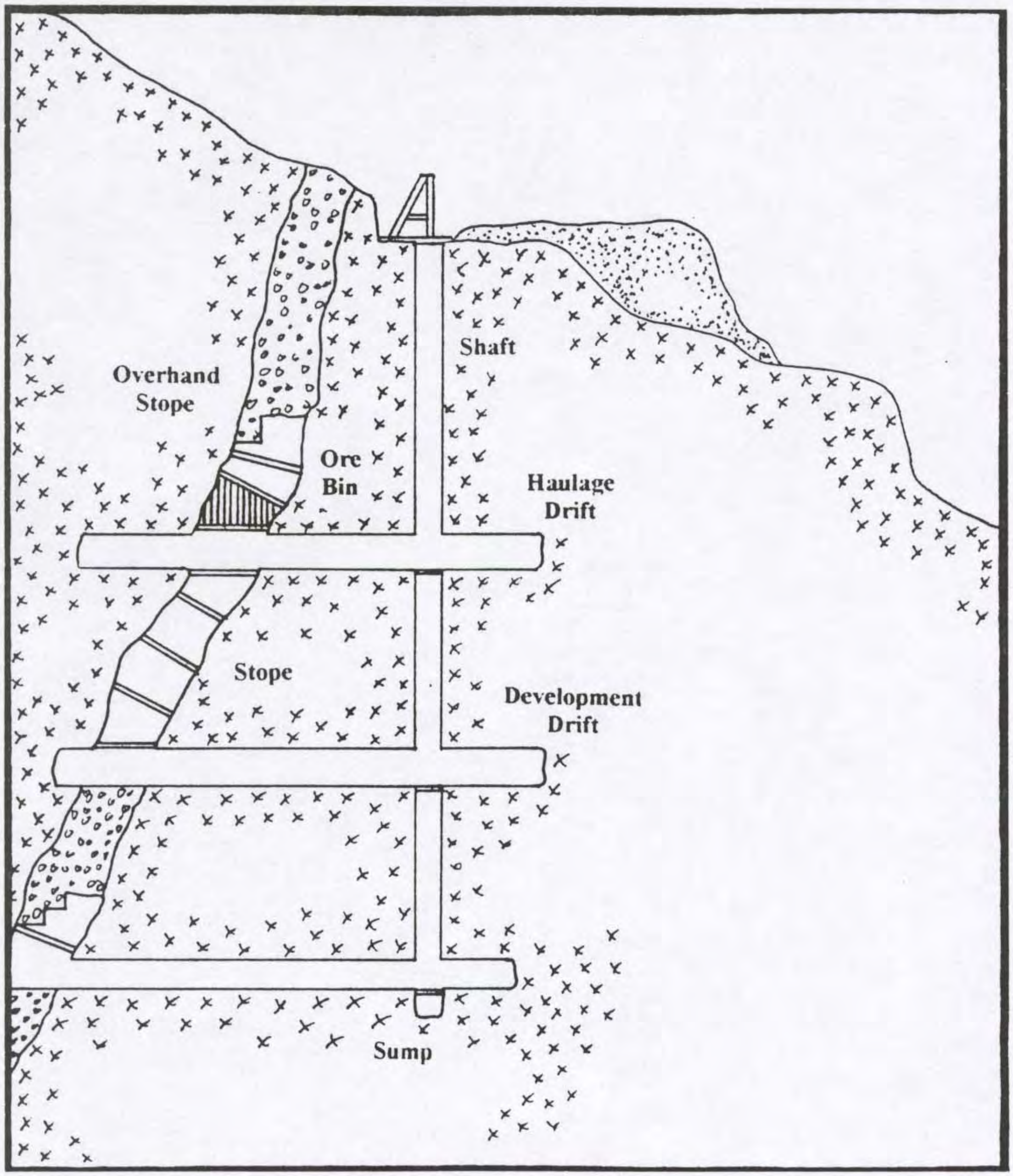
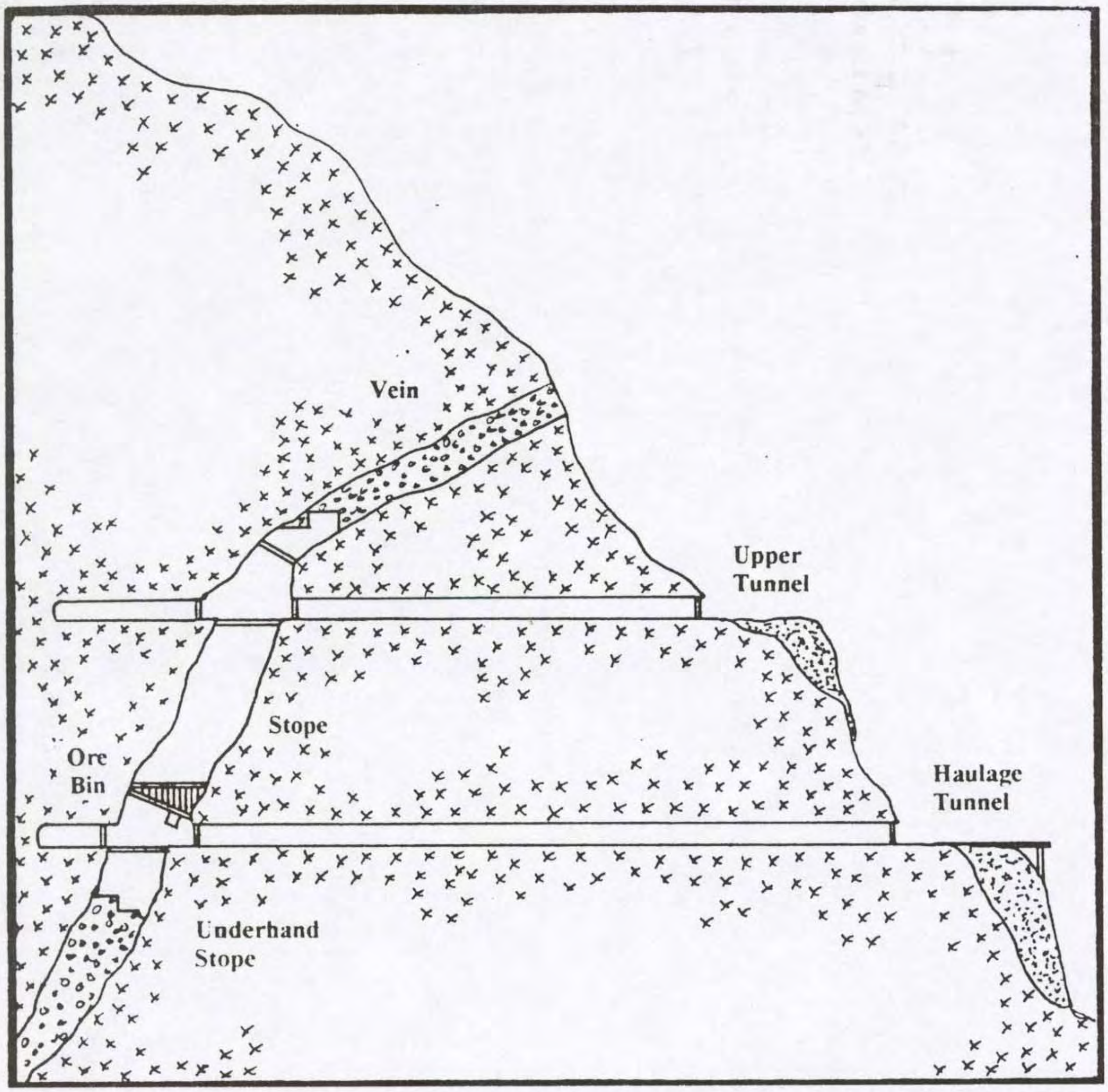


Figure 4.2 The cut-away view illustrates the typical mine workings associated with a tunnel operation. Miners drove tunnels to intersect the ore body, they conducted the necessary development work, and began removing ore. If the company was well-capitalized, it may have driven two tunnels, the bottom serving as a haulageway.



shafts for developing deep ore bodies, because interior hoisting and ore transfer stations had to be blasted out, which proved costly and created traffic congestion. One other problem, significant in districts where the rock was weak, lay in the enormous cost of timbering adits and tunnels against cave-in. However, much to relief of Creede's mining companies, the district featured sound rock requiring little support.[v] But the most fundamental consideration in deciding whether to drive an adit or sink a shaft lay with economics. Driving an adit was easier, faster, and required significantly less capital than sinking a shaft. Some mining engineers had determined that the cost of drilling and blasting a shaft was as much as three times more than excavating an adit. Prospectors and mining engineers alike understood that adits were self-draining, they required no hoisting equipment, and transporting rock out and materials into the mine was easier than it was in shafts. Regardless, in many cases prospectors, those with the least access to capital, sank small shafts to explore ore bodies for the reasons cited above, and for one additional significant factor.[vi]

Historians of the West have aptly characterized mineral rushes to heavily promoted mining districts as a frenzy of prospectors who blanketed the surrounding territory with claims. In most districts the recognized hardrock claim was restricted to being 1,500 feet long and 600 feet wide, which left limited work space, both above and below ground. In Colorado prospectors were legally obligated to drive an adit or shaft, or sink a pit to a minimum depth of 10 feet to hold title to a hardrock claim. They had to conduct $100 worth of labor in other states. A small adit or pit was not adequate to fully explore the depths bounded by a 1,500 by 600 foot plot of ground, let alone extract ore, forcing prospectors and mining companies to sink shafts.[vii]

The Creede Mining District serves as an excellent example of how crowded conditions forced mining companies to sink shafts to work at depth within their claim boundaries. The Amethyst and Soloman-Holy Moses veins were blanketed with claims during the district's heyday, few of which mining companies consolidated in the early years. Prospectors and mining companies were forced to sink shafts because they lacked the surface space necessary to explore and develop ore bodies at depth through tunnels. In districts where competition for space was not as severe, mining companies had greater latitude to drive tunnels.

The Mine Surface Plant

The driving of underground workings associated with both mines and deep prospect operations required support from on-site facilities. Known among miners and engineers of-the-day as the *surface plant*, these facilities were equipped to meet the needs of the work underground. Large, productive mines boasted sizable surface plants while small prospect operations tended to have simple facilities. Regardless of whether the operation was small or large, the surface plant had to meet five fundamental needs. First, the plant had to provide a stable and unobstructed entry into the underground workings. Second, it had to include a facility for tool and equipment maintenance and fabrication. Third, the plant had to allow for the transportation of materials and waste rock out of the underground workings and supplies in. Fourth, the workings had to be ventilated, and fifth, the plant had to facilitate the storage of up to tens of thousands of tons of waste rock generated during underground development, often within the boundaries of the mineral claim. Generally, productive mines, as well as complex and deep prospects, had needs in addition to the above basic five requirements, and their surface plants included the necessary associated components.[viii]

The basic form of a surface plant, whether haphazardly constructed by a party of inexperienced prospectors or designed by experienced mining engineers, consisted of a set of *components*. The entry underground usually consisted of either a stabilized shaft collar or an adit portal. While the exact differentiation between a tunnel and an adit is somewhat nebulous, mining engineers and self-made mining men have referred to narrow and low tunnels with limited space and length as *adits*. Passages wide enough to permit incoming miners to pass outgoing ore cars, high enough to accommodate air and water plumbing suspended from the ceiling, and extending into substantial workings have been loosely referred to as *tunnels*. Most surface plants featured transportation arteries permitting the free movement of men and materials into and out of the underground entry. Miners moved materials at adit operations in ore cars on baby-gauge mine rail lines, while shafts required an additional hoisting system to lift vehicles out of the workings. Materials and rock at shaft mines were usually transferred into an ore car for transportation on the surface. The surface plants for both adits and shafts included a blacksmith shop where tools and equipment were maintained and fabricated, and large mines often had additional machining and carpentry facilities. Most of these plant components were clustered around the adit or shaft and built on cut-and-fill earthen platforms made when mine workers excavated material from the hillslope and used the fill to extend the level surface. Once enough waste rock had been extracted from the underground workings and dumped around the mouth of the mine, the facilities may have been moved onto the resultant level area. The physical size, degree of mechanization, and capital expenditure of a surface plant was relative to the constitution of the workings below ground.

In addition to differentiating between surface plants that served tunnels from those associated with shafts, mining engineers further subdivided mine facilities into two more classes. Engineers considered surface plants geared for shaft sinking, driving adits, and underground exploration to be different from those designed to facilitate ore production. Engineers referred to exploration facilities as *temporary plants*, and as *sinking plants* when associated with shafts. Such facilities were by nature small, labor-intensive, energy inefficient, and most important, they required little capital.

Production plants on the other hand usually represented long-term investment, and they were intended to maximize production while minimizing operating costs such as labor, maintenance, and energy consumption. Such facilities emphasized capital-intensive mechanization, engineering, planning, and scientific calculation.

Mines underwent an evolutionary process in which discovery of ore, the driving of a prospect shaft or adit, installation of a temporary plant, upgrade to a production plant, and eventual abandonment of the property all were points along a spectrum. Depending on whether prospectors or a mining company found ore and how much, a mine could have been abandoned in any stage of evolution, as many in Creede had been. Of course, the ultimate goal of most mining companies, capitalists, and engineers was to locate, prove, and develop fabulous ore reserves, and to install a surface plant large and efficient enough to arouse accolades from the Western mining industry. Mining engineers and mining companies usually took a cautionary, pragmatic approach when upgrading a sinking plant to a production plant. Until significant ore reserves had been proven, most mining companies minimized their outlay of capital by installing inexpensive machines adequate only for meeting immediate needs.

Mining engineers and self-made mining men understood that temporary plants consisted of light-duty, inexpensive, and impermanent components. Many engineers classified the duty of these components, especially machines such as hoists, boilers, blowers, and air compressors by their size, energy efficiency, performance, and purchase price. Machine foundations, necessary to anchor and stabilize what were critical plant components, also fell under this scope of classification. Because of a low cost, ease of erection, and brief serviceable life, mining engineers considered timber and hewn log machine foundations to be strictly temporary, while production-class foundations consisted of concrete or masonry. The structure of wooden foundations usually consisted of cribbing, a framed cube, or a frame fastened to a pallet, all of which were assembled with bolts and iron pins, and buried in waste rock for stability and immobility. The construction and classification of machine foundations is of particular importance, because they often constitute principal evidence at Creede's mine sites capable of conveying the composition of the surface plant in terms of structures and machinery.[ix]

Surface Plants for Adits

The surface plants for adits and shafts shared many of the same components. Yet, because of the fundamental differences between the nature of the two mines, the layout patterns and characteristic for each were different. The typical surface plant layouts for Creede's adit-based operations mirrored those erected throughout the

West, and here we will examine their common components.

The Adit Portal

The adit portal was a primary component of both simple prospects as well as complex, profitable mines. Professionally trained mining engineers recognized a difference between prospect adits and production-class tunnels. Height and width were the primary defining criteria. A production-class tunnel was wide enough to permit an outgoing ore car to pass an in-going miner, and headroom had to be ample enough to house compressed air lines and ventilation tubing. During the latter portion of the Gilded Age, some mining engineers defined production-class tunnels as being at least 3½ to 4 feet wide and 6 to 6½ feet high. Anything smaller, they claimed, was merely a prospect adit. Many of these engineers reflected an attitude post-dating the adoption of compressed air powered rockdrills which had reduced the costs of drilling and blasting.[x]

Mining engineers in Creede, like those at other districts in the West, paid due attention to the adit portal, because it guarded against cave-ins of loose rock and soil. Engineers recognized *cap-and-post timber sets* to be best suited for supporting both the portal and areas of fractured rock further in the adit. This ubiquitous means of support consisted of two upright posts and a cross-member, which mine workers fitted together with precision using measuring rules and carpentry tools. They cut square notches into the cap member, nailed it onto the tops of the posts, and raised the set into place. Afterward, the miners hammered wooden wedges between the cap and the adit ceiling, and between the posts and adit walls to make the set weight-bearing. Because the adit usually penetrated tons of loose soil and fractured rock, a series of cap-and-post sets were required to resist the heavy forces, and they had to be lined with *lagging* to fend off loose rock and earth. In areas penetrating swelling ground, the bottoms of the posts had to be secured to a floor-level cross-timber or log footer to prevent them from being pushed inward.

Wood used for the purposes of supporting wet ground decayed quickly and had to be replaced as often as several times a year, and as infrequently as every few decades in dry mines. Professionally trained mining engineers claimed that dimension lumber was best for timber sets because it decayed slowly and was easy to frame, but a relatively high purchase price and the cost of transportation discouraged its use where cheaper alternatives were available. Most down-to-earth miners and engineers favored using hewn logs for their timber sets and lagging because they cost less than milled lumber, and they could be harvested from nearby forests, which abounded in Creede.[xi]

Mine Transportation

Miners working underground at Creede generated tons of waste rock that had to be hauled out, while tools, timbers, and explosives had to be brought in. As a result, both prospect operations and large, paying mines had to rely on some form of a transportation system. The conveyances used by prospectors had to be inexpensive, adaptable to tight workings, and capable of being carried into the backcountry. To meet these needs prospect outfits often used the old-fashioned wheelbarrow on a plank runway. A wheelbarrow cost as little as $12, it was easy to pack on a mule, and it fit into tight workings. Mining engineers recognized the functionality of wheelbarrows, but classified them as strictly serving the needs of subsurface prospecting because of their limited load capacity, awkwardness of handling, and propensity for being crushed.[xii]

Outfits driving substantial underground workings required a vehicle with a capacity greater than the few hundred pounds that a prospector could have trundled in a wheelbarrow. The vehicle most mining outfits chose was the ore car - today the immortalized symbol of hardrock mining. The ore car commonly associated with metal mining consisted of a plate iron body mounted on a turntable that was riveted to a rail truck. Cars were approximately 2 feet high, 4 feet long, and 2½ feet wide, they held at least a ton of rock, and they had a swing gate at the front to facilitate dumping. Further, the body pivoted on the turntable to permit the operator to deposit a load of rock on either side of or at the end of the rail line. While iron ore cars were extremely durable, often outlasting the mining companies that purchased them, the iron components were heavy.

Table 4.1: ***Dimensions & Duty of Mine Rail***

Rail Type (pounds per yard)	Rail Height	Width of Base	Width of Head	Duty of Rail
Strap Rail	4 in.	1 ½ in.	1 ½ in.	Rail consists of iron strap nailed to the top of 2x4 boards. Such rail is temporary.
8 lb	1 ½ in.	1 ½ in.	½ in.	Temporary: for use with hand-pushed ore cars.
10 lb	1 ¾ in.	1 ¾ in.	¾ in.	Light duty: for use with hand-pushed ore cars.
12 lb	2 in.	2 in.	1 in.	Light duty: for use with hand-pushed ore cars.
16 lb	2 3/8 in.	2 3/8 in.	1 3/16 in.	Light duty: for use with hand-pushed ore cars and short ore car trains drawn by draft animals.
20 lb	2 5/8 in.	2 5/8 in.	1 3/8 in.	Moderate duty: for use with short ore car trains drawn by draft animals or locomotives weighing 8 tons or less.
25 lb	2 ¾ in.	2 ¾ in.	1 ½ in.	Moderate duty: for use with ore car trains drawn by draft animals or locomotives weighing at most 10 tons.
30 lb	3 1/8 in.	3 1/8 in.	1 ¾ in.	Moderate to heavy duty: for use with ore car trains drawn by draft animals or locomotives weighing at most 13 tons.
35 lb	3 1/4 in.	3 1/4 in.	1 ¾ in.	Moderate to heavy duty: for use with ore car trains drawn by locomotives weighing at most 16 tons.
40 lb	3 ½ in.	3 ½ in.	1 7/8 in.	Heavy duty: for use with ore car trains drawn by locomotives 15 tons or less, and for narrow-gauge railroad spurs.
45 lb	3 3/4 in.	3 3/4 in.	2 in.	Heavy duty: for use with ore car trains drawn by locomotives, and for narrow-gauge railroad spurs.
50 lb	3 7/8 in.	3 7/8 in.	2 1/8 in.	Heavy duty: for use with ore car trains drawn by locomotives, and for narrow-gauge railroad spurs.

(Copied from Twitty, 1999, p140).

Ore cars ran on rails sold in a variety of standard sizes by mine supply houses. The units of measure were based on the rail's weight-per-yard. Light-duty rail ranged from 6 to 12 pounds-per-yard, medium-duty weight rails included 12,16, 18, and 20 pounds-per-yard, heavy mine rail weighed from 24 to 50 pounds-per-yard, and anything heavier was used for railroad lines. Prospecting outfits installing temporary plants usually purchased light-duty rail because of its transportability and low cost.[xiii] Mining engineers erecting production-class transportation systems had miners lay track using at least medium-duty rail, because it lasted longer.

The specific type of rail system installed by a mining operation reflected the experience and judgement of the engineer, or superintendent acting as such, as well as the financial status of the company, the extent of the underground workings, and whether the mine produced much if any ore. The basic rail system used in nearly all Western mines was fairly simple and straightforward. The track consisted of a main rail line that extended from the areas of work underground, though the surface plants, and out to the waste rock dump. Miners in the underground drilled and blasted, and shoveled the resultant shot rock into an ore car, and a miner then pushed the loaded car out of the adit and onto the edge of the waste rock dump where he discharged the car's contents. As the drilling and blasting crew advanced the adit, they laid rails in the new space to facilitate bringing the car close for loading. Large mining companies, such as the Amethyst, Bachelor, and Holy Moses operations at Creede, generated enough rock and ore car traffic underground to warrant hiring mine laborers known as *muckers* to load empty ore cars, and *trammers* to push the cars about the mine. Productive mines and deep prospect operations usually had rail spurs extending off the main line underground to other headings in feeder drifts and crosscuts where drilling and blasting teams were at work. Spurs also branched off into stopes and ore bin stations. Substantial mines with extensive surface plants also featured spurs off the main line on ground-surface that extended to different parts of the waste rock dump, to a storage area, and to the mine shop. Many large mines built special stake-side, flatbed, and latrine cars for the coordinated movement of specific materials and wastes.

The general rule of thumb followed by both self-made and professionally educated engineers working at small operations was to spend little capital improving the rail system, provided it already consisted of steel components. Typically, at small and medium-sized operations miners installed lines consisting of rail no heavier than 16 pounds per yard spiked at 18 inch gauge to ties spaced every three feet. Further, the ties usually consisted of hewn logs or salvaged lumber ranging from 2x4 to 6x6 inch stock. In efforts to save money, miners often reused the ties several times over. This type of line was ubiquitous throughout the West because it accommodated hand-pushed ore cars, and it was relatively inexpensive to build. Many self-made engineers saw no reason for subjecting the company to the considerable expense of installing heavier rails and possibly a broader gauge as the mine underwent significant expansion. Instead, they merely extended the line with the same weight of rail already in use. Academically trained engineers working at large mines, however, had miners replace light-duty rails with heavier, lasting rails as the iron succumbed to corrosion, or they had miners replace only the trunk portions of the main rail line with heavy rails, leaving alone the lighter ends and spurs.[xiv]

Many professionally educated mining engineers understood that hiring miners to hand-tram single ore cars was the most cost-effective means of transportation at small and medium-sized operations. But at large mines, where high volumes of materials had to be handled efficiently over great distances, they strongly recommended the use of ore trains pulled by a motive source greater than one or two struggling miners. Mining companies at Creede, like others throughout the West, turned to the use of draft animals. As hardrock mining matured through the nineteenth century miners learned that mules were the best animals suited for work underground because they were reliable, strong, of even temperament, and intelligent. Mining engineers, seeking to put science and calculation behind the use of mules to improve efficiency, defined 16 pound rail as being best weight in conjunction with small ore trains because it resisted wear.

The electric locomotive, termed an *electric mule* by some miners, arrived in the West during the 1890s. Mining engineers working for coal mines in the East and in the Appalachians introduced the first electric locomotives in 1887 or 1888 to move the immense volumes of the fossil fuel produced by coal companies. The early machines consisted of a trolley car motor custom mounted onto a steel chassis, and they took their power from overhead *trolley lines* strung along the mine's ceiling.

The spread of the electric mules to hardrock mining in the West proved slow. Locomotives required special mechanical and electrical engineering, which was in a nascent state during the 1890s and 1900s. In addition, electric mules were too big for the tortuous drifts typical of most metal mines, and they required considerable capital to purchase, install, and operate. During the first decade of the twentieth century the electrical system necessary to power a locomotive included a steam engine, a generator, electrical circuitry, plumbing for the engine, installation, and an enclosing building. The system alone cost around $3,100, and a small locomotive cost an additional $1,500. Further, an electric locomotive cost approximately $7.50 per day to operate. A mule, on the other hand, cost only $150 to $300 to purchase and house, and between 60? and $1.25 to feed and care for per day.[xv]

Upgrades to the rail line necessary to accommodate a heavy locomotive presented the engineer with additional costs. Mules were able to draw between three and five ore cars that weighed approximately 2,500 pounds each, and for this 16 pound rails spiked at an 18 inch gauge proved adequate. But electric locomotives and their associated ore trains usually weighed dozens of tons, and as a result they required broad tracks consisting of heavier rail. Mining engineers recommended that at least 20 pound rail spiked 24 inches apart on ties spaced every two feet be laid for small to medium-sized locomotives. Heavy locomotives required rail up to 40 pounds per yard spiked at 36 inch gauge. The reason for the heavy rails and closely spaced ties was that the heavy machines pressed down on the rail line and perpetually worked uphill against the downward-flexed rails. This wasted much of the locomotive's power and energy, and engineers sought to minimize the sag with stiff rails on a sound foundation of closely spaced ties. In addition, light rails presented a greater chance of derailment, which proved to be a logistical and economic disaster in the confines of a haulage tunnel.[xvi]

Some academic mining engineers criticized the fact that electric locomotives were tied to the fixed route defined by the trolley wires. To remedy this problem, electric machinery makers introduced the storage battery locomotive around 1900, which had free reign of the mine's rail lines. Despite its independence, very few Western hardrock mining companies employed battery-powered locomotives because they were costly, they required a recharging facility, and they too were physically inhibited by the mine's tight passageways. In general, electric locomotives required wide tunnels, and because they had long wheel-bases and ran on broad-gauge track, they were unable to negotiate the tight corners typical of Western hardrock mines. While the mighty machines were able to pull significant numbers of loaded cars and increase a mining company's economy of scale, the physical limitations presented by locomotives required engineers to virtually preplan expansive underground workings with broad curves, side tracks, and areas to turn the locomotive around. While such efforts were conducive for, even typical of, coal mining, they were not appropriate for the piecemeal work endemic to Western hardrock mining.

A few prominent academic mining engineers espoused the compressed air locomotive, which saw limited use in Western hardrock mines beginning in the 1890s. This interesting contraption consisted of a compressed air tank fastened to a miniature steam locomotive chassis. The tank forced air under extremely high pressure into drive cylinders that powered wheels in a fashion almost identical to steam railroad engines. Eastern mining engineers disliked the locomotives, criticizing their need for an expensive three to four stage compressor, valves and fittings for charging the tank with air, and a limited range of travel. Western mining engineers rebuffed the complaints, claiming that the machines were well-suited for their mines. The locomotives were able to negotiate tight passageways, they had plenty of motive power, they spread fresh air wherever they went, some of the machines were able to operate on the ubiquitous 18 inch rail gauge, and they did not require complex electrical circuitry. However, compressed air locomotives were not inexpensive, costing as much as their electric cousins. True, the little engines required a costly compressor capable of delivering air at pressures of 700 to 1000 pounds per square inch. But most metal mines large enough to warrant a locomotive required a high-pressure compressor to run rockdrills and other air-driven machinery anyway. Such arguments were a moot point for most western mines, which continued to rely primarily on the efforts of struggling trammers, and occasionally on mules for moving the heavy materials of mining.

During the Great Depression, greater numbers of well-financed mining companies relied on mechanical locomotives in hopes of producing ore in the high volumes necessary to make a profit at that time, while many outfits working medium-sized mines continued the tradition of employing mules. For mining companies with capital, electric trolley locomotives remained popular while compressed air and battery-powered locomotives saw increased use. Echoing the arguments of mining engineers past, Western mining companies operating during the Depression felt that compressed air locomotives had the advantage of being able to run on track constructed with heavy rail spiked at 18 inch gauge, while electric trolley locomotives required an expensive broad gauge and heavier rail. Mining machinery makers had reduced the costs and physical sizes of battery-powered locomotives, permitting them to also run on 18 inch gauge track.

The West's small mines did not have to worry about such issues because locomotives and the necessary improvements to the rail lines were well beyond their financial means. These companies continued the ages-old method of relying on the power of miners to move cars. During the capital-scarce times of the Depression, these outfits constructed rail lines out of whatever rails and ties they were able to salvage. They straightened bent rails, they used large nails instead of proper rail spikes, and they fashioned ties from a variety of pieces of lumber. To save materials, impoverished mining outfits spaced the ties far apart, they spliced rails of varying lengths and weights into a single line, and they broke connector plates that usually featured four bolt holes in two to make them join twice as many rails.

The Mine Shop

During the Gilded Age, every prospect operation and paying mine required the services of a blacksmith who maintained and fabricated equipment, tools, and hardware. Most small prospect operations lacked the capital and volume of work to hire dedicated specialists, and as a result one of the crewmembers comprising the outfit served as a miner when not working in the shop. The common rate for driving a prospect adit with hand-drills and dynamite in hard rock was approximately one to three feet per 10 hour shift. Over the course of such a day miners drilled numerous blast-holes and blunted drill-steels in substantial quantities. For this reason, the blacksmith's primary duty was to sharpen the steels.[xvii]

To permit the blacksmith to work in foul weather, mining companies erected buildings to shelter the shop. The shop structure tended to be small, simple, and rough, and operations lacking capital often relied on local building materials such as hewn logs or dry-laid rock masonry. Prospecting and mining outfits almost invariably located the blacksmith shop adjacent to the adit portal to minimize handling heavy batches of dull drill-steels.

Sharpening drill-steels was a delicate and exacting process that required an experienced mine blacksmith. Drill-steels, specialized tools that withstood the brutal work of mining, were of the utmost importance for driving underground workings. Miners used them to bore blast-holes, which was the primary method of breaking ground in Western mines. These unique tools were made of hardened hexagonal or octagonal

¾ to 1¼ inch-diameter bars of high-quality steel, and miners always used them in graduated sets. *Starter-steels*, also known as *bull steels*, were often twelve-inches long, but numerous trips to the blacksmith's forge reduced them to as short as eight inches, and the rest of the steels followed in successive six to ten-inch increments. With each increase in length, a steel's blade decreased slightly in width, ensuring that it did not wedge tight in the drill-hole. Generally, drill-steels for single jacking were no longer than three feet, and the longest steels used for double jacking were usually four to six feet long.

Sharpening drill-steels began at the forge, where the blacksmith carefully arranged a layer of fuel over the gravel bed surrounding the tuyere. The choice of fuel for working iron was limited to a few sources that were clean-burning, fairly inexpensive, and easily sacked for transportation. Prior to the 1870s blacksmiths heavily used wood charcoal, but they substituted coke and metallurgical coal, also known as forge coal, by the 1880s. Metallurgical coal included anthracite, semi-anthracite, and unusually pure bituminous coals, all other grades of coal having too much sulfur and other impurities. While metallurgical coal burned relatively cleanly, over time it left deposits of ash and clinker in the forge. Clinker is a residue which appears dark, vitreous, and glassy. Further, clinker possesses a scoria-like texture which formed in nodules up to three-quarters of an inch in diameter. The soot-smudged blacksmith had to periodically clean this nuisance out, and he either dumped it on the shop floor or threw it out of the building's doorway.

After the blacksmith received a load of dull steels, he either pumped a bellows or slowly turned a hand-blower connected to the tuyere, which fed oxygen to the fire. As the fire grew hot and began consuming fuel, he used a forge sprinkler to create a perimeter of wet coal to stop the fire from spreading. Blacksmiths often made forge sprinklers from food cans by perforating the bottom with many small holes. The smith placed the ends of several drill-steels in the center of the fire until they grew almost white-hot. One by one he extracted them, hammered the blade against the step between the heel and top face of the anvil to reform the drill's sharp angle of attack, placed the steels back in the fire, and repeated the process using a special swage fitted into a socket in the anvil. The swage had a better-defined crevice, which gave the final steep profile to the sharpened blade. The steels went back into the fire yet again, and the denizen of the shop extracted them one-at-a-time for quenching in a small tank of cool water. Quick submersion hardened the steel so it would remain sharp. A second, slower immersion tempered the steel, adjusting the softness of the blade tip after hardening, which prevented fragments from spauling off in the drill-hole. In the event the miners had managed to crack or damage the drill-steel blade, the blacksmith heated it white-hot and *upset* the steel before sharpening, meaning he used a cold chisel to cut off the damaged end. After upsetting the tip, the smith had to reform a fresh cutting end.

To temper a drill-steel, the blacksmith extracted it from the fire again while it was in a white-hot state and briefly immersed the blade in the quenching tank, quickly extracted it, and permitted the steel to cool in the open air. The incandescent colors of the steel changed as it cooled, and when it reached the desired temperature, as indicated by color, the blacksmith plunged it into the quenching tank to arrest the cooling. During the time the steel lay in the open, the skin cooled faster than the core and turned brown to gray, masking over the steel's true incandescent colors. To examine the colors of the inner steel, the blacksmith rubbed the blade on either a brick or whetstone, which scratched off the grayish scale.

Blacksmiths at small operations required few tools and much skill for their work. A typical basic field shop associated with prospect operations consisted of a forge, bellows or blower, anvil, anvil block, quenching tank, several hammers, tongs, a swage, a cutter, a chisel, a hacksaw, snips, a small drill, a workbench, iron stock, hardware, and basic woodworking tools. Prior to the 1910s some mining outfits working deep in the backcountry far from commercial centers dispensed with factory-made forges, both to save money and because they were cumbersome to pack, and used local building materials to make a vernacular forge. The most popular type of custom-made forge consisted of a gravel-filled dry-laid rock enclosure usually 3 by 3 feet in area and 2 feet high. Miners working in forested regions substituted small hewn log walls for rock. A tuyere, often made of a 2 foot length of pipe with a hole punched through the side, was carefully embedded in the gravel, and its function was to direct the air blast from the blower or bellows upward into the fire in the forge.[xviii]

The shops that served prospect operations were inadequate to handle the materials of larger, productive mines. The size of a shop and its appliances were functions of capital, levels of ore production, and the era during which it was built. The shops at small mines typically featured a forge and blower in one corner of the structure, an anvil and quenching tank next to the forge, a work bench with a vice located along one of the walls, and a lathe and drill-press. Rarely did shops at small mines include power appliances; instead, most of these shops were equipped with manually operated machinery.

A greater availability and affordability of steam engines, air compressors, and electricity during the 1890s brought power appliances within reach of modestly funded mining operations. By the time mining commenced at Creede, typical shops at medium-sized hardrock mines featured traditional labor-intensive facilities occasionally augmented with between one and several power appliances. Such shops were equipped with at least one forge, an accompanying blower, an anvil, a quenching tank, two stout workbenches, a lathe, a drill-press, and array of machine and carpentry tools. Because medium-sized mines had materials handling needs exceeding those at small mines, associated forges were typically either a 4 by 4 foot free-standing iron pan model, a gravel-filled iron tank 4 feet in diameter and 2 feet high, or a 3 by 3 foot gravel-filled wood box. Blacksmiths often lined their pan forges with firebricks and poured a thin cap of grout over their tank and box forges, which provided a sound bed for the fuel, focused the flow of oxygen toward the fire, and facilitated removal of residue and clinker. The lathes and drill-presses may have been power-driven at mines in developed mining districts, and manually powered at remote mines. In addition to the above appliances, many shops at large mines were also equipped with a mechanical saw, a grinder, and a pipe threader, which may have been power-driven.[xix]

The physical composure of a shop building reflects the financial state of a mining company. Outfits with limited financing used local building materials, while well-capitalized mining companies with access to commercial centers often erected dimension lumber frame buildings. One trait shared by most shops was the use of windows to afford natural light to permit the blacksmith to see what he was doing through the smoke and soot. Due to the risk of fire started by loose embers, the floors of most blacksmith shops at adit mines were earthen. The blacksmith arranged the shop interior to suit the cramped space, usually scattering his tools on the workbench and forge, arranging iron stock and hardware inside and outside the shop building, and he kept his coal either in a sack or wood box near the forge.

In the tradition of Western mining, the primary function of shop laborers at substantial mines continued to be drill-steel sharpening. But the mechanization of mining during this time period required the sooty blacksmiths to change their sharpening methods, as well as their materials handling processes. The most significant changes came about as a result of the widespread embrace of compressed-air powered rockdrills to bore blast-holes underground. While the machines proved to be a mixed blessing for their operators, generating silicosis-causing rockdust and being backbreaking to handle, they were a boon for shop workers. The noisy and greasy machines produced volumes of dulled steels and broken fittings. Contrary to today's popular misconceptions, rockdrills replaced hand-drilling wholesale in Western mines by the late 1910s, and not earlier as supposed. The conversion evolved over the course of 30 years, progressing more rapidly among well-financed mining companies than at small operations. During the conversion period blacksmiths became proficient in sharpening both hand-steels and machine drill-steels, each of which had specific requirements.[xx]

The large volume of dull rockdrill steels, machine repair work, and the manufacture of fittings constituted a heavy workload for shop workers. In an effort to facilitate the completion of projects in a timely manner, mining companies usually hired a blacksmith and a helper for metalwork, and a carpenter and another assistant for woodwork. In terms of metalworking, the blacksmith's helper proved to be particularly important. Blacksmiths had traditionally sharpened hand-steels alone because the implements were relatively short, light, and easily managed. But this was not the case with machine drill-steels, which were made of heavy iron rods up to eight feet in length, and blacksmiths quickly found them to be ungainly to handle.[xxi]

Before discussing the specific processes blacksmiths employed for sharpening machine drill-steels, it is important to become familiar with the basic forms commonly used by Western mines prior to World War II. Simon Ingersoll and the Rand brothers introduced the first commercial rock drilling machines in the early 1870s. Termed by mining machinery makers the *piston drill*, the early rockdrills consisted of a compressed air-powered piston in a tubular body, with a drill-steel chuck cast as part of the piston. As the piston chugged back and forth at the rate of several hundred cycles per second, it repeatedly rammed a drill-steel against the rock in a manner similar to a high-speed battering ram. When in operation the mechanical drill also imparted a spinning motion to the piston and drill-steel to keep the hole round and prevent the steel from wedging tight.

It may be apparent to the reader that drill-steels used in conjunction with the heavy machines were specialized implements that had to withstand tremendous forces. As early as the 1870s *machine runners*, also known as *machine men*, found that single-blade cutting bits like those used for hand-drilling dulled quickly, impeded progress, and interfered with the rotation imparted by the machine. The most effective bit proved to be a cruciform shape where two chisel blades crossed in dead center. This *star bit* better withstood the punishment of being rammed against rock, it cut faster, and was conducive to rotation. The butt of rockdrill steels was round to fit into the drill chuck, and the steel was usually made from 1 to 1½ inch hexagonal steel rod stock.[xxii]

Many miners found that piston drills had severe limitations and inconveniences. For example, every time the *chuck tender*, the machine runner's assistant, changed a dull steel for a fresh one, he had to use a heavy wrench to unbolt the chuck shackle, trade steels, and refasten the nuts using tremendous strength. In addition, miners were ready to admit that the monstrous piston drills were exceedingly heavy, often weighing between 200 and 350 pounds without accessories, and their drilling speeds were limited. George Leyner, Denver machinist and former Colorado hardrock miner, invented a superior rockdrill in 1893 that was based on a mechanical simulation of double jacking. Instead of repeatedly ramming the rock as did piston drills, Leyner's drill employed a loose piston known as a *hammer* which cycled back and forth inside the drill and struck the butt-end of the drill steel, which rested loosely in the chuck. Like most rockdrill makers, Leyner designed his drill for positive chuck rotation to make round holes and to keep the drill-steel from jamming. Leyner patented the first marketable *hammer drill* in 1897 and began producing an improved version in 1899.[xxiii]

During the 1900s and into the 1910s Leyner's drill began finding great favor with the hardrock mining industry. Time and again miners demonstrated that hammer drills bored holes faster than piston drills, and miners found them easier to work with in terms of changing steels. All the chuck tender had to do was give the dull drill-steel a twist to unlock it, and twist in a fresh drill-steel; no longer did miners have to deal with clumsy shackle bolts. Leyner's steels were made of 1¼ inch round bar stock, and they featured star-shaped cutting bits like piston drill steels. A crew of two miners was necessary to handle Leyner's machine, and it too had the drawback of running dry like the old piston drills. To this regard Leyner devised a hollow drill-steel which jetted water into the drill-hole while the drill was running, allaying rock dust. Leyner's technology gradually caught on throughout the mining industry until, by the mid-1910s, drill companies were curtailing the manufacture of piston drills in favor of the hammer drill.

During the time spanning 1897 to 1912, mechanical engineers introduced a number of new types of rockdrills utilizing Leyner's hammer principle. The first new drill was the *stoper*, which was a light-weight machine designed to bore holes upward. The stoper's main significance lay in that it was the first self-contained power drill portable and operable by one man. Early stopers lacked a chuck rotation mechanism, and as a result the miners running them had to use a long handle that extended out of the machine's body to turn the unit side to side to keep the drill-hole round. Miners and stoper manufacturers found that the best type of drill-steel proved to be cruciform in shape, which prevented the steel from twisting and jamming in the machine.

In 1912 Ingersoll-Rand, formed by the 1906 merger of the Rand and Ingersoll companies, developed a revolutionary hammer drill for boring down-holes. Known among miners generically as a *plugger*, *shaft sinker*, and as simply a *sinker*, Ingersoll-Rand named its model the *Jackhammer*, which is the origin of the slang name used today. The machine consisted of a gracile hammer drill fitted with handles, and a mechanism for rotating the chuck. The relatively small hand-held machine required a drill-steel lighter than those used with the larger Leyner hammer drill, and Ingersoll-Rand and subsequent manufacturers found that 7/8 inch hexagonal bar steel proved best. The butt of sinker steels was hexagonal and featured a collar that fit into a special hinged clamp. Like all of the other types of drills, miners used graduated sets of drill-steels in conjunction with the sinker machines. During the 1910s hammer drill technology had mushroomed, and as a result drill manufacturers experimented with several alternative forms of drill-steels. Manufacturers settled on round, hexagonal, and square varieties. By around 1930 they ceased production of cruciform steel.

Regardless of the specific type of stock that a drill-steel had been made from, the blacksmith had to confront the problem of sharpening the star cutting bit. As with hand steels, the blacksmith had to place the machine steels in the forge to heat them to the proper temperature. He simply laid short steels on the forge, but he had to use either a special stand or a long hook suspended from the building's roof rafters to support drill-steels in excess of three feet long. When the blacksmith extracted a steel from the forge with the intent of dressing the bit, he used a tool known as both a *swage*, and as a *dressing dolly*, to resurface the star's cutting edges. If the drill-steel arrived in the shop with a chipped or cracked bit, the blacksmith upset the damaged portion by using a chisel to cut it off, and he hammered out a new end with enough flare to facilitate creation of a star bit. The blacksmith also ensured that he had centered the star, that the blades were uniform in width, and that the butt of the steel was smooth and symmetrical. After he had dressed the bit, the blacksmith filed imperfections out of the blades, followed by tempering and hardening. All through this process the helper assisted the blacksmith when handling long steels.[xxiv]

Some companies running medium-sized mines supplied their blacksmiths with an appliance known as a *backing block* to ease the difficulties of sharpening unwieldy machine drill-steels. Ordinarily, the blacksmithing team had to act in close concert when sharpening machine steels. The helper leaned the red-hot drill-steel against the anvil located adjacent to the forge and braced it with both hands while the blacksmith dressed the bit with a dolly. However the propensity of the steel to slide, sway, and move under the blacksmith's blows, and the giving nature of the shop's earthen floor presented problems that often resulted in poor sharpening. A backing block provided a sound platform for drill-steels, permitting blacksmith teams to better dress bits in less time. Backing blocks consisted of a long rectangular bar of iron, often 4x4 inches in cross-section and up to 8 feet long, divoted with 1½ inch diameter holes spaced every half foot. The iron bar was firmly anchored in the ground and it extended outward from the anvil block. To use it, the blacksmith's helper placed the butt of a red-hot drill-steel in one of the block's divots and leaned the steel's neck against the anvil to permit the blacksmith to dress the bit. The backing block provided sound resistance to the blacksmith's heavy blows while holding the drill-steel in place. Each divot in the backing block accommodated a different length of drill-steel, from two foot starter-steels to ten-foot finishing steels. These ingenious appliances began appearing during the 1890s in the shops of medium-sized and large mines where rockdrills were used. Mining companies with sufficient capital purchased factory-made cast-iron models, while penny pinching outfits engaged their shop workers to forge their own from scrap iron such as salvaged railroad rail.[xxv]

In the first decade of the twentieth century the largest of the Western mines, where up to hundreds of miners dulled carloads of drill-steels per shift, attempted to mechanize the sharpening process in hopes of drastically increasing the efficiency of the harried shop crew. The well-financed mining companies purchased, seemingly on an experimental basis, compressed air powered *drill-steel sharpening machines*, which had just been released onto the market by manufacturers such as T.H. Proske in Denver and the Compressed Air Machinery Company in San Francisco. The early drill-steel sharpeners, similar in appearance to large horizontal lathes, consisted of a cradle approximately eight feet long and a tall sharpening mechanism which stood on several legs bolted to a substantial foundation. A blacksmith operated the sharpener by clamping a red-hot drill-steel into a small sliding carriage on the cradle, he pushed the steel under the sharpening mechanism, and locked it in place. The shop worker threw a lever that activated a modified piston drill fixed onto the machine's end, which hammered the red-hot end of the dulled steel with a special swage. Most of the early drill-steel sharpeners also featured a second piston drill mounted overhead, which used a special chisel bit to upset the dull steel, should it have any significant defects.

Manufacturers advertised their sharpeners as streamlining the sharpening process while reducing costs. Drill-steel sharpeners were operable by one man, they had the capacity to replace the traditional crew of blacksmith and helper, and with a change of dies they could have been used to sharpen hand-steels and pick tines. Even though the drill-steel sharpeners cost in the hundreds of dollars at turn-of-the-century prices, they proved economical and grew in popularity.

Leading rockdrill makers, including the Sullivan Machinery Company of New Hampshire, the Ingersoll-Rand Drill Company, and the Denver Rock Drill Company introduced competing units during the early 1910s that had abandoned the lathe-like sliding track and large piston drill swages. The new drill-steel sharpeners instead featured a heavy compressed air-powered clamp capable holding drill-steels of any length, and they had small, light hammer drills to work the swages. In addition, manufacturers supplied interchangeable dies that permitted shop workers to sharpen any of the varieties of drill-steel types used in the West at that time. The net result of the changes in the form and function of drill-steel sharpeners was a reduction in the amount of floor space they occupied, from at least 10 by 2 feet in area to between 5 by 2 feet and 2.5 by 2.5 feet. The labor saving machines primarily made themselves of value to mining outfits because they drastically reduced the time required to sharpen dull drill-steels. They reduced the process to less than one minute per steel, with the potential to retouch up to 1015 dull drill-steels in a nine hour shift. It stands as a curious fact that many of these machines had been designed in Denver; Sullivan purchased the Imperial sharpener from T.H. Proske, Ingersoll-Rand used a design manufactured by George Leyner, and the Denver Rock Drill Company produced the third machine.[xxvi]

The reduction of size and price of the new drill-steel sharpeners, and their ease of use made them attractive to a broad spectrum of medium-sized and large mines. Both moderate and well-financed mining companies with an expectation of longevity installed the improved drill-steel sharpeners with increased frequency through the 1910s. Most small mining companies with limited funds, on the other hand, did not purchase drill-steel sharpeners because such outfits lacked available capital, their miners were unlikely to generate enough dull steels to justify the expense, and they did not possess adequate air compressors. Instead, they relied on traditional forge sharpening methods.

Particularly large and highly profitable mining companies, usually backed by significant capital, were able to afford the costs associated with building highly mechanized and heavily equipped shops. Progressive mining engineers and shop superintendents suggested that shop facilities be arranged according to the stages drill-steels underwent during sharpening. The bulk of the appliances, according to the engineers, should have been in order of forge, drill-steel sharpener, another forge for tempering, quenching tank, grinder, and finally finished drill-steel rack. Such an arrangement of shop appliances required a spacious building, at least 50 by 30 feet in area, and particularly large shops included multiple sharpening circuits. These shops were also equipped for heavy machine work, and in accordance they featured power appliances, a mine rail line running through the interior, and one to several small boom derricks for moving heavy items.[xxvii]

Mining engineers and shop superintendents at large mining operations also installed power hammers to permit a single blacksmith to do some types of fabrication work that usually required a team of two. Shop superintendents overseeing the best mines in the West installed factory-made steam or compressed air-powered models, which consisted of a heavy plate iron table fixed to the top of a cast iron pedestal, and a piston hammer that pounded items with tremendous force. These hammers were expensive to purchase and transport, they occupied the same area as a drill-steel sharpener, and they weighed several tons. Many engineers, especially seasoned self-made individuals, were unwilling to spend the considerable quantities of capital required to install expensive factory-made hammers, yet they recognized the usefulness of such a power appliance.

The alternative they employed consisted of affixing a heavily worn but operational piston drill onto a stout vertical timber. The old drill stood over a plate iron table fastened onto the top of a truncated timber post often 1 to 2 feet high, and when a shop worker threw the air valve open, the drill's piston chuck rapidly tapped the iron table. Usually a special hammerhead fitting had been clamped into the chuck to facilitate blacksmith work, and in rare cases the shop superintendent had the drill suspended from a special track hanging from the building's rafters for mobility.[28]

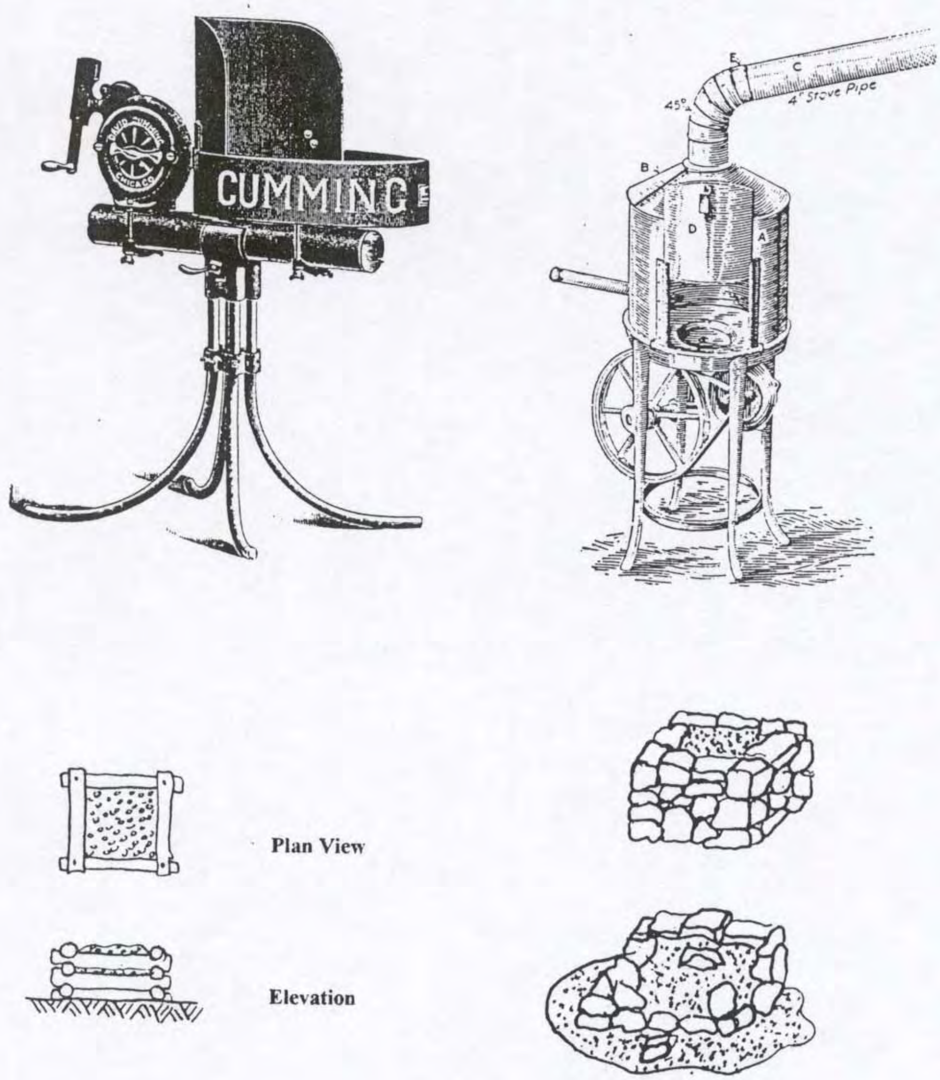


Figure 4.3 The line drawing depict the types of forges commonly employed at blacksmith shops. Clockwise: a portable pan forge, a second portable pan forge, a vernacular dry-laid rock forge, a collapsed rock forge as they often appear today, and a vernacular log cribbing forge. *EMJ 10/6/17*; Author.

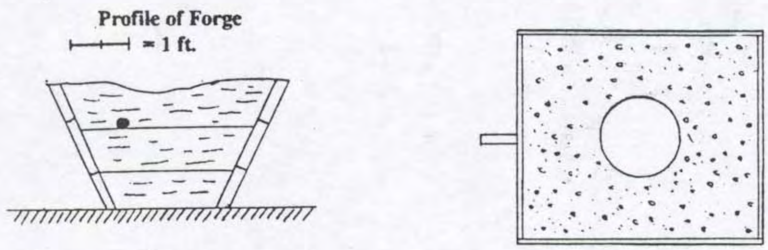


Figure 4.4 At left is a profile of a vernacular gravel-filled wood box forge, and at right is a plan view. The forge has a grout cap with a hole at center, which permits an air blast to pass up into the coals. Author.

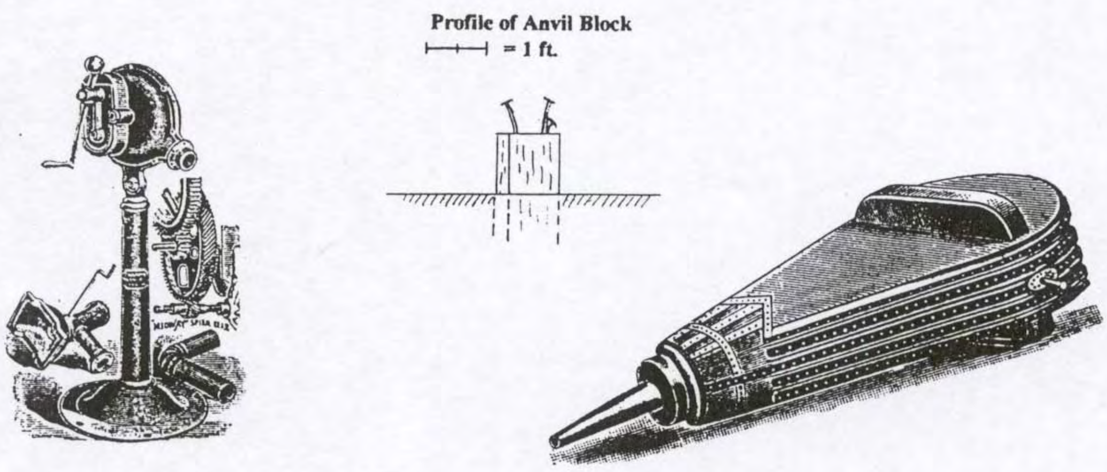


Figure 4.5 The line drawings illustrate appliances common to mine shops. Left to right: a hand-powered blower for a forge, a profile of an anvil block, and forge bellows for a forge. Mine & Smelter Supply, 1912 p724; Author.

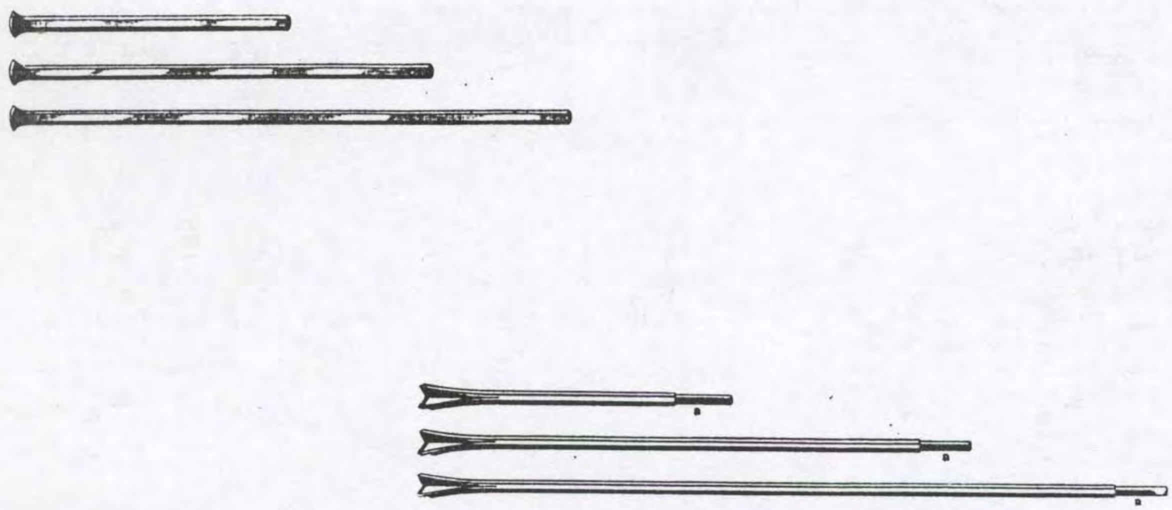


Figure 4.6 At upper left is a set of drill-steels that miners used to bore blast-holes by hand. At right is a set of drill-steels used in conjunction with mechanical compressed air piston drills.

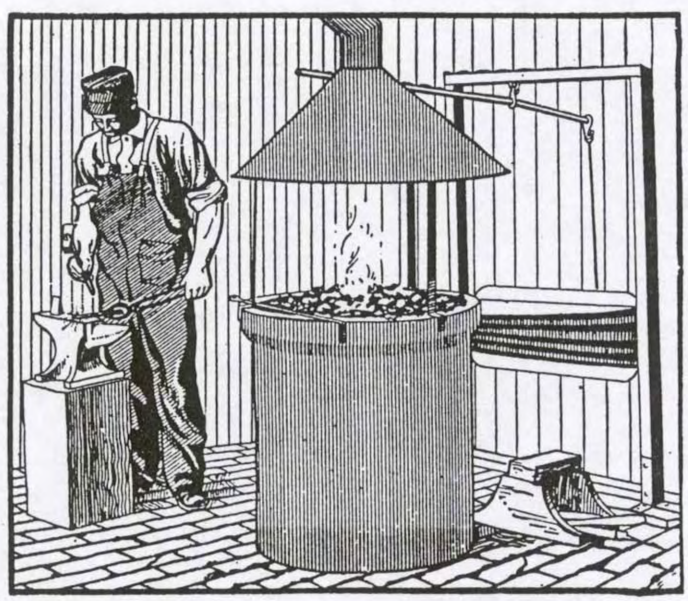


Figure 4.7 The line drawing depicts the interior of the blacksmith shops typical of medium-sized to small mines. The consists of basic appliances, including a tank forge, an anvil on an anvil block, and bellows.

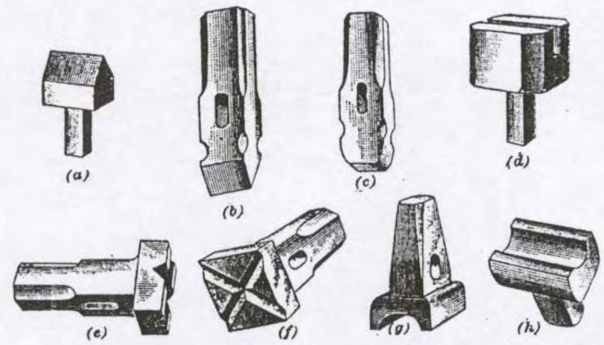


Figure 4.8 The line drawings illustrate a set of tools that blacksmiths used to sharpen machine drill-steels. Swages *a*, *d*, and *h* fit into a socket in an anvil, and swages *b*, *c*, *e*, *f*, and *g* were fixed onto hammer handles. The blacksmith used swages *g* and *h* to dress the drill-steel butt, swages *e* and *f* to sharpen the star bit, and the other swages to manufacture new bits from scratch. International Textbook Company, 1907 A35 p36.

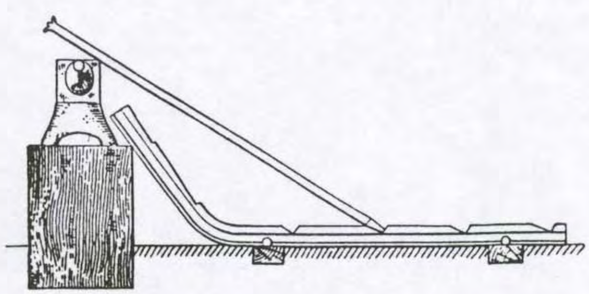


Figure 4.9 Blacksmiths used backing blocks to brace red-hot machine drill-steels for sharpening. As the profile illustrates, the blacksmith placed the steel's butt into a receptacle in the backing block and leaned the steel's neck against the anvil. When his assistant braced the steel, the blacksmith used a swage to reform the bit. Engineering & Mining Journal, 1916 p14.

Mine Ventilation

The use of explosives for blasting, open flame lights, and the respiration of laboring miners turned the atmosphere in underground workings into an intolerably stifling and even poisonous environment. Ventilating mine workings was not an easy proposition, but it was necessary. Many mining outfits completely ignored the problem until the workings attained significant length, and even then efforts were feeble at best. Mining engineers approached the ventilation problem by relying on one or a combination of two basic systems. The first, *passive ventilation*, relied on natural air currents to remove foul air, but it proved marginal to ineffective in dead-end workings. *Mechanically assisted systems*, the second, were expensive and intended for production-class plants. As a result they were rarely used at prospect adits.

Necessity being the mother of invention, prospecting outfits employed several variations of ventilation systems that cleverly combined passive and mechanical means. One of the simplest semi-mechanical ventilation systems consisted of a canvas windsock fastened to a wooden pole. The windsock collected air wafted by breezes and directed it through either canvas tubing or stovepipes into the underground workings. The obvious drawback to the system was poor performance on calm days, forcing miners to work in suffocating gases. Prospecting outfits employed another semi-mechanical system in which they linked the air intake on a stove or furnace to tubing ducted into the workings. A surface worker stoked a fire in the stove, which drew foul air out of the underground through the ducting. While this system was simple and ingenious, most prospecting outfits declined to take the trouble of setting it up.[xxix]

Some Western prospecting operations were adamant about providing adequate ventilation, and they used primitive mechanical systems. These outfits installed large forge bellows' and small hand-turned blowers at the mouths of adits, and used stovepipes or canvas tubing to duct the air into the workings. Bellows' effectively ventilated shallow workings, but they lacked the pressure to clear gases out of relatively deep adits and shafts. Hand-turned blowers cost more money and took greater effort to pack to a prospect operation, but they forced foul air much more surely from workings.

The simple windsocks and hand-turned mechanical blowers that had worked for prospect operations were not effective for the workings comprising medium-sized and large mines. Mining engineers applied several better methods for providing the miners with fresh air. One of the most popular systems involved relying on passive ventilation, which required an *incast* air current balanced by an *outcast* current laden with the bad air. Multiple mine openings proved to be the most effective means of achieving a flushing current, and temperature and pressure differentials acted as the driving forces that moved the air.[xxx]

In most busy mining districts where operations were spaced close together, such as at Creede, mining companies ordinarily at odds with one another cooperated in terms of ventilation and linked their workings together to attain multiple openings. But at isolated operations with no neighbors this was not an option, and instead some mining engineers put drilling and blasting crews to work driving air shafts upward from deep within the underground workings. Such shafts both improved the air flow through the mine, and they served as secondary entrances for efficient movement of miners and materials into the upper levels. When an adit had been linked to a shaft, the temperature differential between the mine's interior environment and the surface conditions became the greatest mover of air. During the warm months of summer the relatively heavy cool, humid mine air flowed out of the adit, drawing fresh air down the shaft, and during the frigid winter geothermally heated air rose up the shaft and drew fresh air in through the adit. Many professionally trained mining engineers felt that natural ventilation had a limited effect because the incast and outcast currents changed direction through the mine seasonally, they fluctuated with the weather, and they rarely reached the dead-end workings where miners spent most of their time.[xxxi]

Mechanical ventilation, on the other hand, was more effective, but also it was much more expensive. At large mines where underground work generated a considerable volume of foul air, using mechanical ventilation to permanently direct the outcast current through a secondary opening was important. The flow of concentrated gases could have rendered main haulage ways, such as Creede's Nelson, Commodor, and Bachelor tunnels, intolerable for man and beast.

Many mines featuring three or more openings to ground surface, be they shafts or stopes where miners had followed the ore to daylight, had inconsistent ventilation. Air currents short-circuited work areas by following the shortest path through the mine. To address this problem, miners installed air-control doors at strategic intersections within the mine, and at the adit portal. Miners customarily made the doors with boards, they hinged them to vernacular jambs, and they filled the gaps with custom-cut lumber, rags, and burlap. Opening and closing specific doors had the effect of routing the air current through the desired portion of the mine, expelling foul gases. Many large abandoned mines in the West existing today still feature air-control doors inside, as well as fastened to the portals of adits and the collars of shafts. Generally the visitor to a mine site can interpret such evidence to mean the mine possessed voluminous and complex underground workings, and probably more than two openings.

Out of laziness, ignorance, or economic necessity some mining engineers claimed that the continuous flow of air emitted by one or two rockdrills run by miners provided sufficient ventilation. While this may have been true for short tunnels and drifts, this method proved inadequate in long tunnels, which filled with unbreathable and poisonous gases following the end-of-shift blast. The exhaust from drills was inadequate in volume, and it was often tainted with oil vapors.

One of the most popular and genuinely effective approaches for ventilating deep tunnels in the West, when natural ventilation was impractical, lay in employing power-driven fans and blowers. Mining machinery manufacturers offered engineers three basic varieties of blowers in a multitude of sizes. Engineers had termed the first design, which dates back to the Comstock era, the *centrifugal fan*, and miners knew it as the *squirrel cage fan*. This machine consisted of a ring of vanes fixed to a central axle, much like a steam boat paddle wheel. The fan, turning at a high speed, drew air in through an opening around the axle and blew it through a port extending out of the shroud. Manufacturers produced centrifugal fans in sizes ranging from one to over ten feet in diameter. The small units were employed for both mining and a variety of other purposes such as ventilating industrial structures, and the largest units were rarely used in the Western mines, being employed principally to force foul air and explosive gases out of large coal mines in the East and Midwest. The exact name engineers gave to a centrifugal fan was a function of the direction the outflow port faced, for example a fan with a port that pointed upward was a *top discharge* fan, and a unit with a port pointing to the tunnel portal was a *front discharge* fan. The second type of fan engineers commonly employed to ventilate tunnels also acted on centrifugal principles, but it consisted of a narrow ring of long vanes encased within a curvaceous cast iron housing. The *propeller fan*, the third type of blower, was similar to modern household fans, and they too were enclosed in shrouds.

Mining engineers made use of the most cost-effective power source available in the mining district to drive ventilation fans. Until around 1910, the most common power source that mining companies relied on during the Gilded Age consisted of an upright steam engine. But as the twentieth century unfolded, steam saw heavy competition from electricity in well-developed mining districts such as Creede, and from gas engines in remote regions. Each of the three motive sources mentioned turned fans via canvas belting.

Miners' need for fresh air underground was one factor in hardrock work that remained unchanged when mining revived in Creede and elsewhere during the Great Depression. The nature of the ventilation systems mining companies erected to supply their miners with fresh air during the 1930s bore great resemblance to the systems used by mining companies in decades past. One difference between the new and the older mining operations, however, was that the use of fans for blowing air into dead-end workings had greatly increased.

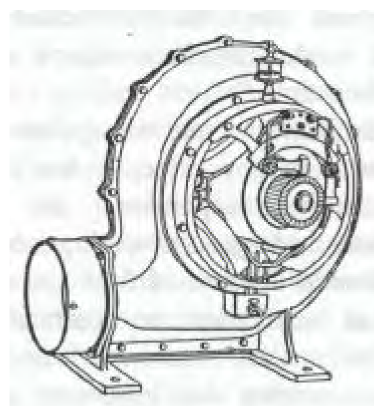


Figure 4.10 The drawing illustrates a centrifugal blower with a direct-drive electric motor. International Textbook Company, 1899 A41 p146.

Regardless, during the 1930s mining companies and partnerships attempted to make-do with natural ventilation when at all possible, because the cost of inducing natural air currents cost little. To the relief of mining companies rehabilitating abandoned mines in districts with developed mines, such as Creede, the nineteenth century operations had made the necessary underground connections with neighboring properties, which had the effect of creating natural air currents. All the Depression-era operation need do to maintain the natural air circulation was ensure that the drifts and crosscuts interlinking neighboring mines remained open.

Mining engineers during the Gilded Age and into the Great Depression continued the practice of installing the fan immediately outside of the adit portal or shaft collar. Many of the fans used in conjunction with tunnels were belt-driven by a motor and had been anchored to portland concrete foundations with four bolts. During this time mining engineers found that using portable fans placed inside of mine workings also afforded ventilation at little cost.[xxxii]

The method of sending the fresh air into the mine through heavy galvanized ducting had changed little from the Gilded Age practices. Depression-era miners usually hung the tube work with bailing wires fastened onto wedges driven into the tunnel ceiling, or lashed it to shaft timbers. Mining outfits with access to only modest capital found it economical to salvage ducting that was even remotely serviceable from neighboring abandoned mines. Miners attempted to hammer dents out of the tubing and seal holes and joints with metal sleeves, burlap, canvas, and tar. As a result the mechanized ventilation systems installed by moderately sized Depression-era mining outfits appeared rough and were not as efficient as they could have been, but they performed their necessary duty. The evidence remaining from a mechanical ventilation system that today's visitor to a Depression-era mine site is likely to encounter consists of an artifact and foundation assemblage similar to the materials left by pre-1910s operations.

The Surface Plants for Shafts

The surface plants that miners erected to support work in shafts incorporated many of the same components as those associated with adit mines. Due to the vertical nature of shafts, the surface plant had to necessarily included a hoisting system, which permitted the movement of miners and materials in and out of the shaft. The type of system that a mining operation selected proved to be important because it both governed the quantity of rock extracted during a given shift, and depth at which the company could have worked. Typical hoisting systems installed by Western prospect operations consisted of a hoist, a headframe, a power source, and a hoisting vehicle. The components of a hoisting system shared fundamental relationships with each other, and they interfaced with the other facilities comprising the surface plant. For example, the type of hoist an engineer selected influenced the type of headframe, the power source, and the transportation system he subsequently installed. Yet, the greatest factors that overshadowed the types of plant facilities an engineer installed included the financial state of the mining company, the operation's physical accessibility, and the quantity of proven ore. The following section discusses the variety of the hoisting systems available to mining companies at Creede, as well as elsewhere, during the Gilded Age and into the Great Depression.

Shaft Form and Hoisting Vehicles

Experienced prospectors and mining engineers recognized that crude prospect shafts were inadequate for anything other than a cursory examination of the geology underground. In instances where a prospecting outfit strongly suspected or had confirmed the existence of ore, they sank a better, more formal shaft that was conducive to deep exploration and even, the outfit hoped, ore production. Between the 1880s and 1920s mining engineers were critical toward distinguishing between temporary shafts and production-class shafts.

The preference among prospectors and engineers for a rectangular shape to the shaft remained unchanged throughout the Gilded Age. The rectangular shape was standard among mining companies for several reasons. First, such shafts were cheaper to sink and easier to timber than circular ones. Second, Western miners inherited the rectangular form through the diffusion of traditional mining practices from Cornwall.[xxxiii]

When Creede experienced its boom, mining engineers understood that the size of a shaft directly influenced a mine's level of production. Small shafts limited the quantity of ore that could have been hauled out per vehicle trip, and large shafts facilitated economies of scale. Mining in Michigan, California, and on the Comstock during the 1860s had set a precedent in which companies working in vertical shafts aspired to install steam-powered hoisting systems that utilized a *cage* as the hoisting vehicle. The cage influenced mining engineers' definitions of production-class and temporary shafts.

A mining industry institution for over 100 years, the cage consisted of a steel frame fitted with flooring for crews of miners coming and going on and off shift, and rails to accommodate an ore car. Nearly all cages used in the West featured a stout cable attachment at top, a bonnet to fend off falling debris, and steel guides which ran on special fine-grained 4x4 inch hardwood rails. After a number of grizzly accidents in which hoist cables parted, mining machinery makers began installing special safety-dogs on cages designed to stop an undesired descent. Usually the dogs consisted of toothed cams that were controlled by springs kept taught by the weight of the suspended cage. If the cable broke, the springs retracted, closing the cams onto the wood rails.

Cages proved to be highly economical because mining companies did not have to spend time transferring ore and waste rock between various vehicles. A miner or trammer merely had to push on an ore car filled at some distant point in the mine, and another worker retrieved it at the surface. But cages presented mining companies with several drawbacks. One of the biggest problems lay in drilling and blasting a shaft that not only possessed enough space in-the-clear to make way for the cage, but one that was large enough to accommodate the timbering that anchored the guide rails.

By the time mining companies began extracting ore at Creede, engineers established a standard for the composition of production-class shafts. The convention followed by mining companies consisted of dividing production-class shafts into a combination of *hoisting compartment* and *manway*, also known as a *utility compartment*. Further, mining engineers in the West had recognized the utility of balanced hoisting. The use of one hoisting vehicle to raise ore had become known as *unbalanced hoisting*, and while this system was very inefficient in terms of production capacity and energy consumption, was the least costly to install. *Balanced hoisting* relied on the use of two shaft vehicles counterweighing each other, so that as one vehicle rose the other descended. The use of two hoisting vehicles required a shaft featuring two hoisting compartments, and it necessitated a double-drum hoist, which constituted a considerable expense. But the hoist only had to do the work of lifting the ore, and as a result this system was energy efficient and provided long-term savings. Wealthy mines anticipating production over an extended period of time spared the expense to install a balanced system. By the 1890s mining engineers had spelled out the classifications of shaft sizes, configurations, and interior structures. They insisted that all deep prospecting and production-class shafts consist of at least one hoisting compartment and a utility compartment, and feature timbering to support the cage guide rails. Further, mining engineers defined production-class shafts as needing to have a hoisting compartment that was at a minimum 4 by 4 feet in-the-clear. By the late nineteenth century the definition expanded as a result of the introduction of larger cages. Mining engineers felt that a 4 by 5 foot hoisting compartment was better suited for ore production, and 5 by 7 feet was best, because it permitted the movement of larger ore cars and machines.[xxxiv]

Western mines used three other types of hoisting vehicles during the Gilded Age, in addition to the cage. The first was the old-fashioned *ore bucket*, the second was the *ore bucket and crosshead*, and the last was the *skip*. The ore bucket that had endeared itself to the Western mining industry became known as a *sinking bucket* because its shape and features were well suited for the primitive conditions typical of mines under development. Sinking buckets consisted of a body with convex sides that prevented the rim from catching on obstructions such as timbers, and permitted the vessel to be able to glance off the shaft walls while being raised. Manufacturers forged a loop into the bail to hold the hoist cable on center, and the bottom of the bucket featured a ring so the vessel could have been upended once it had reached the surface. Most sinking buckets were far too heavy for use with hand-windlasses, and prospectors instead relied on small pail-shaped buckets known as *kibbles*. Some mining companies, engaged in minor production after 1900, continued the ages-old practice of using ore buckets instead of cages, and some employed a straight-sided variant known as the *Joplin Bucket*, named for its prevalence in the lead and zinc mines near Joplin, Missouri. To expedite the production of rock while continuing to use ore buckets as their principal hoist vehicle, mining companies discovered that the vessels could have been easily mobilized underground when unhooked from the hoist cable and placed on flatcars. While ore buckets did not have the same compartment restrictions as skips and cages, most outfits in the West followed the conventions of shaft sizes and configurations recommended by mining engineers.

Mining companies engaged in deep shaft sinking took great risks when they attempted to use free-swinging ore buckets. To prevent the bucket from swinging and catching on the shaft walls, emptying its contents onto the miners below, some mining companies installed a hybrid hoist vehicle that consisted of an ore bucket suspended from a frame that ran on the same types of guide rails as cages. The frame, known as a *crosshead*, held the ore bucket steady and provided miners with a platform to stand on, albeit dubious, during their ascents and descents in the shaft. The advantage of using a crosshead was that miners working underground were able to switch empty buckets with full ones, and the system could have been easily adapted to a cage or skip at a later point. Many small, poorly financed, and marginally productive mining companies in remote locations favored this type of hoisting vehicle.

Cornish mining engineers had developed the skip for haulage in the inclined shafts of Michigan copper mines during the 1840s and 1850s. The typical skip consisted of a large iron box on wheels that ran on a mine rail line. Skips had little deadweight, they held much ore or waste rock, and because they ran on rails they could have been raised quickly. They were also easy to fill and empty. The hoistman on the surface lowered the skip to a shaft station underground that featured either an ore bin with a chute or a loading platform where a miner dumped rock directly into the vehicle from an ore car. The hoistman then put on steam and raised the skip into the headframe where it was automatically upset, and belched forth its contents. Skips were similar in size to cages and they ran in shafts approximately the same in area.

During the 1890s mining engineers began to recognize the skip as being superior to the cage for ore production in vertical shafts. Skips were lighter than cages because they did not have the combined dead weight of the vehicle and an ore car, and the reduced weight resulted in energy savings. Skips also offered the benefit of being quickly filled and emptied, resulting in a rapid turnover of rock. Shortly after the turn-of-the-century, large Western mining companies began replacing cages with skips for use in vertical shafts. The change over proceeded slowly through the 1900s, it accelerated rapidly during the 1910s, and by the 1930s most large and many medium-sized Western mines used skips. Of course, mining companies were able to switch skips and cages at the shaft collar when necessary by unhooking the hoist cable and pulling the vehicle off of the guide rails.

Mining engineers recognized that cages and skips were the vehicles of choice for productive mines, and they relegated ore buckets strictly to a status of shaft sinking and minor ore production. Cages and skips permitted hoisting speeds far and above what was possible with free-swinging ore buckets, from 300 to 400 feet per minute up to 3,000 feet per minute in deep shafts, and with them mining companies hauled great tonnages of rock from the underground. Miners were able to rapidly load cages and skips, while they had to hand-shovel rock into ore buckets. Despite the advantages offered by cages and skips, small and poorly financed mining companies continued to use relatively inexpensive ore buckets into the 1930s because they did not require expensive guide rails and support timbering constructed the length of a shaft.

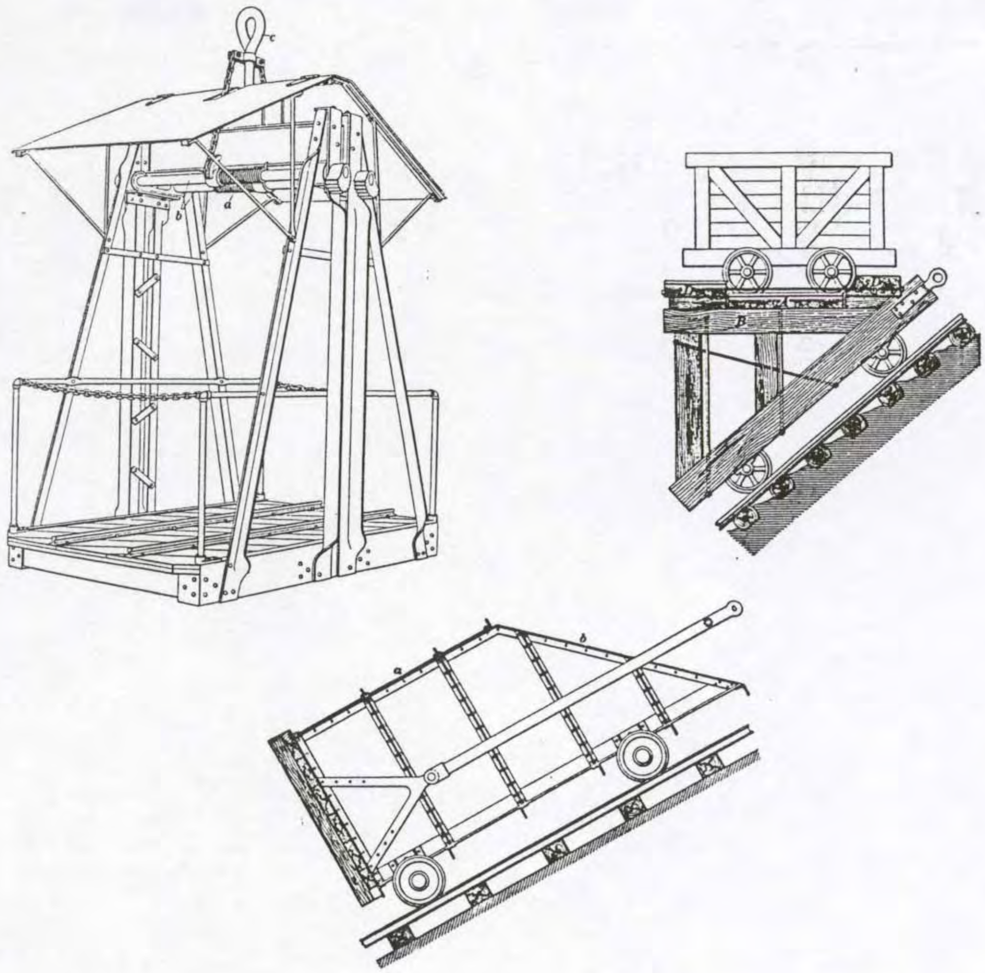


Figure 4.11 Top left is the traditional cage used in vertical shafts. Top right is a vehicle that some engineers referred to as a cage for inclined shafts, and at bottom is a skip. The skip proved to be the most efficient vehicle for hoisting rock out of inclined shafts. International Textbook Company, 1906 A53 p9; International Text book Company, 1899 A23 p 79, 86.

Hoists

When prospectors and mining companies decided to sink a shaft to explore a mineral body at depth, they were forced to install a hoisting system to permit vertical work. Like other surface plant components, hoists came in a wide range of sizes, types, and duties suited for prospecting and for ore extraction. Hoists designed for prospecting adhered to *sinking class* characteristics, and hoists intended for ore production adhered to *production class* characteristics. The *hand windlass* was the simplest form of sinking-class hoist, and prospectors used it for shallow work. The windlass was an ages-old manually powered winch consisting of a spool made from a lathed log, fitted with crank handles, and its working depth was limited to approximately 100 feet. Prospectors sinking inclined shafts had the option of using what mining engineers termed a *geared windlass* or *crab winch*, which offered a greater pulling power and depth capacity. Geared windlasses cost much less than other types of mechanical hoists, and they were small and light enough to be packed into the backcountry. The winch was not easily used at vertical shafts, however, because the rope spool and hand-crank fitted onto a frame which had to be anchored onto a well-built timber structure.[xxxv]

Prospect operations often worked at depths greater than the limitations presented by windlasses, and they had to install a more advanced hoisting system to permit work. The *horse whim* proved to be a favorite in the mining West, because it was relatively inexpensive to purchase, operating costs were low, it was portable, and it was simple to install. Through the 1860s the Western mining industry accepted the horse whim as being state-of-the-art hoisting technology for both prospecting and ore production. But by the 1870s practical steam hoists were finally coming of age, and the status the mining industry had accorded to horse whims began a downward slide. By around 1880 medium-sized and large Western mining operations had fully embraced steam hoists, and mining engineers felt that horse whims were well-suited for backcountry prospecting, but they were too slow and limited in lifting power for ore production. The problem with horse whims, according to mining engineers, was that they had a load capacity of around 800 pounds, a depth limitation of 300 feet, and a painfully slow hoisting speed of 50 to 80 feet per minute. However, they were ideally suited for work at remote locations because they were light and could have been transported on mule-back, they were easily disassembled, and inexpensive. Horizontal reel whims weighed between 600 and 800 pounds and cost as little as $150, while geared whims weighed twice as much and cost a little more. The draft animal that labored in the harness constituted what we know in the late twentieth century as a renewable energy source, requiring only local feed and water. Because of these factors, whims fit a special niche among poorly financed Western prospect operations, including those at Creede, into the 1910s.[xxxvi]

Mining companies and prospect outfits could select from several varieties of horse whims. The simplest and oldest version, christened by Hispanic miners as the *malacate* (mal-a-ca-tay), consisted of a horizontal wooden drum or reel directly turned by a draft animal. Early malacates featured a wooden cable drum, a stout iron axle, and bearings fastened onto both an overhead beam and to a timber foundation.

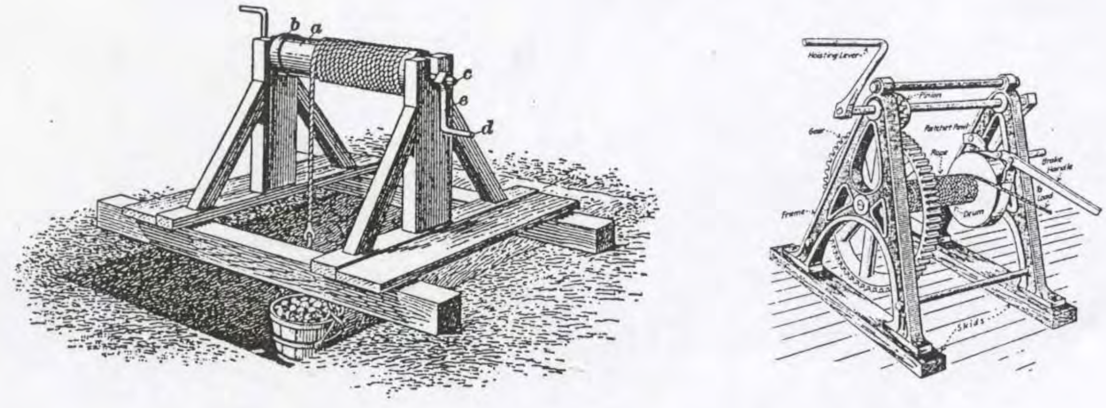


Figure 4.12 At left is a typical windlass, and at right is a crab winch. Prospectors used windlasses for raising light loads out of small shafts less than 100 feet deep, and they installed crab winches to service small exploratory inclined shafts. International Textbook Company, 1906 A50 p2; Croft, Terrell, 1923 p605.

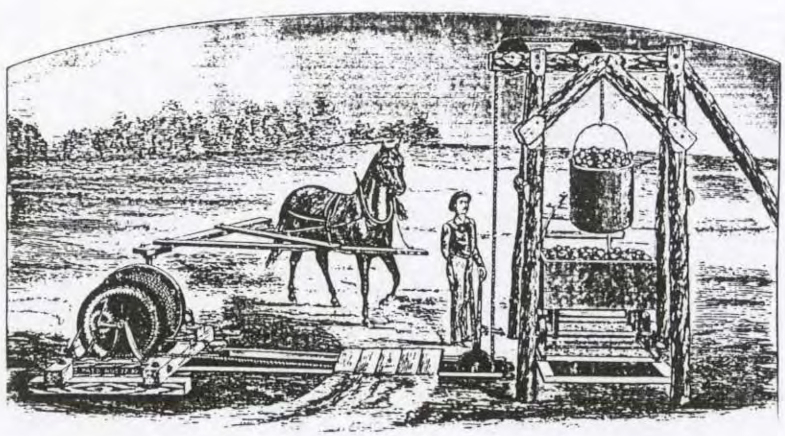


Figure 4.13 An artist's rendition of a complete horse whim system. The hoist, employed by small remote prospect operations, consists of a geared whim affixed to a timber foundation, a cable trench, and a small hewn log tetrapod headframe. The hoist cable passes from the whim through the trench to a pulley bolted onto the headframe's base, up and over small sheaves at the headframe's top, then down the shaft. The horse whim was the only system to feature this odd manner of routing the hoisting cable. The hoistman, who doubled as the topman, manipulated brake and clutch levers located at the shaft collar. The control linkages passed through the cable trench as well. Note the track for the draft animal. Ingersoll Rock Drill Company, [1887] p62.

Prospectors usually positioned the drum so that it rotated in a shallow pit that they lined with either rockwork or wood planking. The cable extended from the drum through a shallow trench toward the shaft. It passed through a pulley bolted to the foot of the headframe, then up and over the sheave at the headframe's top. The draft animal walked around the whim on a prepared track, and the party of prospectors usually laid a plank over the cable trench for the animal to walk across. The controls for the malacate consisted of brake and clutch levers mounted to the shaft collar, and they were connected to the apparatus by wood or iron linkages that passed through the trench.[xxxvii]

Mining machinery makers offered factory-made horse whims which were sturdier and performed better than the hand-made units used by impoverished miners. The Risdon Iron Works in San Francisco began manufacturing a variety sold as the "Common Sense Horse Whim". Similar in form to the malacate, Risdon's machine consisted of a spoked iron cable reel mounted on a timber foundation that miners had embedded in the ground. These *horizontal reel horse whims* remained popular among poorly funded prospect operations into the 1900s. The *geared horse whim* appeared in the West during the 1880s and it remained popular among prospect operations into the 1900s. The machine consisted of a cable drum mounted vertically onto a timber frame, a beveled gear connected to the draft animal's harness beam. Geared horse whims were supposedly faster and could lift more than horizontal reel models. They also featured controls and cable arrangements like the other types of whims, and the drum and gearing was bolted onto a timber foundation buried in waste rock.[xxxviii]

In keeping with the themes of impermanence and limited budgets common to prospecting during the Gilded Age, mining operations erected small and simple headframes in conjunction with horse whims. Prospectors favored using either a tripod, tetrapod, or a small four-post derrick that was just wide enough to straddle the shaft. The primary stresses these headframes had to contend with were vertical, consisting of the combined weight of the loaded hoisting vehicle and the cable paid down the shaft. The lack of other stresses permitted prospect operations to erect structures that were simple and unique to horse whims. The headframes were made of light-duty materials, and they did not need backbraces, a firm foundation, and other structural elements necessary for power hoisting. Further, prospectors often used hewn logs up to 25 feet long that they cut at little cost.

Prospect operations working in deep shafts began to use steam hoists in large numbers by around 1880. These systems were beyond the financial means of simple, poorly financed partnerships, nor were they easy to transport deep into the backcountry. Steam hoists and their associated boilers required capital, and at least several men among the crew had to have knowledge of how to install and operate such machinery. Deep prospect operations equipped with mechanical hoists usually fell under the auspices of organized mining companies.

Steam hoisting systems required a relatively substantive infrastructure. They consisted of a heavy hoist and boiler, cable, pipes, a headframe, and foundations. Because of the numerous heavy components, the steam system had to be planned, engineered, and the claim made ready with a road. The mining company had to provide a reliable source of soft water and a source of fuel for the boiler. Investors and company management expected deep prospect operations to work year 'round until they found ore or until the money ran out, necessitating the construction of a shaft house to fend off the elements.

Prospect operations throughout the West active after around 1880 typically used *geared single-drum duplex steam hoists*, known simply as single drum steam hoists. These hoists became the ubiquitous Gilded Age workhorse for shaft mining. Single drum steam hoists consisted of a cable drum, two steam cylinders flanking the drum, reduction gears, a clutch, a brake mechanism, and a throttle. The steam pistons chuffed away like a railroad engine and turned the drum through the gearing. Single-drum hoists featured durable and simple controls, and they were easy to use. All hoists had a clutch that uncoupled the drum from the drive shaft, and they also had a reverse link that permitted the engine to run backward. The reverse lever moved a rod that switched the positions of the exhaust and steam valves, closing one if it had been open and opening the other if it had been closed. While the reverse link proved invaluable for slowing the hoist and vehicle during long descents in deep shafts, hoists also featured a mandatory brake.

Mining engineers selected the specific model and size of hoist primarily according to the budget granted by the company, and secondary on the speed and depth he anticipated working. Nearly all of the sinking-class hoists that engineers selected for deep prospecting had bedplates smaller than 6 by 6 feet in area and were driven either by gearing or by a *friction drive* mechanism. A friction-drive consisted of rubber rollers which pressed against the hoist's drum flanges, and while these systems cost less than geared hoists, they were slow and apt to slip under load. Both types of hoists had limited strength, which was often less than 40 horsepower, a slow speed of 350 feet per minute, and a payload of only several tons. Professionally educated engineers defined such hoists as meeting the criteria for sinking-class mine machinery and not for ore production, which applied well into the twentieth century.[xxxix]

A significant number of deep prospect operations in the West fell into an awkward niche where horse whims were inadequate, but the outfit could not, or would not, come up with the capital necessary to install a conventional stationary steam hoist and boiler. During the late 1870s machinery manufacturers introduced a revolutionary type of hoisting system that met the needs of these small operations. The *steam donkey hoist*, so named for its broad utility, consisted of either a small single cylinder or duplex steam hoist and an upright boiler mounted onto a common wood or steel frame. While donkey hoists were not manufactured exclusively for mining, being used for logging and in freight yards, they endeared themselves to Western prospect operations. The durable machines withstood mistreatment, they were relatively inexpensive, they did not require much site preparation, and they could literally drag themselves around the landscape. In addition, donkey hoists did not require a deep understanding of engineering, and nearly anyone on the payroll of a mining company could have operated one.

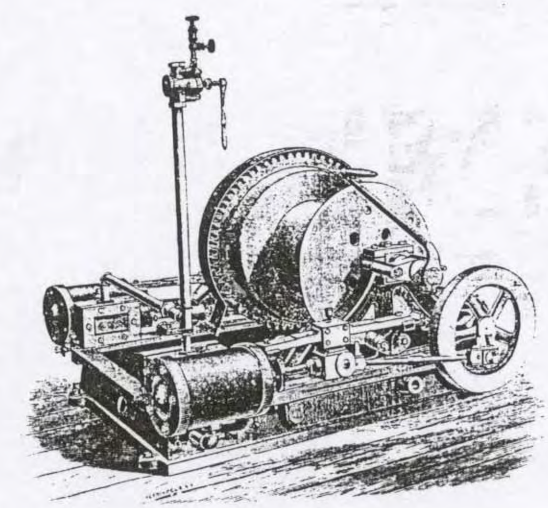


Figure 4.14 The single-drum duplex geared steam hoist, popularly known as the "single drum hoist" revolutionized shaft mining because it permitted companies to efficiently raise great weight from deep workings. The installation of such an apparatus and the associated mandatory steam boiler required capital to purchase and engineering skills to install. The front of the illustrated hoist is at right and the rear, where the hoistman stood to operate the controls, is at left. Ingersoll Rock Drill Company, [1887] p56.

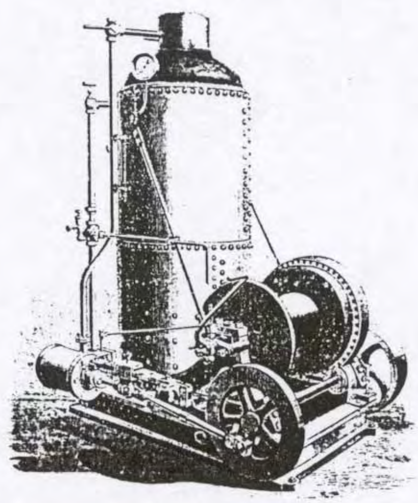


Figure 4.15 Prospect operations engaged in deep subsurface exploration employed highly versatile and modestly priced donkey hoists. The durable machines were self-contained on a common bedplate, and because they were heavy when assembled, they required no anchor foundation. When the hoistman disconnected the drum's clutch, he could have used the drive-belt pulley at far right to power other machines such as ventilation blowers while the steam engine idled. Ingersoll Rock Drill Company, [1887] p54.

Table 4.2: General Hoist Specifications: *Type, Duty, Foundation*

Hoist Type	Hoist Class	Foundation Size	Foundation Footprint	Foundation Profile	Foundation Material
Hand Windlass	Shallow Sinking		Rectangular	Wood frame over shaft	Timber
Hand Winch	Shallow Sinking	3x3 ft.	Square or Rectangular	Flat	Timber
Horse Whim: Malacate	Shallow Sinking	7 to 10 ft. Diameter	Ovoid Depression	Cable Reel Axle Located in Pit	Timber
Horse Whim: Horizontal Reel	Sinking	4x4 ft.	Rectangular	Timber Footers in Depression	Timber
Horse Whim: Geared	Sinking	4x4 ft.	Rectangular	Timber Footers in Depression	Timber
Steam Donkey	Sinking	Portable	Rectangular	None	None
Gasoline Donkey	Sinking	Portable	Rectangular	None	None
Single Drum Gasoline	Sinking	2.5x8 ft. to 4x14.5 ft.	Rectangular	Flat	Timber or Concrete
Single Drum Gasoline	Sinking	2.5x8 ft. to 4x14.5 ft.	T-Shaped	Flat	Timber or Concrete
Single Drum Geared to Gasoline Engine	Sinking	3x8 ft. to 8x14.5 ft.	L-Shaped	Flat	Timber or Concrete
Single Drum Steam	Sinking	6x6 ft. and Smaller	Rectangular	Flat	Timber or Concrete
Single Drum Steam	Light Production	6x6 ft. to 7.5x10 ft.	Square or Rectangular	Flat	Concrete or Masonry
Single Drum Steam	Moderate Production	7.5x10 ft. and Larger	Rectangular	Irregular	Concrete or Masonry
Double Drum Steam	Moderate Production	4x7 ft. to 7x12 ft.	Rectangular	Irregular	Concrete or Masonry
Double Drum Steam	Heavy Production	7x12 ft. and Larger.	Rectangular	Irregular	Concrete and Masonry
Single Drum Geared Electric	Sinking	5x6 ft. and Smaller	Square or Rectangular	Flat	Concrete
Single Drum Geared Electric	Production	6x6 ft. and Larger	Square or Rectangular	Flat	Concrete
Single Drum Direct Drive Electric	Production	5x6 ft. and Larger	Square or Rectangular	Flat	Concrete
Double Drum Geared Electric	Heavy Production	6x12 ft.	Rectangular	Irregular	Concrete
Double Drum Direct Drive Electric	Heavy Production	6x12 ft.	Rectangular	Irregular	Concrete

(Copied from Twitty, 1999, p291).

Mining engineers recognized that donkey hoists strictly met sinking-class specifications because of their limited performances. The machines possessed slow hoisting speeds, the boilers offered poor fuel economy, and the hoists had limitations of up to an 8,000 pound payload and a 1,000 foot working depth. Preparing a donkey hoist for use was extremely easy once it had been brought to the prospect shaft. A crew of laborers graded a platform a short distance from the shaft and placed the donkey hoist on it. Usually the shear weight of the machine was enough to keep it in place during operation, but in many cases prospect operations staked down the rear as a safety precaution. Like all steam hoists, donkey hoists required sources of fuel and water.[xl]

Prospect operations seeking riches deep in the backcountry reluctantly spent the capital required to install steam equipment. The problems they faced were twofold. Not only did these operations have to ship and erect the hoisting system, but they also had to continuously feed it fuel and water, which proved costly. In the early 1890s the Witte Iron Works Company and the Weber Gas & Gasoline Engine Company both began experimenting with a new hoisting technology that alleviated many of the fuel and water issues faced by remote prospect operations. Witte and Weber both introduced the first practical petroleum engine hoists. These innovative machines were smaller than many steam models, they required no boilers, and their concentrated liquid fuel was by far easier to transport than wood or coal.

Despite their potential advantages, Western mining companies did not immediately embrace petroleum hoists. Steam technology, the workhorse of the Industrial Revolution, held convention in the mining industry through all but the last few years of the nineteenth century for several reasons. First, many mining companies and practicing mining engineers were by nature conservative, and out of familiarity they stayed the course with steam into the 1910s. Second, during this time petroleum engine technology was relatively new and had not seen widespread application, especially for hoisting. The few operations to employ petroleum hoists during the 1890s found the engines to be cantankerous and that their performances were limited. Further, petroleum hoists were slow, possessing speeds of 300 to 400 feet per minute, they could not raise much more than 4,500 pounds, and their working depth was limited to less than 1,000 feet. For these reasons professionally educated mining engineers felt they were barely adequate for sinking duty, and total acceptance took approximately fifteen years.[xli]

The petroleum hoists seen among Western prospect operations were similar in form to the old-fashioned and well-loved steam donkey hoists. The engine, a large single cylinder oriented either vertically or horizontally, had been fixed to the rear of a heavy cast iron frame and its piston rod connected to a heavy crankshaft located in the frame's center. Manufacturers located the cable drum, turned by reduction gearing, at front, and the hoistman stood to one side and operated brake and clutch levers, and the throttle. Because the early petroleum engines were incapable of starting and stopping under load or of being reversed, they had to run continuously, requiring the hoistman to delicately work the clutch when hoisting, and disengage the drum and lower the ore bucket via the brake. Miners truly placed their lives on the line when riding an ore bucket controlled by a petroleum hoist.

Western prospect operations began showing interest in petroleum hoists during the late 1890s because the small sizes and light weights of the machines made the apparatuses easy to ship. Equally important, petroleum fuel cost much less to pack to a prospect site than coal or wood, and the purchase prices of the hoists were modest. By the 1900s professionally trained mining engineers granted the hoists recognition for the ability to play an effective role in deep prospecting at remote sites. But their means of operation bothered some mining engineers, such as the famous Herbert C. Hoover:

> "Gasoline hoists have a distinct place in prospecting and early-

> stage mining, especially in desert countries where transport and fuel conditions are onerous, for both the machines and their fuel are easy of transport. As direct gas-engines entail constant motion of the engine at the power demand of the peak load, they are hopeless in mechanical efficiency." (34)

Despite running at full throttle much of the day, many early petroleum hoists consumed at most 10 gallons of gasoline, diesel, or kerosene per ten hour shift, which cost a total of approximately $2.00 in turn-of-the-century dollars. By comparison, a cord of wood, typically consumed by a sinking class steam hoisting system during a shift, also cost around $2.00 where cut, but then it had to be shipped to the prospect site, raising the total cost to as much as $10. Some prospect operations under the guidance of clever engineers put the constant running of petroleum hoists to efficient use by adding a pulley to the flywheel, which then powered air compressors and shop appliances via canvas belting. This at least partially negated Hoover's criticism of the inefficiencies of petroleum hoists.[xlii]

The Western mining industry did not begin to truly embrace petroleum hoists for deep prospecting, let alone minor ore production, until the late 1900s. By the 1910s gas engine technology had improved and hoistmen understood how to operate the machines without stalling them, and even to work the throttle to maximize efficiency. Petroleum hoists had made such an impact by this time that steam hoists were becoming obsolete among remote prospect operations in the Great Basin and Southwest, but in areas where cord wood or coal was plentiful, such as Creede, the transition was slower.

Steam technology maintained supremacy among Western mines for production-class hoisting systems until gasoline and electric power superceded it in the early 1920s. During this time period mining machinery makers such as Allis-Chalmers, the Lidgerwood Manufacturing Company, the Lambert Hoisting Engine Company, Hendrie & Bolthoff, the Union Iron Works, and the Ottumwa Iron Works offered steam hoists in a wide array of sizes. These manufacturers also offered hoists equipped with either *first-motion* or *second motion* drive trains. First-motion drive, also known among mining engineers as *direct-drive*, meant that the steam engine drive rods were coupled directly onto the cable drum shaft, much like the way the drive rods were directly pinned onto a steam locomotive's wheels. Second motion drive, also commonly known as a *geared-drive*, consisted of reduction gearing like the sinking-class hoists discussed above.

The difference in the driving mechanisms was significant in both performance and cost, and each served a distinct function in Western mining. Gearing offered great mechanical advantage, which permitted the use of relatively small steam cylinders. The arrangement of the gear shafting and cylinders on a common bedplate permitted the hoist's footprint to be compact. First-motion hoists, on the other hand, required that the cable drum be mounted at the ends of large dual steam cylinders so that the drive rods could gain leverage. Where the footprint of geared hoists was almost square, the footprint of first-motion hoists was that of an elongated rectangle with the long axis oriented toward the shaft. First-motion hoists were intended by manufacturers to serve as high-quality production-class machines designed to save money only over protracted and constant use, while geared hoists were intended to be inexpensive and meet the short term needs of small, modestly capitalized mines. First-motion hoists were stronger, faster, and more fuel-efficient than geared models. The large size, necessity of using high-quality steel to withstand tremendous mechanical forces, and the fine engines made the purchase price of first-motion hoists three to four times that of geared hoists, the latter costing from approximately $1,000 to $3,000 for light to heavy production-class models. First-motion hoists had a speed of 1,500 to 3,000 feet per minute, compared with 500 to 700 feet per minute for geared hoists. These hoisting speeds reflect the ability of first-motion hoists to work in shafts with depths well into the thousands of feet. Geared hoists usually relied on old-fashioned but durable slide valves to admit steam into and release exhaust from the cylinders, while first-motion hoists usually were equipped with corliss valves for the engine, which were initially more expensive but consumed half the fuel.[xliii]

Not only were the costs of purchasing first-motion hoists high, the expenses associated with their installation were exorbitant. Because geared hoists were self-contained on a common bedplate, the surface crew at a mine merely had to build a small foundation with anchor bolts projecting out of a flat surface, and drop the hoist into place. First-motion hoists, on the other hand, required raised masonry pylons for the steam cylinders, pylons for the cable drum bearings, a well for the drum, and anchor bolts in masonry between the pylons for the brake posts. The hoist pieces then had to be brought over, maneuvered into place, and simultaneously assembled.

Mining engineers chose specific hoists based on the power delivered by the engine, which had a proportional relationship with the hoist's overall size. Geared hoists smaller than 6 by 6 feet were usually made for deep exploration and delivered less than 50 horsepower. Hoists between 7 by 7 feet and 9 by 9 feet were for minor ore production and offered 75 to 100 horsepower. Hoists 10 by 10 feet to 11 by 11 feet were for moderate to heavy production and generated up to 150 horsepower, and larger units were exclusively for heavy production. Mining engineers rarely installed geared hoists larger than 12 by 12 feet, because for a little more money they could have obtained an efficient first-motion hoist.[xliv]

Regardless of the nature of the drive mechanism, single drum geared and direct-drive hoists were restricted to serving a shaft with a single hoisting compartment, which had inherent inefficiencies. Double-drum hoists, on the other hand, offered greater economical performance because they increased the tonnages of rock produced while saving energy costs. They achieved this through a balanced hoisting system, which required two hoisting vehicles. As the hoist raised one vehicle, the other descended down the shaft in a balanced fashion. Not only did the hoist only have to do the work of raising the ore and not the deadweight of the hoisting vehicle, thus saving energy, but also two vehicles raised more rock than one. However, double drum hoists possessed several drawbacks that limited their appeal to particularly well-financed mining companies. The hoists were considerably more expensive than single drum models to purchase and install, and sinking and timbering a shaft with two hoisting compartments and the obligatory utility compartment constituted a great cost.

Like single-drum hoists, double-drum units came with geared or first-motion drives, which were either self-contained on a bedplate or consisted of components that had to be anchored to masonry foundation piers. Double-drum geared hoists, ranging in size from between 7 by 12 feet to 12 by 17 feet, were slower, less powerful, and noisier than their direct-drive brethren, and they cost much less to purchase, transport, and install. Like single-drum geared hoists, double-drum geared models had weight, speed, and depth limitations mining engineers with

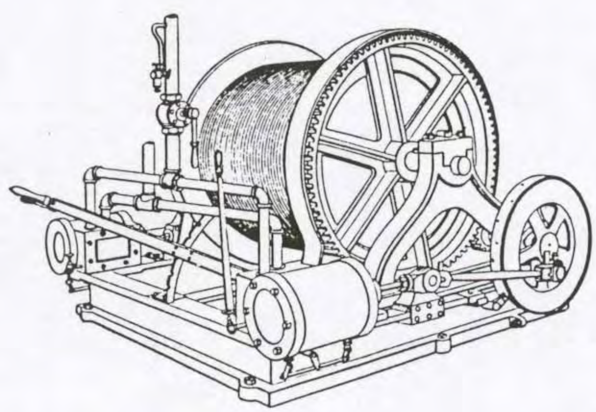


Figure 4.16 "Made by the mile and cut off by the yard", mining companies throughout the West favored the single drum duplex geared steam hoist above all other varieties until electric power and petroleum fuel replaced steam in the early 1920s. These hoists were relatively inexpensive and easy to install because they came assembled onto a common bedplate. However, geared hoists lacked efficiency. The rear of the hoist where the controls were located is at left, and the front where the drive shaft rotates is at right. International Textbook Company, 1906. A50 p8.

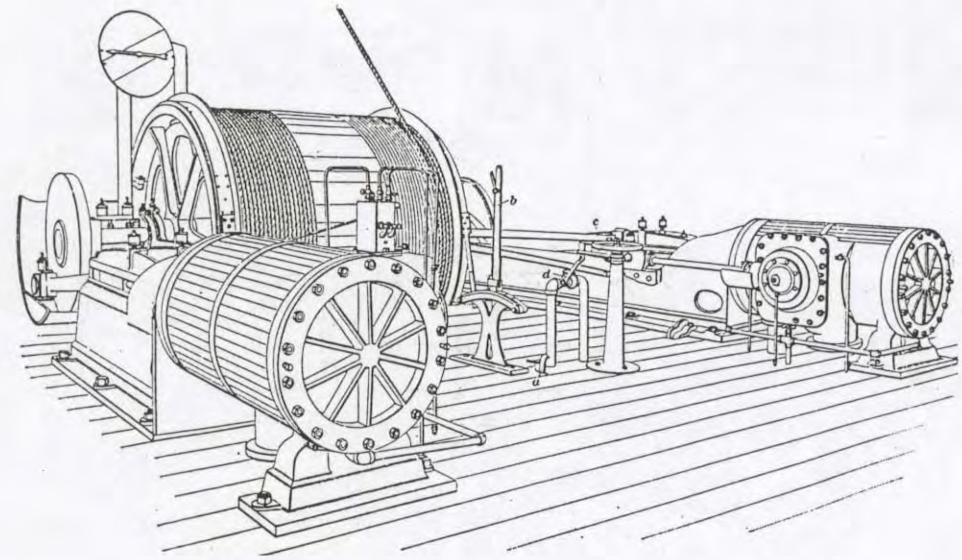


Figure 4.17 First-motion steam hoists consisted of two powerful steam engines coupled directly to the drum shaft. The direct-drive motion enabled these mighty machines to raise loads much quicker while using less fuel than the geared hoists illustrated above, suiting them for heavy ore production. Because first-motion hoists were very costly, generally only well-capitalized mining outfits installed them. Note the level gauge in the upper left which displayed where the hoisting vehicle was in the shaft. The hoist in the illustration has been wound with two hoist cables for balanced hoisting. International Textbook Company, 1906. A50 p17.

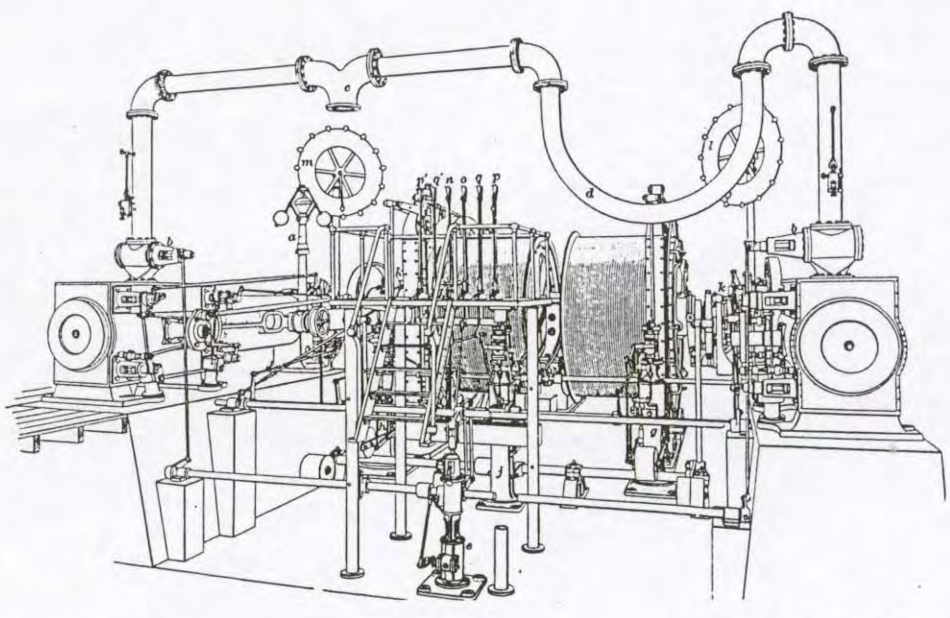


Figure 4.18 Double drum first-motion steam hoists represented the culmination of efficient and costly production-class hoisting systems. The line drawing provides a rear view of the complex machinery comprising the hoist. The hoist components include two massive steam cylinders flanking the hoistman's platform, the cable drums, and steam cylinders located in the pit that powered the clutch and brake. Few mining companies were productive enough or possessed sufficient capital to install these types of hoists. International Textbook Company, 1906. A50 p18.

high expectations would not tolerate. The ultimate answer for raising the maximum quantity of ore in minimal time was the installation of a double-drum first-motion hoist. The extreme difficulty and exorbitant costs of transporting and installing these massive machines relegated them to only the most heavily capitalized mining companies with highly productive operations in well-developed districts, such as the Last Chance Mine on Creede's Amethyst Vein. Not only did these types of double drum hoists permit mining companies to maximize profits, but also they served as a statement to the mining world of a company's financial status, levels of productivity, and quality of engineering.

Double drum first-motion hoists ranged in size from approximately 18 by 25 feet to over 30 by 40 feet in area, and their visual impact mirrored their performances. Small models, large by comparison to other types of hoists, generated a tremendous 600 horsepower while large units created over 1,200 horsepower. The power behind these hoists' massive steam pistons permitted the machines to raise over many tons at a speed of at least 3,000 feet per minute, making geared hoists seem like toys. Their working depths were well over 3,000 feet.[xlv]

The installation of such immense hoists required exacting engineering, highly skilled labor, and significant site preparation. While mine machinery makers shipped the smaller geared hoists either intact or in several large components which were easily assembled, the large first-motion units came in many pieces, weighing between several pounds and several tons, and they required special arrangements of anchor bolts built into elaborate masonry foundations. The steam assist cylinders that powered the clutches and brakes, as well as the brake posts, control linkages, and the main hoist parts all had to be perfectly mounted onto bolts set in masonry pylons placed at exact heights and locations. Because these powerful machines were highly specialized and their installation required precision work, manufacturers such as Webster, Camp & Lane, Wellman-Seaver-Morgan Company, Allis-Chalmers Company, and the Stearns-Roger Manufacturing Company dispatched mechanical engineers to assist in site preparation and final assembly. During the Gilded Age, the installation of a first-motion hoist usually represented the culmination of a production-class plant. While the mammoth machines delivered savings in terms of producing ore in economies of scale, they also consumed much money. Double drum steam hoists required frequent maintenance and they required huge quantities of fuel. As a result, mining engineers began to replace them with double drum electric hoists when electrical technology had attained a competitive state by around 1920.

By the Great Depression, professionally educated mining engineers celebrated the industry's embrace of the electric hoist for most types of shaft work. Machinery makers had ironed out wrinkles in the technology experienced by the mining industry during the 1900s and 1910s, and by the 1930s they were producing a variety of single and double drum models for shaft sinking and for heavy ore production. Like the steam hoists of old, electric models came in four basic varieties: geared single and double drum units, and direct-drive single and double drum units. The geared electric hoists were built much like their steam ancestors in that the motor turned a set of reduction gears connected to the cable drum, and the components came from the manufacturer assembled onto a heavy bedplate. The gearing permitted hoist manufacturers to install small and inexpensive motors ranging from 30 to 300 horsepower. Direct-drive electric hoists, on the other hand, had huge motors rated up to 2,000 horsepower attached to the same shaft that the cable drums had been mounted on. These hoists, considerable in size, had to be assembled as components onto special foundations, as did the old direct-drive steam hoists.[xlvi]

Any twentieth century mining engineer felt immense pride when his mine became host to a direct drive electric hoist. These machines were fast, powerful, efficient, and clearly intended for heavy ore production. They had hoisting speeds in the thousands of feet-per-minute, their payload capacity was over ten tons, and they were able to work at great depths. But because they were very costly, only highly profitable and heavily capitalized mining companies could justify installing such machines. Further, the electrical systems required to operate direct-drive hoists were expensive to install. These large machines typically operated with DC electric current, and as a result they required a substation where the AC current wired to the mine could have been converted. In addition, because the massive motors for direct-drive hoists drew heavily from the electrical circuit upon starting, mining companies that installed direct-drive hoists found it best to put in an associated rotary converter to moderate the power drain.[xlvii]

Like the antiquated steam hoists used during the Gilded Age, during the 1930s mining engineers classified single drum electric hoists smaller that 6 by 6 feet in area as meeting the qualifications for sinking duty. Most of the production class hoists installed by engineers during this time featured motors rated to at least 60 horsepower for single drum units and 100 horsepower for double drum units. Even with large motors, these geared hoists had slow hoisting speeds, being under 600 feet-per-minute, their payload capacity was limited, and they were not able to work in the deepest shafts. Yet out of economic necessity during the capital-scarce Great Depression, many mining companies had to settle for these machines, even though they hindered ore production. Less-fortunate mining outfits severely constrained by tight budgets had to settle for small, slow, sinking-class hoists. It was not uncommon for these companies to use hoists with motors rated at only 15 horsepower, which in better times might have been used instead for work over winzes.[xlviii]

Some outfits attempting to recondition abandoned mines on shoestring budgets cobbled together hoists from machinery that had been cast off at the close of the Gilded Age. Miners employed creativity and talent in making old machinery work, and their solutions fell into several basic patterns. One method common among operations in the mountain states involved obtaining an old geared steam hoist, stripping it of the steam equipment, and adapting an electric motor to turn the hoist's large bull gear. Miners used what ever type of motor they could get their hands on, and they understood that large motors were most desirable because of their performance. To adapt the motor to run the hoist, they had to build a small foundation with anchor bolts adjacent to the hoist, and they had a machine shop custom-make a pinion gear for the motor that had teeth capable of meshing with the bull gear. The only other modification that the mining outfit had to make to the hoist was to mount the electric controller on the hoistman's platform. After ensuring that the original clutch and brake worked and that the hoisting cable was sound, the miners were ready to go to work.[xlix]

Mining outfits with limited funding practiced another clever means of bringing new life to antiquated steam hoists. Unlike the method described above, the miners left the steam equipment on the hoist intact, and they went so far as to ensure that the pistons, piston rings, and valves were in good condition. They reconnected pipes to the steam intakes on the hoist's cylinders and instead of routing the line to a boiler, they used compressed air to power the hoist. As far back as the 1890s mining engineers had found that they could adapt steam hoists to run off compressed air, especially for work underground in winzes where piping in steam was uneconomical. The only drawback to such an innovative use of compressed air was that a large multi-stage compressor had to be installed. In a few cases impoverished mining operations were fortunate to have as a neighbor a well-funded mine equipped with just such a compressor.

The third practice that impoverished mining companies adhered to when rehabilitating old mines involved assembling mechanical hoists from odd and unlikely pieces of machinery. A favorite system favored by outfits lacking money, resources, and an understanding of fine engineering consisted of installing a small friction-drive hoist or geared hoist stripped of everything but the brake and clutch, coupled to the transmission of a salvaged automobile. Ugly, slow, noisy, and of questionable reliability, these contraptions worked well enough so that shoestring mining operations were able to turn a small profit. Lacking the will, money, and possibly the knowledge of how to construct a proper foundation, miners simply bolted the hoist onto a flimsy timber frame that had not necessarily been anchored in the ground, and they mounted the engine to an even less formal timber frame. These small outfits commonly obtained either a wrecked automobile or one in disrepair, they stripped off the body, cut away the rear portion of the chassis, and left the engine, transmission, firewall, and radiator intact. They aligned the chassis so that they were able to connect the drive shaft to the hoist's gears, the connections being made with custom-made and adapted hardware.[l]

Small and medium-sized mining outfits that had access to modest capital were able to afford to install factory-made gasoline hoists similar to the type introduced to the mining industry during the 1900s. Mining companies continued to use the old single-cylinder gasoline hoists, and they also purchased factory-made donkey hoists offered by machinery suppliers such as Fairbanks-Morse and the Mine & Smelter Supply Company. The donkey hoist manufactured during the 1930s consisted of a small automobile engine that turned a cable drum through reduction gearing. The makers designed the little machines to be portable, and they affixed all of the components onto a steel frame. The affordability, portability, and independence suited these machines for backcountry use, especially during the capital-poor times of the Depression.

Several conditions played into a small outfit's decision as to which type of hoisting contraption they would attempt to build. Available capital constituted the most fundamental factor because mining outfits lacking funding had to find alternatives to new equipment. In light of the lack of capital, another influential factor consisted of whether the mine an outfit intended to rehabilitate was fortunate enough to retain its original hoist. In such cases mining outfits elected to work with what the remains of the mine plant offered them. Retrofitting steam hoists with motors seems to have been a popular means of bringing hoisting system on line. The visitor encountering such a mine site today may observe an old steam hoist bolted onto its original foundation, constructed of either masonry or natural concrete, with an adjacent portland concrete motor mount, usually 2 by 3 feet in area studded with four anchor bolts.[li]

In the event that a mine under rehabilitation did not possess its original hoist, the mining company was forced to install another apparatus afresh. Outfits with limited capital may have opted to buy a small new or used factory-made electric model, or they may have attempted to retrofit a hoist salvaged from a neighboring defunct mine. For economic reasons, some operations intentionally purchased used steam hoists because their obsolescence had rendered them extremely inexpensive. Due to lack of funding and possibly a lack of training in engineering, small mining companies operating during the Great Depression rarely poured new concrete foundations for their hoists. In most cases the mining outfits affixed the hoist to a substandard timber foundation, or they adapted the new hoist to an old foundation that already existed at the mine, employing the methods discussed above in association with air compressors.

Steam Boilers

Steam boilers were an absolutely necessary component of nineteenth century power hoisting systems. While specific designs of boilers evolved and improved over time, the basic principle and function remained unchanged. Boilers were iron vessels in which intense heat converted large volumes of water into steam under great pressure. Such specialized devices had to be constructed of heavy boilerplate iron riveted to exacting specifications, and they had to arrive in the mining West ready to withstand neglect and abuse. The problem that boilers presented to mining companies was that they were bulky, heavy, cumbersome, and required engineering to install. The mere thought of attempting to maneuver even a small boiler deep into the backcountry was enough to convince many poorly financed mining companies to continue using traditional horse whims.

Adhering to the objectives of maximizing performance and minimizing operating costs, mining engineers used calculation and mechanical specification in their attempts to meet the power needs of a mine. The mining engineer had to add up the steam demands of all machines, usually measured in *boiler horsepower*, to calculate the size, type, and number of boiler units he would need. Between the 1880s and 1910s the main surface plant components an engineer may have included in his calculations consisted of the hoist, an air compressor, and a tiny water pump to feed water to the boilers. Small mines may not have had a compressor, while large operations may have included several. Engineers working in most of the West also had to figure on generating enough steam to run a small dewatering pump at the bottom of the shaft and possibly a donkey engine to drive a ventilation fan or mechanized shop appliances.

During the 1880s the *Pennsylvania boiler*, the *locomotive boiler*, and the *upright boiler*, also known as the *vertical boiler*, quickly gained popularity among the West's prospect operations. These boilers were well-suited to the mining West because they were self-contained and freestanding, ready to fire up, and able to withstand mistreatment. Because the above three types of boilers were designed to be portable at the expense of fuel-efficiency, mining engineers declared them fit only for sinking duty.

In general, all of the above sinking-class boilers consisted of a shell that contained water, flue tubes extending through the shell, a firebox inside the shell at one end, and a smoke manifold. When the *fireman* stoked a fire in the *firebox*, he adjusted the *dampers* to admit enough oxygen to bring the flames to a steady roar. The *flue gases*, which were superheated, flowed from the fire through the *flue tubes*, imparting their energy to the surrounding water, and they flowed out the *smoke manifold* and up the *smokestack*.

Great danger lay in neglecting the water level. An explosion was imminent if the flue gases contacted portions of the shell that were not immersed in water on a prolonged basis. Usually the front of the boiler featured a *glass sight tube* much like the level indicator on a coffee urn. When the water began to get low, the fireman turned the valve on the main that had been connected to the boiler, or he operated a small hand pump if the plumbing had no pressure. Boiler tenders, often serving also as hoistmen, usually kept the boiler three-quarters full of water, the dead space being necessary for the gathering of steam. When the fire grew low the boiler tender opened the *fire door*, the upper of two sets of cast iron hatches, and threw in fuel. Self-made and professionally educated mining engineers recognized that cord wood was the most appropriate fuel to feed boilers in remote and undeveloped mining districts, because poor road systems and great distances from railheads made importing coal too expensive. However, coal was the most energy-efficient fuel, a half ton equaling the heat generated by a cord of wood, and as a result mining operations proximal to sources of the fossil fuel, such as in the eastern and central Rockies, preferred it.

During the 1880s mining companies came to appreciate the utility and horsepower of the locomotive boiler. The locomotive boiler, so named because railroad engine manufacturers favored it for building locomotives, consisted of a horizontal shell with a firebox built into one end and a smokestack projecting out of the other end. Nearly all of the models used in the West stood on wood skids and were easily portable, but some units required a small masonry pad underneath the firebox, and a masonry pillar supporting the other end. Locomotive boilers were usually 10 to 16 feet long, 3 feet in diameter, and stood up to around 6 feet high, not including the steam dome on top. These workhorses, the single most popular sinking-class source of steam into the 1910s, typically generated from to 30 to 50 horsepower, which was enough to run a sinking-class hoist. Large locomotive boilers capable of powering a big sinking-class hoist and compressor were available, but prospect operations rarely used them. When a mine attained the size large enough to include such apparatuses, the engineer usually upgraded the plant with an efficient production-class return tube boiler.[lii]

Upright boilers were the least costly of all boiler types. They tolerated abuse well, and they were the most portable. However, because upright boilers could not generate the same horsepower as locomotive or Pennsylvania units, they could not power large sinking-class hoists, let alone additional machines such as air compressors. Upright boilers consisted of a vertical water shell that stood over a firebox and ash pit that had been built as part of a cast iron base. The flue tubes extended upward through the shell and opened into a smoke chamber enclosed by a hood and smokestack, which appeared much like an inverted funnel. The flue gases' path up directly up and out of the firebox made these steam generators highly inefficient, and the rapid escape of gases and the quick combustion of fuel caused great fluctuation and inconsistency in the pressure and volume of steam. The short path for the gases and intense fire put heavy heat stress on the top end, causing it to wear out quickly and leak, and the firebox and doors also saw considerable erosion. However, upright boilers required little floor space, little maintenance, and were so durable that they almost could have been rolled from site to site. The West had plenty of remote prospect operations with limited capital that saw great advantage in the qualities offered by vertical boilers, and consequently these steam generators enjoyed substantial popularity during the Gilded Age.[liii]

The third basic type of sinking-class boiler that Western prospect operations used in noteworthy numbers was the Pennsylvania boiler. This unit consisted of a cross between the form and portability of the locomotive boiler and the function of the Scotch marine boiler, discussed below. Like the other portable boilers, the Pennsylvania boiler featured an enclosed firebox that was surrounded by a jacket of water. The flue gases traveled through a broad tunnel in the shell, they rose into a small smoke chamber, then reversed direction and traveled toward the front of the shell through flue tubes. The gases escaped the boiler through the smokestack. The Pennsylvania boiler, which originated in the Keystone State's oil fields, proved to be remarkably efficient and saw use at a number of Western mining operations.[liv]

Table 4.3: Boiler Specifications: ***Type, Duty, Age Range***

Boiler Type	Boiler Design	Popularity Age Range	Sinking-Class Size Range	Production-Class Size Range
Plain Cylindrical	Water-filled tank with no flue tubes.	1800-1860s	Up to 6 ft. diam. 18 ft. L.	6 ft. diam., 20 ft. L to 8 ft. diam., 40 ft. L.
Flue	1-2 ft flue tubes through shell. Smoke stack at front	1820-1870s	Up to 3 ft. diam. 14 ft. L.	4 ft. diam., 16 ft. L to 5 ft. diam., 22 ft. L.
Return Tube	Multiple 3-4" flue tubes extending through shell.	1870s-1920s	Up to 3 ft. diam. 12 ft. L.	3 ft. diam, 12 ft. L to 7ft. diam., 20 ft. L.
Scotch Marine	Firebox and flue chamber enclosed in horizontal shell. Flue tubes through shell.	1890s-1910s	All Sizes.	
Locomotive	Firebox enclosed in steel casing under shell. Flue tubes through shell, smokestack at rear.	1870s-1920s	All Sizes.	Not Manufactured.
Upright/ Vertical	Boiler shell is vertical and stands on cast iron base. Firebox is at base. Flue tubes through shell, smokestack on top.	1880s-1920s	All Sizes.	Not manufactured.
Water Tube	Water tubes and header drums suspended over brick setting by steel girder frame.	1900s-1920s	Not Manufactured	All Sizes.
Water Tube	Water tubes and header drums are suspended over firebox enclosed in a cast iron shell.	1900s-1920s	Not Manufactured	All Sizes.

(Copied from Twitty, 1999, p250).

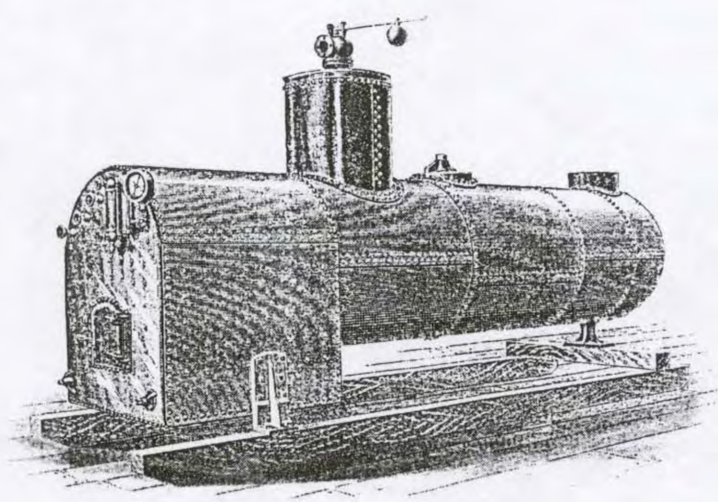


Figure 4.19 By 1880, if not earlier, mining companies throughout the West used locomotive boilers to power sinking-class hoists, and possibly small compressors. Manufacturers mounted locomotive boilers on skids to facilitate portability. The model illustrated appears to be wood-fired, and the ashes probably dropped through an opening in the bottom of the firebox. Note the water level sight tube and pressure gauge. Ingersoll Rock Drill Company, [1887] p45.

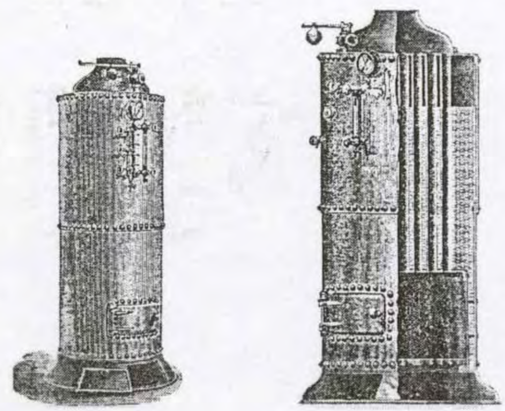


Figure 4.20 Durable, inexpensive, and highly inefficient, upright boilers had the capacity to power small sinking-class steam hoists or other mine machines. The great ease of portability rendered upright boilers popular among small, poorly funded mining operations working in remote areas. However, because upright boilers could not have generated much steam they saw limited application. Note the water level sight tube and pressure gauge. Ingersoll Rock Drill Company, [1887] p47.

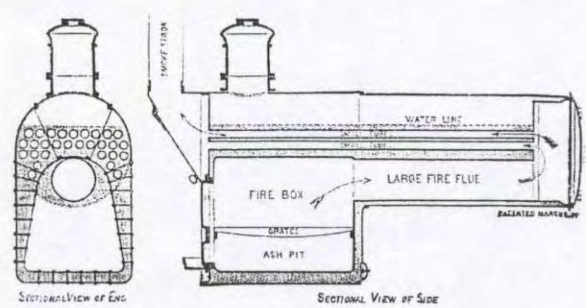


Figure 4.21 Cut-away view of a Pennsylvania boiler. The path of the flue gases, indicated by the arrows, extended through a tunnel in the bottom of the water shell, it reversed direction in the smoke chamber and traveled through the flue tubes in the central portion of the shell, and rose up through the smokestack. Pennsylvania boilers were mounted onto timber skids like locomotive boilers, and while they were introduced during the 1880s, the efficient power sources did not experience even mild popularity until the 1890s due to a high initial cost. Mining companies with limited funding in remote areas used Pennsylvania boilers to power small production-class hoists. Rand Drill Company, 1886 p46.

Developed in Scotland for maritime purposes, the Scotch marine boiler was the least popular sinking-class steam generator in the West. Scotch marine boilers consisted of a large-diameter shell enclosing the firebox, and the path for the flue gases was similar to that of the Pennsylvania boiler. While this type of boiler was one of the most efficient portable units, it never saw popularity in the West primarily because convention dictated the use of the other types, and because it was heavy, large, and difficult to haul to remote locations.[lv]

Engineers equipping production-class surface plants almost never relied on portable boilers to supply steam because of their inefficiency. Rather, the masters of mine mechanics predominantly used *return tube boilers* in masonry settings, or they erected *water tube boilers*, which offered the ultimate fuel economy. In a few rare cases, engineers working deep in the backcountry were forced to make due with Pennsylvania and locomotive boilers, but they preferred not to do so.

Manufacturers designed most steam machinery to work under pressures ranging between 100 and 150 pounds-per-square-inch. At this pressure a return tube boiler 5 feet in diameter and 16 feet long provided enough steam to run a hoist, a Cameron sinking pump, heating pipes in the shaft house, and another engine for a small tramming system, all totaling approximately 80 boiler horsepower. A slightly larger boiler was needed to run additional machinery such as a small air compressor, or a compressor could have been substituted for the tramway engine. Mine plants that included production-class single and double-drum hoists, duplex compressors, and other large, production-class machinery usually required the steam generated by at least two to three return tube boilers totaling over 200 boiler horsepower. Mining companies with a progressive engineer and plenty of capital often installed an extra boiler so that in the event one of the others had to be cooled off for servicing or following a malfunction, the mine could have continued ore extraction.[lvi]

The concept behind the return tube boiler was brilliant. The boiler shell, part of a complex structure, was suspended from iron legs known as *buckstaves*, so named because they prevented the associated masonry walls from *bucking* outward. Brick walls enclosed the area underneath the boiler shell, and a heavy iron façade shrouded the front. A *firebox* lay behind the façade underneath the boiler shell. Under the firebox lay an *ash pit*, and both were sealed off from the outside world by heavy cast iron doors. When a fire burned, the superheated flue gases traveled from the firebox along the belly of the boiler shell and rose up into a *smoke chamber* at the rear of the structure. They reversed direction and traveled toward the front through large flue tubes extending through the shell, and then exited through the *smoke manifold*. The path under and then back through the boiler shell offered the flue gases every opportunity to transfer energy to the water within and convert it into steam.

Return tube boilers were workhorses that withstood the harsh treatment and neglect endemic to western mines. Boiler tenders and firemen had to ensure that they carried out a few basic services to avoid life-taking disastrous explosions and ruptures. First, they had to keep the boiler at least two-thirds full of water. Second, the fireman had to clean the ashes out of the ash pit regularly to ensure that the fire did not suffocate. Shoveling ashes was a foul and dirty job that no one enjoyed. Usually the fireman shoveled the unwanted refuse into a wheelbarrow and trundled it out to a crook in the waste rock dump where the crew regularly dumped other trash. Pity the unfortunate worker who had to undertake such an unpleasant task on a gusty day! Third, the fireman ensured that the water and steam valves were operational, and that the pressure did not exceed the critical point. Last, the fireman had to feed the fire. Skilled firemen were able to throw on just enough fuel in an even distribution so that the fire kept a fairly constant glow. To ensure that firemen and boiler tenders had easy access to plenty of coal, the mining engineer usually had a coal bin built facing the firebox doors. In other circumstances cordwood may have been stacked in the bin's place.

Professionally trained mining engineers with access to plenty of capital employed additional devices designed to improve the energy efficiency and performance of their return tube boilers. First, they may have elected to install up to three feed water holding tanks to allow sediment and mineralization to settle out. Second, some engineers working in the West installed feed water heaters, which were small heat exchanging tanks that used some of the boiler's hot water or steam to preheat the fresh feed water. These had been proven to moderate the shock of temperature changes to the boiler, prolonging the vessel's life, as well as increasing fuel efficiency. A few engineers working at the largest mines attempted to mechanize the input of coal into the fireboxes of heavily used boilers with mechanical stokers. While they were costly, mechanical stokers did a better job than laborers. Engineers also fitted heavily stoked boilers with rocking or shaking grates that sifted the ashes downward, promoting better combustion of the fuel. Last, many engineers had mineworkers wrap the heater, the steam pipes, and exposed parts of the boiler with horsehair or asbestos plaster as an insulation. Except for feed water heaters and insulation, only a few large Western mining companies spent the capital to employ the other accessories because of the expense involved.[lvii]

During the time that boiler technology was young, in 1856 an American inventor named Wilcox devised a boiler radically different and much more efficient that the best return tube models. Wilcox's system consisted of a large brick vault capped with several horizontal iron water tanks. The vault contained a firebox, an ash pit, and a smoke chamber, all underneath 50 to 60 water-filled iron tubes. The tubes drew water from one end of the tanks and sent the resultant steam to the other end. By 1870 the design, known as the *water tube boiler*, had been commercialized and was being manufactured by the firm Babcock & Wilcox.[lviii]

After Babcock & Wilcox's water tube boiler had proven itself in a number of industrial applications, mining engineers began to take an interest. The fact that the water ran through the tubes, not around them, greatly increased the liquid's heating area, which resulted in much greater efficiency than return tube boilers. In addition, the threat of a catastrophic explosion was almost nonexistent. By the 1890s a number of mechanical engineers had devised other water tube boilers that saw production, such as the Heine, the Sterling, the Wickes, the Hazelton, and the Harrisburg-Starr.

The problem with all of the above models, however, was that they required much more attention than the rugged return tube boilers, they were significantly more costly to purchase, and they were beyond the understanding and field skills of average mining engineers. As a result water tube boilers saw use only at large, well capitalized mines under the supervision of talented, professionally trained engineers. As the prices of water tube boilers fell during the 1900s and capital became more abundant as the mining industry recovered from the Silver Crash of 1893, the popularity of the efficient steam generators began growing. However, the introduction of practical electricity in the 1910s prevented the widespread adoption of water tube boilers.

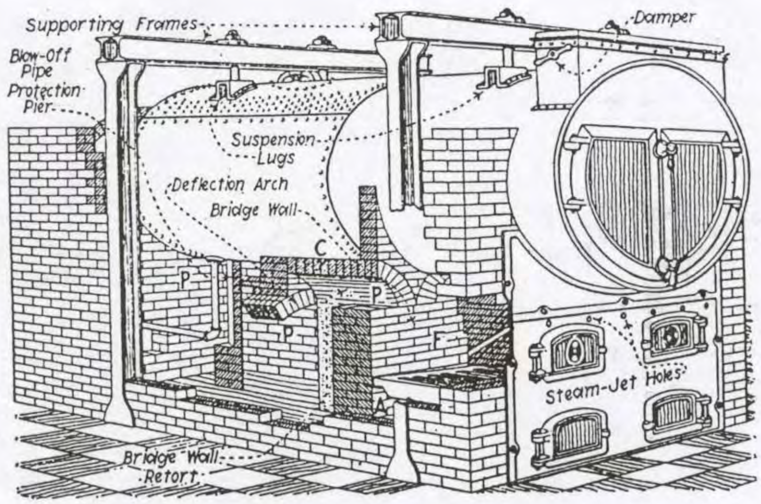


Figure 4.22 The lithograph illustrates a typical return tube boiler. The full façade, the only uncommon feature depicted, includes double doors providing access for cleaning the flue tubes, a firebox door under the shell, and an ash pit door underneath the firebox door. Removable iron grates form the floor of the firebox, and the masonry bridgewall stands behind the firebox. The boiler has been suspended by riveted brackets resting on the setting walls, which engineers only allowed when masons had used cement mortar. Rand Drill Company, 1886 p44.

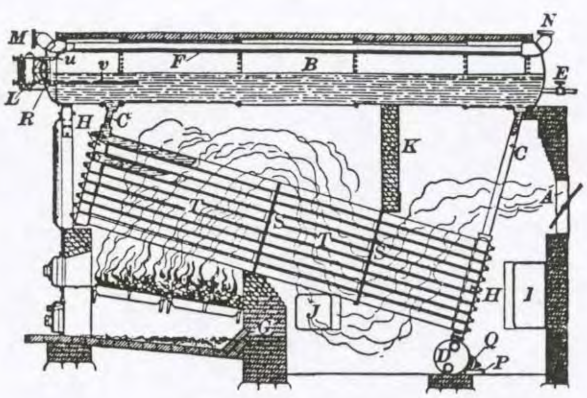


Figure 4.23 Water tube boilers consisted of a tank and water tubes suspended from a steel girder framework encased by a brick setting. Water tube boilers functioned in a manner opposite to the workings of return tube boilers. The flue gases swirled around tubes filled with water, rather than the other way around. Water tube boilers saw application in the West beginning in the 1890s, and their high cost, high maintenance, and great efficiency relegated them to productive and well-capitalized mining companies. Interior brick baffles kept the flue gases in close contact with the water tubes. The unit illustrated is a Babcock & Wilcox boiler. International Textbook Company, 1899 A18 p36.

Headframes

Nearly all mechanical hoisting systems in the West required that the mining operation erect a headframe over the shaft. The purpose of the headframe was to support and guide the hoist cable into the workings, and to assist in the transfer of rock from and supplies into the hoisting vehicle. Professionally educated mining engineers recognized six basic structural forms of headframes, including the tripod and tetrapod used with horse whims, the two-post gallows, four and six-post derricks, and the A-frame.

The *two-post gallows* was one of the most common headframes erected throughout the West, and self-made and professionally educated engineers unanimously agreed that it was best for prospecting. The variety used by small operations usually consisted of two upright posts, a cap timber and another cross-member several feet below, and diagonal braces, all standing at most 25 feet high. The cap timber and lower cross-member featured brackets that held the sheave wheel in place. The gallows portion of the structure stood on one end of a timber foundation that crews built equal in length to the headframe's height. The diagonal backbraces extended from the posts down toward the hoist, where they were tied into the foundation footers. The foundation, made of parallel timbers held together with cross members, rested on the surface of the ground, and it straddled the shaft collar.

The four-post derrick erected for prospecting was similar in height, construction, and materials to two-post headframes, and it too stood on a timber foundation. The A-frame was based on the same design as the two-post gallows. The difference between the two types of structures was that the A-frame featured fore and aft diagonal braces to buttress the structure in both directions. A-frames were not erected directly over an inclined shaft, rather they were placed between the hoist and shaft so that the angle of the cable extending upward from the hoist equaled that extending down the incline shaft.

The common features shared by the above structures included a small size, simplicity, minimization of materials, ease of erection, and portability of materials. For comparison, a two-post gallows frame 20 feet high cost as little as $50 and a slightly larger structure cost $150, while a production-class A-frame cost $650, and a production-class four-post derrick headframe cost up to $900. [lix]

Sinking-class headframes had to withstand only a few basic stresses that the mining engineer had to consider. The three most significant forces consisted of the *live load*, created by the weight of a full hoist vehicle and cable, the *braking load*, which was a surge of force created when the hoistman quickly brought the vehicle to a halt in the shaft, and the *horizontal pull* of the hoist. To counter these forces, mining engineers had workers build their headframes of 8x8 timbers, and they installed diagonal backbraces to counter the pull of the hoist. Usually carpenters assembled the primary components with mortise-and-tennon joints, 1 inch diameter iron tie rods, and lag bolts. Professionally trained mining engineers specified that the diagonal backbraces were most effective when they bisected the angle of dead vertical and the angle formed by the hoist cable ascending to the top of the headframe. By tying the backbraces into the foundation between the shaft and hoist, engineers had determined that the total horizontal and vertical forces put on the headframe would have been equally distributed among both the vertical and the diagonal posts. When a mining engineer attempted to find the mathematically perfect location for a hoist after erecting a headframe at a prospect shaft, he merely had to measure the distance from the shaft collar to the diagonal brace, double the length, and built the hoist foundation. Most Western prospect operations followed this general guideline and arranged their hoisting systems accordingly, but a few poorly educated engineers strayed and gave the diagonal braces either too much or too little of an angle.[lx]

Unlike the simplicity of sinking-class headframes, production-class headframes were more complex, and designing them was an art. The mining engineer had to plan for a variety of significant stresses, consider the structure's multiple functions, and coordinate the structure with other hoisting system components. Western mining engineers have been criticized for overbuilding their headframes and hence wasting capital. However, the stresses mining engineers had to consider were many. They had to build a structure capable of withstanding vertical forces including an immense *dead load*, *live load*, and *braking load* generated when the hoistman brought to a halt the descent of heavy machines and supplies sent underground. Engineers had to calculate horizontal forces including the powerful pull of the hoist and *windshear*, which could not have been underestimated in the rugged West. Last, mining engineers had to plan for *racking* and *swaying* under loads, and *vibration*, and *shocks* to the structure.[lxi]

Building a headframe that could stand under the sum of the above forces was not enough for service at a producing mine. Mining engineers had to forecast how they thought the headframe would interacted with the mine's production goals, and how it would interface with the rest of the hoisting system. The depth of the shaft, the speed of the hoist, and the rail system at the mine directly influenced the height of the structure. Deep shafts served by fast hoists, such as direct-drive steam units, required a tall headframe, usually higher than 50 feet, to allow the hoistman plenty or room to stop the hoisting vehicle before it slammed into the sheave at top. Highly productive mining operations often utilized vertical space on their claims, which required multiple shaft landings. Some mines using skips as hoist vehicles had rock pockets built into the headframe, and this also required height. The headframe had to be tall enough to permit the hoistman to raise a skip to a point well above the rock pocket where a special guide track upset the vehicle, emptying the rock into the bin.

Both self-educated and professionally trained engineers had the skills to erect structures that proved lasting and functional under the conditions of Western mining, but perhaps the headframes built by professionally trained engineers possessed the greatest economical value and grace. Mining engineers found four basic designs adequate for meeting the rigors of heavy ore production. These included the *four-post derrick*, the *six-post derrick*, an *A-frame* known also as the *California frame*, and a heavily-braced two-post structure known also as the *Montana type*. As the names suggest, engineers working in specific regions in the West favored certain headframe designs over others. While the above structures were intended to serve vertical shafts, two-post gallows headframes and a variety of A-frame up to 35 feet high were also erected to serve inclined shafts.[lxii]

To meet the combination of horizontal and vertical forces and the performance needs endemic to ore-producing mines, nearly all mining engineers in the West built their headframes with heavy timber beams assembled with mortise-and-tennon joints, timber bolts, and iron tie rods. In general they used 10x10 posts for headframes up to around 40 feet high, 12x12 to 18x18 stock for headframes up to 60 feet high, and up to 12x24 timbers for large two-post headframes. Mining engineers attempted to allocate full-length uncut timbers for the posts and backbraces because of the solidity they offered. Skilled carpenters assembled the materials into towers that featured cross-members and diagonal bracing spaced every 6 to 10 feet. Solid, relatively clear 16x16 inch timbers 60 to 70 feet long are almost unimaginable commodities today, yet these were the standard materials mining engineers and their crews worked with. All four and six-post headframes featured stout backbracing anchored between the shaft and the hoist, and the entire structure stood on foundation footers straddling the shaft. The posts on A-frames, on the other hand, were set at an exaggerated batter, meaning they splayed out to absorb all of the vertical and horizontal stresses, and as a result A-frames used in association with both vertical shafts and inclines rarely had backbraces. Four and six-post headframes were much more common in the West than A-frames, even though they were more materials-intensive and costly to build, because these vertical structures were within the technical means of most professionally educated and self-taught engineers. A-frames, on the other hand, required a greater knowledge of mechanics and physics, and they were harder to build.[lxiii]

Mining engineers determined that production-class headframes, which weighed dozens of tons, required a sound and substantial foundation in order to remain stable. A pre-planned and well-built foundation was one factor that set these structures apart from sinking-class headframes. When an engineer erected a production-class surface plant from scratch he simply put a crew to work clearing soil to bedrock around the proposed shaft, on which the crew built a timber framework for the headframe. The engineer who inherited a semi-developed prospect shaft had significant and expensive work ahead of him, because the previous operation may have left a large, unconsolidated waste rock dump that workers had to clear away to expose bedrock.

Professionally educated and self-made engineers used one of three basic types of foundations to support production-class headframes. The first consisted of a squat timber cube featuring bottom sills, timber posts, and caps bolted over the posts. Construction workers stuffed logs, timber blocks, and boulders under the bottom sills to level them when the foundation was built on sloped ground. The other types of foundations included a group of hewn log cribbing cells assembled with saddle notches and fastened with forged iron spikes, and a hewn log or timber latticework consisting of open cubes between 4 and 6 feet high, capped with dimension timbers. When

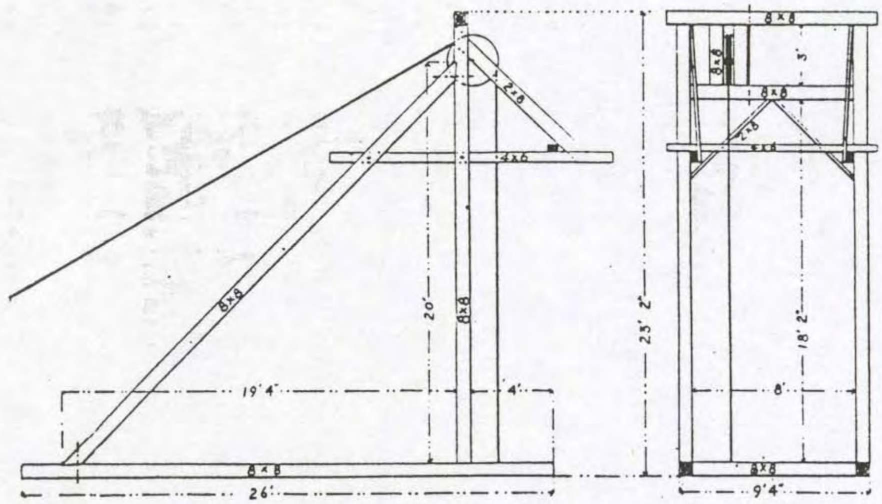


Figure 4.24 Two-post gallows headframes were ubiquitous across the West and were favored by prospect operations because of their relative ease of erection and light use of materials, which translated into low costs. A horizontal beam is visible in the profile near the headframe's top, which held the dumping chain for emptying ore buckets. Forsyth, Alexander, 1903.

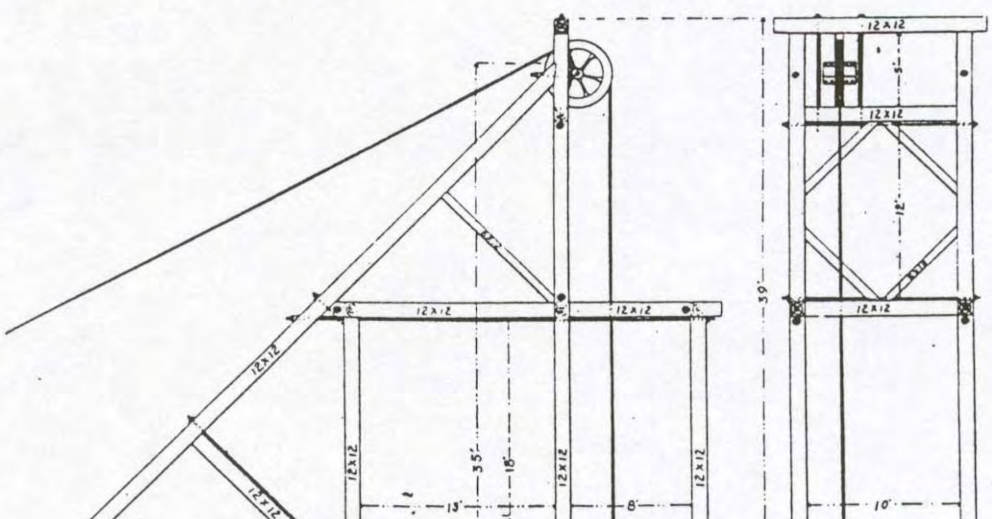


Figure 4.25 The illustration depicts a large two-post gallows headframe erected for deep shaft sinking. This structure and the above headframe lack guide rails for cages or skips, indicating the mining companies used ore buckets. Forsyth, Alexander, 1903.

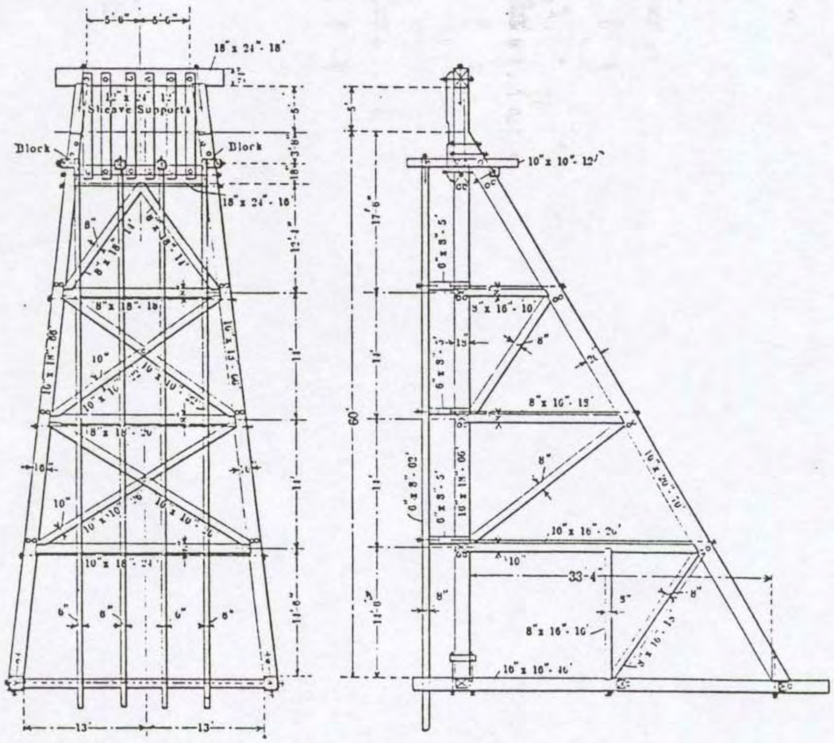


Figure 4.26 The Montana type headframe can be described as a large version of the two-post gallows headframe. The structure illustrated belonged to the Goldfield Consolidated Mines Company in Goldfield, Nevada, and it stood 55 feet tall. The Montana design, which incorporated less timber than other forms of headframes, was well-suited for productive mines in remote districts where the cost of materials was high. Barbour, Percy E., 1911.

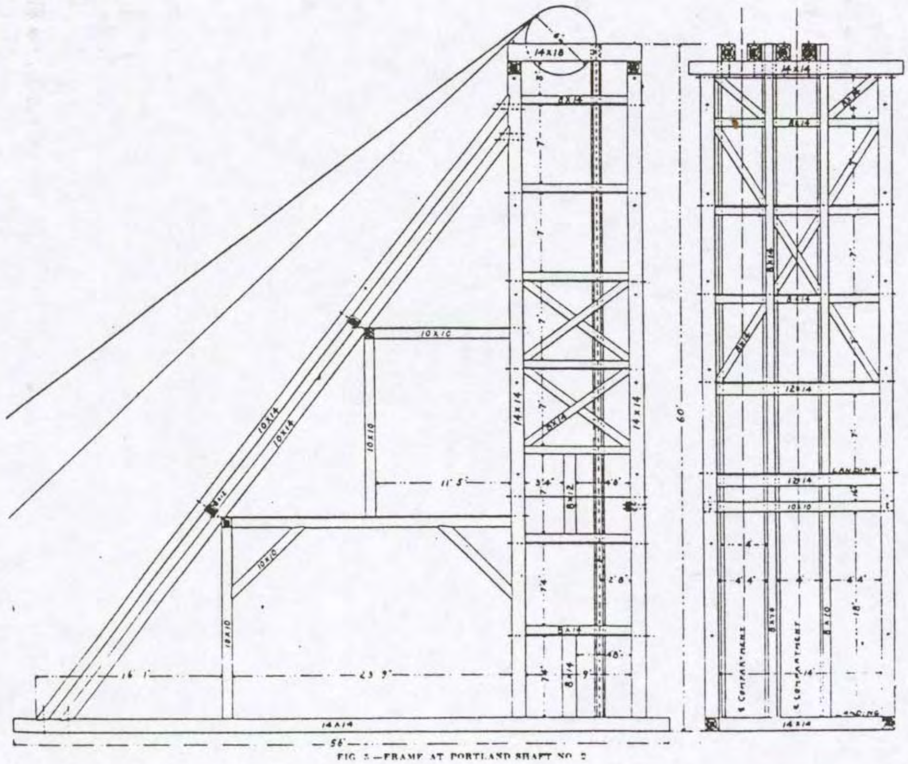


Figure 4.27 The line drawing depicts a classic production-class four-post derrick headframe. The structure stands 60 feet high, it is well-braced, and features two sets of sheave wheels and guide rails for balanced hoisting. The headframe belongs to the Portland Shaft and can still be seen looming over Victor, Colorado. Forsyth, Alexander, 1903.

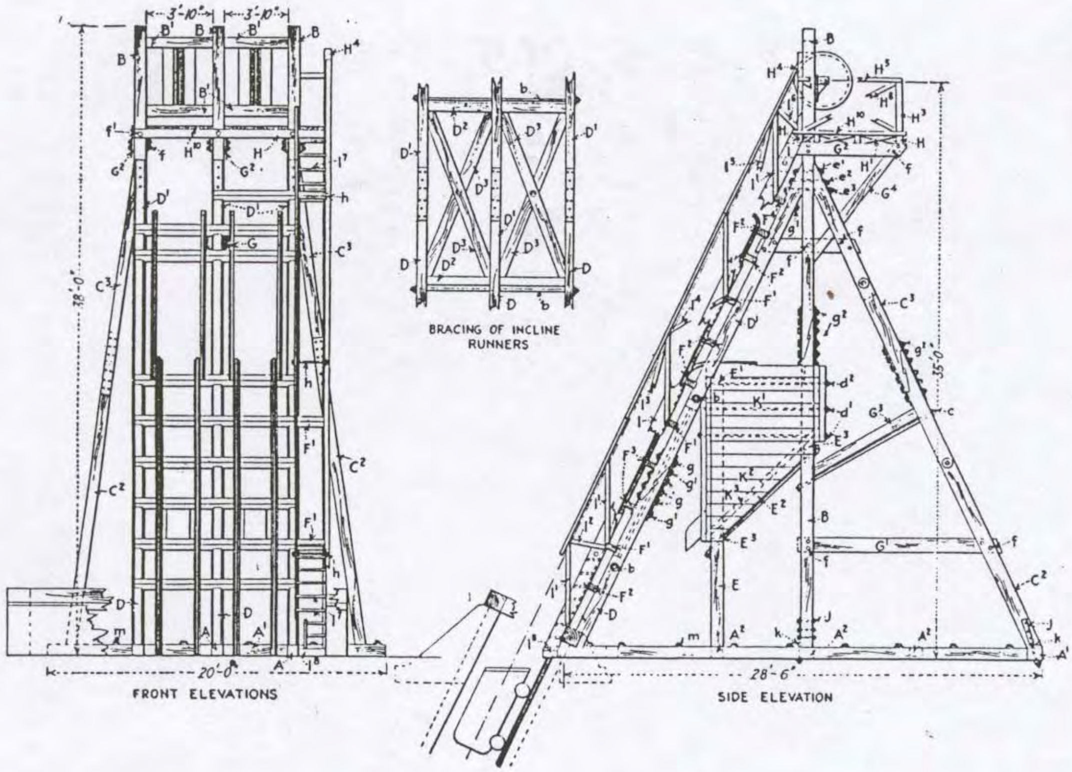


Figure 4.28 Mining engineers favored erecting A-frames for inclined shafts. Because inclined shafts were favorable to the use of a skip, A-frames often featured rock pockets to accept the loads disgorged by the skips when emptied. *E&MJ* 5/30/14.

Table 4.4: Specifications of Headframes: *Type, Material, Class*

Headframe Type	Material	Class	Capital Investment
Tripod	Hewn Logs	Sinking	Very Low
Tripod	Light Timber	Sinking	Very Low
Two Post (Gallows Frame): Small	Timber	Sinking	Low
Two Post (Gallows Frame): Large	Timber	Production	Low to Moderate
Two Post (Gallows Frame): Large	Steel	Production	Moderate to High
Four Post: Small	Light Timber	Sinking	Low
Four Post	Timber	Production	Moderate
Six Post	Timber	Production	Moderate to High
Four and Six Post	Steel	Production	High
A-Frame	Timber	Production	Moderate to High
A-Frame	Steel	Production	High

(Copied from Twitty, 1999, p281).

any of the three foundation systems were built, workers sided the shaft walls with plank lagging and shaft-set timbering, and filled the surrounding foundation framework with waste rock as quickly as the miners underground generated it. The last two above-mentioned foundation systems were the most popular in the West because many mining districts featured the raw materials, and they required little exact engineering. The problem with all of the above systems was that the perishable wood rotted when covered with waste rock, especially when the rock was highly mineralized. A few forward-thinking mining engineers attempted to substitute concrete for wood to gain a lasting foundation, but only well-financed companies anticipating lengthy operation spent the time and money to erect such foundations.[lxiv]

In the 1890s professionally trained mining engineers working for the West's wealthiest and largest mining companies began experimenting with steel girders for headframes as an alternative to timber. In the eyes of many prominent professionally educated mining engineers, steel was the ultimate building material for production-class operations because it did not decay, it was much stronger, it was non flammable, and it facilitated the erection of taller headframes. However, steel was significantly more expensive than timber, especially in the West where the distances from steel manufacturing centers was vast. As a result, only the most heavily capitalized and highly productive mines in the West put up steel structures

Like mining operations active during the Gilded Age, hoisting systems used by Depression-era mining companies required a headframe to guide the hoist cable into the shaft and to facilitate materials handling. Some mining outfits rehabilitating abandoned mines were blessed to find that the headframe put up by the previous operation still stood in good repair. In the arid West some fortunate mining companies rehabilitating old mines merely had to have few mine laborers examine the structure for integrity, oil the sheave bearings, and ensure that the signal bell functioned.

Much to the dismay of many Depression-era mining operations rehabilitating abandoned shafts, the headframe had been removed, which they had to replace. Erecting a new structure proved to be much less of a burden for well-funded mining companies than it did for shoestring outfits. Large mining companies, under the guidance of a formally trained engineer, continued the practice of building four and six post derricks and A-frames to meet the rigors of ore production. Mining engineers still considered steel to be the ultimate answer for production-class headframes, although out of financial necessity in many cases they had to resort to timbers. Still, the structures they put up were well-built and handsome. Yet, it seems that a certain element of quality in construction typical of mining prior to the 1910s had been lost. Construction crews no longer took the pains to assemble the structure with intricate mortise-and-tennon joints. Instead, the workers simply butted the timbers against each other, or created shallow square notch joints, and bolted the frame together.

Impoverished outfits had neither the funding nor the means to build substantial production-class headframes. Instead they assembled small structures designed to be functional while incorporating little material. When possible these small mining operations relocated entire headframes from abandoned mines to the property they sought to rehabilitate. By nature the headframes they either built or relocated tended to be the old-fashioned sinking-class two-post gallows type because they were simple, inexpensive, and required no formal engineering. In a few cases these small mining companies built what amounted to small four-post derricks of the sort that academically trained engineers would have classified as conforming to sinking duty. Poorly funded and well-capitalized mining companies both installed timber A-frames to serve inclined shafts.

One factor that many mining companies shared, rich and poor, was the utilization of salvaged timbers for building their headframes. Stout timbers were a precious and costly commodity during the Great Depression, and in hopes of saving capital mining companies reused the heavy beams left by abandoned operations. As a result, today's visitor examining headframes built during the 1930s may note that some of the timbers seem out of place in the context of the overall structure. Salvaged timbers may differ in terms of exact dimensions, weathering, and quality of the wood. In addition, they frequently exhibit abandoned mortise-and-tennon joint sockets, old bolt-holes, and nail holes. Heavy use of such material for use in headframes, as well as for other structures, is fairly typical of Depression-era construction.

During the last several decades of the Gilded Age, professionally educated mining engineers at a few productive mines began to use skips as the principle hoisting vehicle in vertical shafts, instead of the ubiquitous cage and ore car used during the Gilded Age. Skips were nothing new by 1930, having been used in previous decades for extracting ore and waste rock from the depths of inclined shafts. As mining engineers sought ways of increasing ore production over less time while consuming less energy, they came to realize that the skip provided great economy. Because the vehicle consisted of a boilerplate iron box, it had the capacity to contain more rock for less dead-weight that the combination of an ore car on a traditional cage. In addition, the skip's open top facilitated rapid loading from an ore chute underground and equally rapid disgorging of its contents once the hoistman had brought it up to daylight. The rapid filling and emptying of the skip increased the tonnage of rock brought out of the mine during a given shift.

The use of a skip was in some ways much easier and safer than relying on a cage. Miners riding up and down the shaft in an enclosed skip were much less likely to snag their arms and legs and suffer dismemberment in the mine timbering, as had happened with cages. When raising rock, the hoistman lowered the skip down the shaft to a station where he stopped it at the mouth of an ore chute. A chute tender or trammer opened the chute gates and let the ore pour forth, then rang the signal bell to communicate that all was ready for the trip up to the surface. The hoistman slowed the ascent of the skip as it approached the shaft collar and he raised the vehicle into the headframe. Typical skips consisted of an iron box held by heavy steel hinges in an iron frame that embraced the shaft's guide rails. The box featured small iron wheels or iron pins fixed to the sides. As the hoistman raised the skip into the headframe the wheels entered a special set of curved iron guides bolted onto the headframe. The guides forced the box to pivot until it reached a point of instability and tipped over, spilling its contents. The hoistman reversed the action and the box's wheels were dragged back through the guides, righting the hoisting vehicle.

Not only did the employment of the skip require miners to drill and blast rock pockets for ore and waste rock at shaft stations underground, but the mining engineer had to retrofit the headframe on the surface with a rock pocket to accept the skip's load when dumped. In mines simultaneously experiencing underground development and ore production, the engineer had to arrange for two rock pockets, one to catch waste rock and the other for ore. To avoid compromising the headframe's integrity and stability, engineers commonly designed rock pockets that consisted of a sloped floor built onto an adjacent and independent timber frame. The engineer had to build the pocket high enough so that the rock it contained could tumble through a chute into an ore car below.

The alterations mining engineers customarily made to headframes for use with a skip may be apparent to visitors examining the remains of yesteryear's historic mine sites. When a Depression-era mining company retrofitted a headframe with a rock pocket, they were rarely able to match the hue, grain, and cut of the headframe's original timbers, which today manifest as a visible contrast. Out of financial motivation many Depression-era mining companies constructed rock pockets with hewn or raw logs, salvaged lumber, and corrugated sheet steel which typically exhibits old nail and bolt-holes. Further, elegantly built heavy timber-work seemed not to have been the forte of many construction workers rehabilitating old mines during the Depression, and this manifests today as a notable disparity between the well-built heavy beam work of the headframe and a modestly constructed rock pocket.

Additional Surface Plant Components

Air Compressors

Blasting was of supreme importance to mining because it was the prime mover of rock underground. During the Gilded Age miners throughout the West traditionally drilled holes by hand, loaded them with explosives, and fired the rounds. Hand-drilling proved slow, but no practical alternative existed to take its place underground until mining companies began introducing mechanical rockdrills during the 1870s and 1880s. When drilling by hand, miners typically advanced tunnels and shafts only one to three feet per shift in hard rock. Using the types of drills manufactured during the 1880s and 1890s, miners were able to advance a tunnel or shaft approximately three to seven feet per shift, instead. The mechanical drills permitted miners to bore greater numbers of deeper holes in the same length of time. Further, improvements in drilling technology effected during the 1890s and 1900s permitted miners to make even greater progress. The rates of work achieved with the greasy and noisy machines convinced many mining engineers that the relatively high costs of installing and running a compressed air system to power the mechanical rockdrills was justified. The air compressor lay at the heart of the compressed air system.[lxv]

While air compressors manufactured between the 1880s and 1920s came in a variety of shapes and sizes, they all operated according to a single basic premise. Compressors of this era consisted of at least one relatively large cylinder, much like a steam engine, which pushed air through valves into plumbing connected to an air receiving tank. The volume of air that a compressor delivered, measured as *cubic feet of air per minute* (cfm), depended on the cylinder's diameter and stroke, as well as how fast the machine operated. The pressure capacity, measured as *pounds per square inch* (psi), depended in part on the above qualities as well as how stout the machine was, its driving mechanism, and on the check valves in the plumbing. Generally, high pressure-high volume compressors were large, strong, durable, complex, and as a result, expensive.

The mechanical workings of the air compressors manufactured prior to around 1890 were relatively simple. The two most popular compressor types manufactured during this time were the *steam-driven straight-line* and the *steam-driven duplex* models, and both styles served as a basis for designs that served the mining industry well for over 60 years. The straight-line compressor, named after its physical configuration, was the least expensive, oldest, and most elemental of the two types of machines. Straight-line compressors were structurally based on the old-fashioned horizontal steam engine, the workhorse of the Industrial Revolution. A mechanical engineer in the eastern states created the straight-line compressor in the 1860s, and machinery manufacturers such as the Clayton Air Compressor Works began making the revolutionary machines by the early 1870s. The earliest compressors were no more than a compression cylinder grafted onto the end of a factory-made steam engine, and the compression piston had been coupled directly to the steam piston via a solid shaft. By the early 1880s when large mining companies throughout the West were beginning to experiment with rockdrills, field-worthy straight-line compressors had taken form. These machines featured a large compression cylinder at one end, a heavy cast iron flywheel at the opposite end, and a steam cylinder situated in the middle, all bolted to a cast iron bedplate. The steam cylinder powered the machine and the flywheel provided momentum and smoothed out the motion.[lxvi]

During the 1870s and early 1880s, before mining began at Creede, mechanical engineers ironed out many of the inefficiencies attributed to straight-line compressors. First, engineers modified the compression cylinder to make it double-acting, much like an old-fashioned butter churn. In this design, which became standard, the compression piston was at work in both directions of travel, being pushed one way by the steam piston and dragged back the other way by the spinning flywheel. In so doing the compression piston devoted 100% of its motion to compressing air.

The other fundamental achievement attained by engineers during the 1880s concerned cooling. By nature air compression generated great heat, which engineers found not only fatigued the machine but also greatly reduced efficiency. As a result early compressor makers added a water-misting jet that squirted a spray into the compression cylinder, cooling the air and the machine's working parts. While the water spray solved the cooling issue, it created other significant problems. The water caused corrosion, it washed lubricants off internal working parts, and it humidified the compressed air, all of which significantly shortened the life of what constituted an expensive system. By the mid-1880s American mining machinery makers had replaced the spray with a cooling jacket consisting of one large void or multiple ports for the circulation of cold water around the outside of the compression cylinder, leaving the internal working parts dry and well-oiled. Mining companies installing compressors amid their surface plants had to include a water system for cooling and they had to allocate a water source. Generally the system erected by engineers was no more that a water tank connected to the compressor through input output lines consisting of one to one-half inch piping.[lxvii]

During the early 1880s mechanical engineers forwarded several other significant improvements in the workings of compressors, creating a foundation for further evolution of the technology. Engineers found that coupling the compression piston to the steam piston with a solid rod, so that both acted in perfect synchronous tandem, proved highly inefficient. The steam piston was at its maximum pushing power when it was just beginning its stroke, while the compression piston, also beginning its stroke, offered the least resistance. When the steam piston had expended its energy and reached the end of its stroke, the compression piston offered the greatest resistance because the air in the cylinder had reached maximum compaction. Mechanical engineers recognized this wasteful imbalance and designed a breed of straight-line compressor with an intermediary crankshaft, so that when the compression piston had reached the end of its stroke and offered the most resistance, the steam piston was beginning its movement and was strongest. Despite the superior efficiency of this design, mining companies usually selected the simpler compressors with solid shafting.

During the late 1880s and early 1890s academic mining engineers fine-tuned compressed air technology used for hardrock mining. During this time they applied cost-benefit analyses and science to further improvements that remained with the mining industry for decades. The most significant advance was the design of compressors that generated greater air pressure than had been used by the mining industry up to that point. Mining engineers found that they wanted more pressure because it made their drills run faster, enabling miners to bore through more rock than before. Engineers had also found by experience that the pressurization of the maze-like networks of plumbing in large mines placed a heavy burden on compressors. In response, mining machinery makers began offering straight-line and duplex compressors capable of achieving what the industry termed *multistage compression*.

Mechanical engineers found that attempting to squeeze more pressure out of the conventional 1880s straight-line and duplex compressors required an uneconomical amount of power and energy. Instead, they realized that they could achieve the pressure demanded by mining engineers if they divided the compression between high and low pressure cylinders in several *stages*, instead of in a single cylinder. They designed the low-pressure cylinder to be relatively large, and it forced semi-compressed air into the small high-pressure cylinder, which highly compressed the air and released it into a receiving tank. Compounding the air compression between several cylinders generated heat which threatened the efficiency that engineers hoped to achieve with their marvelous machines. Like the simpler single stage compressors, engineers designed effective cooling apparatuses for the added cylinders, and they also found that chilling the compressed air between stages significantly improved efficiency. The air rarely passed directly from one compression cylinder to the next. Rather, the air exited the machine altogether and passed through an *intercooler*, which essentially was a heat exchanger cooled by circulating water, and then it entered the high-compression cylinder.

Mining machinery makers released variations of multistage straight-line compressors with two and even three compression cylinders coupled onto the steam drive piston, and they produced duplex compressors with several multistage cylinder arrangements. The most common multistage duplex compressor was the *cross-compound* arrangement, in which one side of the machine featured the low-pressure cylinder, and the air passed from it, through an intercooler, to the high-pressure cylinder on the other side. For mines with heavy air needs mining machinery manufacturers offered a duplex machine with high and low pressure cylinders on both sides, which produced twice the volume of high-pressure air.

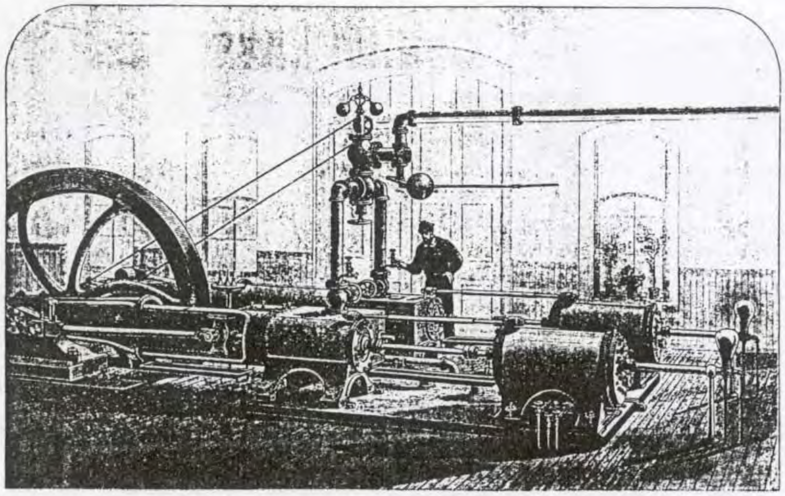


Figure 4.29 During the 1880s and 1890s only well-financed mining companies wishing to power numerous rockdrills spent the lavish sums of money to install massive duplex compressors such as the unit illustrated. Each compression cylinder (on the right), each steam cylinder, and the flywheel bearings bolted onto individual masonry pylons underneath the plank flooring. Note the potted plants on the right windowsill. Rand Drill Company, 1886 p20.

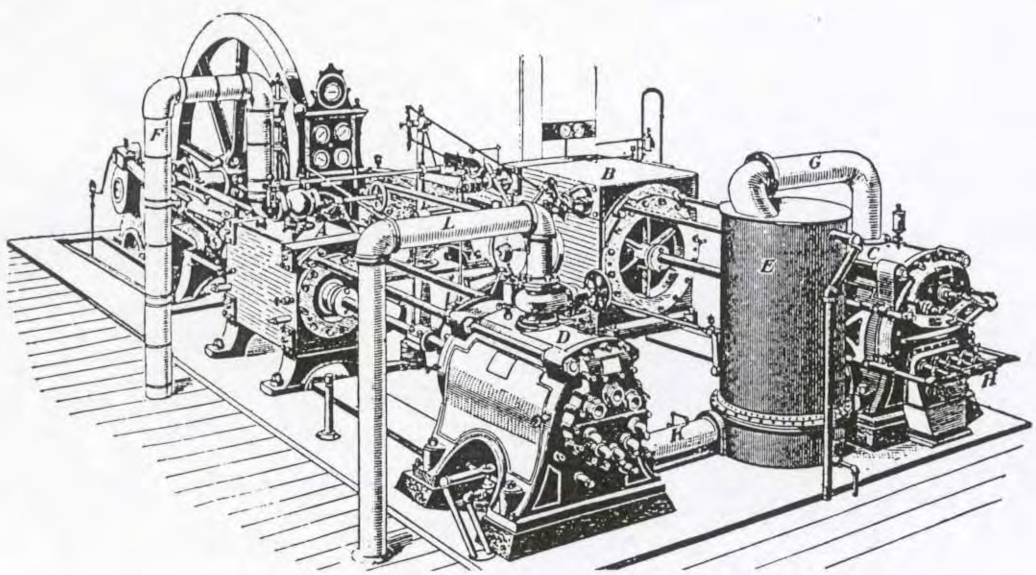


Figure 4.30 Mining engineers realized that multi-stage compression was best for fulfilling the high-volume and high-pressure needs of expansive mines. The machines were large, the costs of purchasing and installing them were exorbitant, and they were not easily shipped into the backcountry. While the illustration depicts a multi-stage duplex unit, many mining companies favored multi-stage straight-line compressors. Multi-stage compressors can be identified by the asymmetry of the compression cylinders *C* and *D*, and the mandatory intercooler *E* between the cylinders. Compound steam cylinders *A* and *B* equipped with corliss valves, the most efficient type of engine the Industrial Revolution offered, drove the machine. International Textbook Company, 1899 A20 p34.

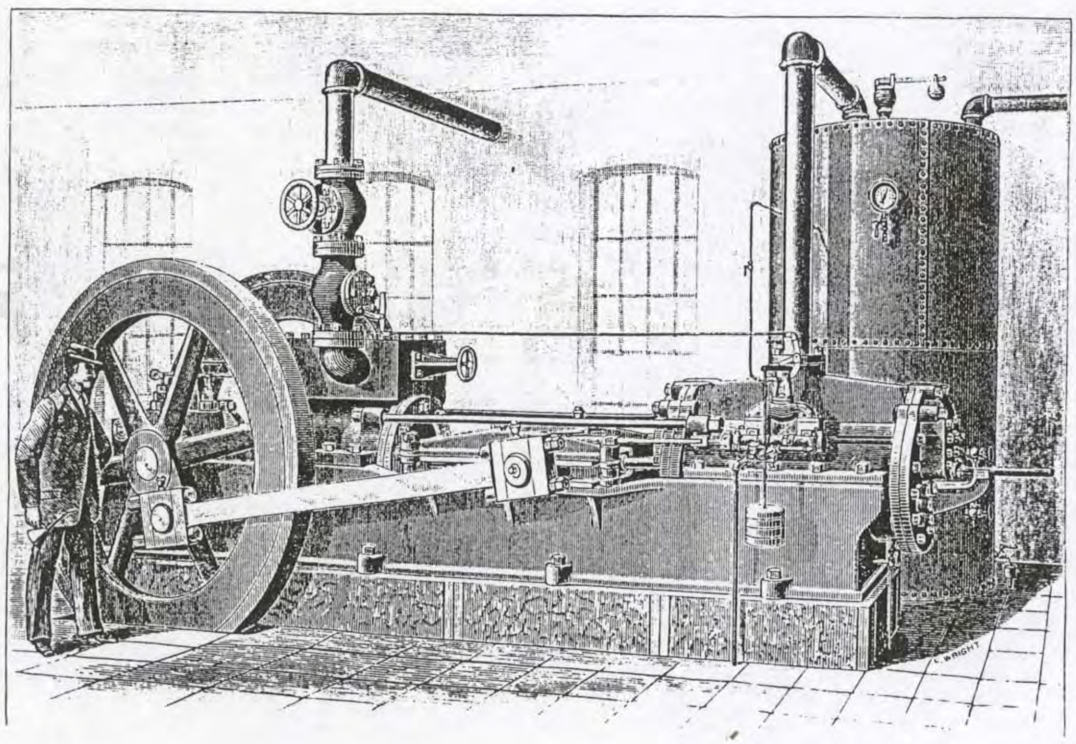


Figure 4.31 An attendant stands ready with an oil cadger as he watches the action of a straight-line compressor in a compressor house. The illustration captures a complete compressed air system, including the steam line extending down to the compressor's steam cylinder, the air line connecting the compression cylinder to the receiving tank, the line extending away from the top of the tank, and the coolant line descending from the compression cylinder. Note the pressure gauge and blow-off valve on the receiving tank. Ingersoll Rock Drill Company, [1887] p30.

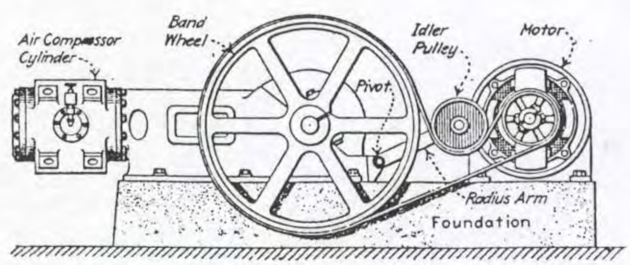


Figure 4.32 Profile of a small belt-driven straight-line compressor. Using a belt was the most popular means in the West for transferring the power from the motor to the compressor. Mining engineers applied the same technology for powering the small duplex compressors shown in previous illustrations. Croft, Terrell, 1923 p398.

Table 4.5: Air Compressor Specifications: ***Type, Duty, Foundation***

Compressor Form	Power Source	Compressor Duty	Foundation Footprint	Foundation Size	Foundation Material
Upright with 2 Cylinders	Belt-Driven: Petroleum Engine	Temporary	Rectangular Foundations	6x2 ft.	Timber Frame
Upright: 3-4 Cylinders	Integral Petroleum Engine	Temporary & Production	Rectangular	7x3 ft to 12x4 ft.	Timber or Steel Frame
V-Pattern: 2-3 Cylinders	Integral Petroleum Engine	Production	Rectangular	6x3 ft. to 8x3 ft.	Concrete
V-Pattern: 4-8 Cylinders	Integral Petroleum Engine	Production	Rectangular	8x3 ft. to 12x3 ft.	Concrete
Straight-Line Gasoline	Integral Petroleum Engine	Temporary	Rectangular	5x2 ft. to 7x2 ft.	Concrete
Straight-Line Single Stage	Integral Steam Engine	Temporary	Rectangular	6x2 ft. to 7x2 ft.	Timber, Concrete or Masonry
Straight-Line: Single Stage	Integral Steam Engine	Production	Rectangular	9x3 ft to 15x3 ft.	Concrete or Masonry
Straight-Line: Two Stage	Integral Steam Engine	Production	Rectangular, or Shallow L	14x4 ft to 27x6 ft.	Concrete or Masonry
Straight-Line: Three Stage	Integral Steam Engine	Production	Rectangular, or Shallow L	16x5 ft. to 30x6 ft.	Concrete or Masonry
Straight-Line	Geared Electric	Production	Rectangular, extension for motor.	9x3 ft to 15x5 ft. Motor: 2x3 ft.	Concrete
Straight-Line	Belt Driven	Production	Rectangular with aligned motor mount	7x2 ft to 15x5 ft. Motor: 2x3 ft.	Concrete
Duplex: Single Stage	Integral Steam Engine	Production	U-Shaped	6x5 ft. to 10x9 ft.	Concrete or Masonry
Duplex,: Single Stage	Integral Steam Engine	Production	Parallel Rectangular Pads	10x7 ft. to 30x10 ft.	Concrete or Masonry
Duplex: Two Stage	Integral Steam Engine	Production	U-Shape	6x5 ft. to 15x15 ft	Concrete or Masonry
Duplex: Two Stage	Integral Steam Engine	Production	Parallel Rectangular Pads.	15x10 ft. to 35x15 ft.	Concrete or Masonry
Duplex: Multi Stage	Geared Electric	Production	U with aligned motor mount	6x5 ft. to 16x15 ft.	Concrete
Duplex: Multi Stage	Belt Driven Electric	Production	U with aligned motor mount	6x5 ft. to 16x15 ft.	Concrete

(Adapted from Twitty, 1999, p131).

After installing straight-line and duplex compound machines at large Western mines in the 1890s technically trained mining engineers found that multistage compression was by far most economical. Further, they determined through both empirical studies and calculation that single stage compression was most economical in the short run and long term for air pressures up to around 90 psi, two-stage compression was best for between 80 and 500 psi, and three-stage compression was most economical for 500 to 1000 psi. Four-stage compression existed, but Western mining companies almost never used it.[lxviii]

During the 1880s most major compressor makers such as the Rand Drill Company and the Ingersoll Rock Drill Company offered single stage compressors designed to be powered by canvas or leather belting, instead of by an integral steam engine. These machines were made for mining companies that relied on a single large steam engine to drive multiple surface plant components and mill machines simultaneously. Western mining companies rarely used a central power source, however. As a result belt-driven compressors were a rarity in the West during the 1880s and 1890s.

The titanic steam-driven compressors that once made engineers swell with pride fell out of favor with the mining industry during the late 1890s, because smaller and faster models became available. While the small compressors of turn-of-the-century vintage were not able to generate as much air as their huge cousins, their higher working speeds did grant them a substantial output. By around 1900 many of America's leading mining machinery makers offered a variety of improved steam-driven duplex compressors less than 15 by 15 feet in area fitted to suit with a variety of single, double, and triple stage compression cylinders.

Table 4.6: Air Compressor Specifications: ***Type, Popularity Timeframe, and Capital Investment***

Compressor Type	Age Range	Capital Investment
Upright: 2 Cylinders, Belt Driven	1900s-1940s	Low
Upright: 3 to 4 Cylinders, Integral Gasoline Piston	1930s-Present	Moderate
V Pattern	1930s-Present	Moderate to High
Straight-Line, Single Stage, Gasoline Engine Driven	1900s-1930s	Low
Straight-Line, Single Stage, Steam Driven	1880s-1920s	Moderate
Straight-Line, Two Stage, Steam Driven	1890s-1920s	High
Straight-Line, Triple Stage, Steam Driven	1890s-1920s	Very High
Straight-Line, Single Stage, Geared to Electric Motor	1900s-1920s	Moderate
Straight-Line, Various Stages, Geared to Electric Motor	1900s-1920s	High
Straight-Line, Single Stage, Belt Driven by Electric Motor	1900s-1940s	Low
Duplex, Single Stage, Steam Driven	1890s-1920s	Moderate
Duplex, Two Stage, Steam Driven	1890s-1920s	High
Duplex, Triple Stage, Steam Driven	1890s-1920s	Very High
Duplex, Two Stage, Belt Driven	1900s-1940s	Moderate
Duplex, Three Stage, Belt Driven	1900s-1940s	Moderate to High

(Adapted from Twitty, 1999, p130).

As the 1890s progressed toward the turn-of-the-century, mining machinery makers began to offer air compressors that were smaller, more efficient, and provided better service for the dollar than the duplex and straight-line designs manufactured up to that time. Machinery makers adapted several designs to be run by electric motors and gasoline engines, which were energy sources well-suited for remote mines. Progressive mining engineers working in regions where fuel was costly eagerly experimented with electricity and gasoline, while mining companies in areas where coal and cord wood were more plentiful continued to install steam compressors as late as the 1910s. Gasoline and electric compressors underwent a process of acceptance, rather than being embraced overnight, but once they had proven their worth by the 1910s, many mining companies throughout the West replaced their aging steam equipment with electric and petroleum-powered machinery.

Motor-driven compressors were ideally suited for progressive mining districts wired for electricity, such as

Creede. Further, because motor-driven compressors lacked steam equipment and needed no boilers, they cost less. The motor-driven compressors offered by machinery manufacturers around the turn-of-the-century were a take-off of the old belt-driven types they had make since the early 1880s. The new units were designed to run at the high speeds associated with electric motors. By the late 1890s mining machinery makers offered three basic types of electric compressors, including a straight-line machine that was approximately the same size as traditional steam versions, a small straight-line unit, and a duplex compressor. Duplex models, conducive to multistage compression, were most popular among medium-sized and large mining companies. Small mining operations favored the small straight-line units. Due to limited air output compared with a relatively large floor space, the large electric straight-line compressors never saw popularity.

Mining machinery manufacturers offered their electric compressors with five basic means of coupling to motors. The first method was a belt-drive, the second was direct-drive in which the motor was integral with the flywheel, third was a gear-drive, fourth was a chain-drive, and the fifth consisted of a rope drive. Western mining outfits by far favored the belt-drive because it was a widely understood technology, it was the least expensive, and it was easiest to install. Gearing and direct-drive compressors were more energy efficient and quieter, but they were unpopular because of their high cost. Gearing also permitted one powerful motor to drive several duplex compressors through one main drive shaft. The motor turned the drive shaft through gearing. The drive shaft rotated in heavy bearings that were bolted onto each compressor foundation, and the shaft featured additional gears that turned the compressors' flywheels. Rope and chain drives were very unpopular for compressors, and had little to recommend them.

Compressor makers also developed economically attractive gasoline units ideal for remote and inaccessible operations. The gasoline compressor, introduced in practical form in the late 1890s, consisted of a straight-line compression cylinder linked to a single cylinder gas engine. Most mining engineers considered gas compressors to be for sinking duty only. Large gasoline machines were capable of producing up to 300 cubic feet of air at 90 pounds per square inch, permitted mining companies to run up to four small rockdrills.[lxix]

The noisy gasoline machines had needs similar to their steam-driven cousins. Gasoline compressors required cooling, a fuel source, and a substantial foundation, and they came from the factory either assembled or in large components for transportation into the backcountry. The cooling system often consisted of no more than a continuous-flow water tank, and the fuel system could have been simply a large sheet iron fuel tank connected to the engine by ¼ to ½ inch metal tubing. Most mining engineers agreed that petroleum compressors required substantial concrete foundations due to severe vibrations. Generally, engineers had laborers pour a rectangular foundation slightly longer and wider than the machine, and up to 3 feet high. In a few instances small, poorly funded mining companies bolted the machines to impermanent timber cribbing foundations conforming to sinking-duty characteristics.

The types of compressors developed around the turn-of-the-century possessed footprints as distinct as the early steam-driven models discussed above. The high-speed duplex models, whether steam or motor-driven, usually stood on substantial U-shaped concrete foundations featuring totally flat surfaces. Unlike their massive steam-driven brethren, the small and faster duplex machines consisted of components both bolted to and cast as part of a large common bed plate that had to be anchored to the concrete foundation. The hollow portion of the U in the foundation accommodated the flywheel. Multistage duplex compressors featured additional cylinders and an intercooler that extended out beyond the foundation edges, while the bedplate remained the same as that used by single-stage units.

The distinguishing characteristic between both steam-powered straight-line and duplex compressors manufactured between the 1890s and 1910s and their belt-driven cousins was a detached rectangular motor mount featuring four small anchor bolts. Because the drive belt passed from the motor pinion to the compressor's flywheel, engineers had workers construct the motor mount between 6 and 18 feet away from the compressor and offset to accommodate the belt. The use of a drive-belt required a tension pulley, which was an adjustable roller that pressed down on the belt to keep it tight. The pulley was often bolted onto the compressor frame, and it was anchored to small timber foundations at floor level in association with large compressors. Direct-drive electric compressors tended to be large, and they required more width in the "U" portion of the foundation to accommodate the motor. Geared compressors featured mounts for the drive shaft bearings at the open end of the "U".

By the 1910s, the use of rockdrills had rendered hand-drilling uneconomical except for special applications. The trend continued through the 1920s as rockdrill makers offered an ever widening variety of machines that accomplished even the limited specialized work previously completed by hand-drilling. Mining during the Great Depression was no exception, and miners had come to rely on drills more than ever to achieve the necessary production of ore in economies of scale.

Motor-driven duplex and straight-line compressors, introduced in the waning years of the Gilded Age, maintained supremacy among Western mining operations through the 1930s. Well-financed mining companies requiring high volumes of air at high pressures continued to favor belt-driven duplex compressors, while companies with slightly reduced air needs, such as running at most six stoper or sinker drills, continued to use relatively inexpensive single-stage belt-drive straight-line compressors.

Despite the common reliance on older designs, compressed air technology had undergone dynamic changes since the close of the Gilded Age. Mechanical engineers began to experiment with unconventional designs beginning in the 1900s, and during the 1910s several of these models experienced commercial production. By the 1930s, a few Western mining companies with substantial capital became interested in installing some of the modern designs in hopes of maximizing efficiency.

The popularization of automobile engines had given rise to the invention of several alternative forms of compressors.

By the 1910s an *upright two-cylinder compressor* with valves and a crankshaft like an automobile engine had become popular. Used on an experimental basis as early as the 1900s by prospect operations, these units were inexpensive, adaptable to any form of power, and weighed little. Further, mining machinery makers had mounted them onto four-wheel trailers or simple wood frames for mobility. As a result, impoverished Western mining outfits embraced them because they required no engineering and were ready to use. During the 1930s Western mining companies hauled these two-cylinder units to mine sites where they bolted them to simple timber frames and coupled the drive shaft to salvaged automobile engines, single cylinder gas engines, or motors for power.

The *angle-compound compressor*, developed during the 1910s, was a major break-away from traditional Industrial Revolution compressor designs. The angle-compound machine consisted of two large compression cylinders oriented 90º from each other, one lying horizontal and the other extending upward vertically. The piston rods for both cylinders bolted onto a common crankshaft in an engine case, much like the piston arrangement for V8 and V6 automobile engines. A large belt pulley that also served as a flywheel turned the crankshaft. One of the cylinders had been designed for low-compression and the other for high compression, and the air passed through an intercooler between them.[lxx]

The operating principles behind the angle compound-compressor were the same as those for compound duplex compressors, and mining and mechanical engineers claimed that the new machines were by far more efficient when driven by an external source such as a motor. These innovative compressors were able to deliver a volume of air up to 900 cfm at high pressures for less energy and for less floor space than either duplex or straight-line units. Despite superior performance of angle-compound compressors, only a few Western mining companies experimented with them during the 1910s and 1920s because of the high purchase prices and the unconventionality of the design. These factors continued to suppress employment of angle-compound compressors into the 1930s, at a time when many mining outfits were forced to be fiscally conservative to maintain profitability. As a result angle compound compressor never saw great popularity in the West.

The last break-away from traditional compressor form employed during the Great Depression consisted of another design that mimicked the structure of the automobile engine. The Chicago Pneumatic Tool Company and Gardner-Denver both introduced compressors known in the mining industry as *V-cylinder compressors* and as *feather valve compressors*. The machines were virtual adaptations of large-displacement truck engines with between 3 and 8 compression cylinders arranged in a "V" configuration, and the pistons were coupled onto a heavy crankshaft. Further, the new designs no longer relied on circulating water from a storage tank for cooling. Instead they featured grossly enlarged radiators similar to the types auto-makers had been installing on the fronts of cars. The compressor makers designed the large machines to be powered by electric motors directly coupled onto the crankshaft. Small machines were belted to a motor. V-cylinder compressors frequently came from the factory mounted onto a heavy steel frame that the mining company bolted onto a concrete foundation.

The variety of new compressors sold by mining machinery makers were of little consequence to small operations, because they were economically forced to employ salvaged and used equipment. Impoverished companies combined any type of compressor they could get their hands on with a likely looking drive motor, creating odd, mismatched sets of machinery installed in a seemingly haphazard manner. Some poorly funded mining operations that worked old claims deep in the backcountry where electric power did not exist employed old-fashioned and inefficient straight-line gasoline compressors.

Like the defunct operations of decades past, when the Depression-era mining companies went broke and shut down, creditors, neighboring mines, and salvage crews dismantled and removed the serviceable portions of their air systems. Visitors to 1930s mine sites today will most likely encounter evidence of compressor systems in the form of foundations. Each of the types of compressors discussed above usually required foundations that conformed to specific footprints. The trait that they all shared, however, was that construction crews almost invariable used portland concrete during the 1930s.

The small upright two-cylinder compressors did not require substantial foundations. Instead, the small outfits that used them bolted the machines onto timber frames, or onto small timber foundations set in the ground. Usually the compressors required anchor bolts ½ to 1 inch in diameter set in a rectangular footprint approximately 2 by 3 feet. The drive motor or engine foundation had to be placed near by. Motor mounts were usually less than 1 by 1 feet in area while gas engine foundations were larger.

Angle-compound compressors were much larger and more complex than other compressors used at Western mines, and as a result their foundations were asymmetrical and presented uneven, stepped profiles. The foundations were often 10 by 8 feet in area and their footprints conformed to "L" and "T" shapes. The central portion of the foundation was typically elevated to provide clearance for the compressor's drive pulley/flywheel, and the surfaces of other portions were lower to anchor different parts of the machine. Angle-compound compressors required anchor bolts ranging from 1 to 2 inches in diameter. The foundation for the drive motor, ranging from 2 by 3 to 4 by 5 feet in area and studded with four anchor bolts, should be located within 12 feet and aligned with the compressor foundation. Like large straight-line compressors, high-capacity angle-compound units often featured an independent concrete pylon to support the heavy flywheel's outboard bearing.

V-cylinder compressors required a foundation that was unlike the footings for the compressors discussed above. Because the manufacturers bolted the V-cylinder's components onto a steel frame, mining engineers found that the new compressors required remarkably simple foundations that were easy and inexpensive to construct. Small V-cylinder compressors required concrete foundations that possessed a slightly rectangular footprint, and engineers usually specified that they be capped with timbers, which cushioned the vibrating machine. Mining engineers usually bolted the steel frame down onto the timber pads. The large compressor units required concrete foundations similar in shape to the footings associated with the antiquated straight-line steam compressors. Today's visitor to historic mine sites can identify the foundation for a large V-cylinder compressor by its composition of portland concrete, because the anchor bolts are typically less than 1 inch in diameter, and by its association with other circa 1930s surface plant features.

The visitor to today's mine sites will find that the foundations for the electric duplex and straight-line compressors, the most common types employed during the 1930s, are the same in form and footprint as the models used in the 1900s and 1910s. The foundations for duplex compressors continued to be U-shaped and the motor mounts for belt-driven units tend to be located a slight distance away. Straight-line compressors, on the other hand, stood on rectangular foundations up to 10 feet long and 2 feet wide, with the motor mount located up to six feet behind. Some well-capitalized Depression-era mining companies used large multi-stage belt-driven straight-line compressors. The remaining foundations often consist of a long and narrow portland concrete block broken into several individual pads for the compression cylinders, a concrete pylon that supported the large flywheel's outboard bearing, and a motor mount aligned with the pylon. The drive belt passed from the flywheel to the motor.

Electricity

Mining engineers working in the West began experimenting with electricity as early as 1881 when the fabulous Alice Mine & Mill in Butte, Montana attempted to illuminate its perpetually dim passages and buildings with Edison's new light bulbs. At that time electric technology was new and its practical application evaded not only mining engineers, but many industrial engineers as well. During the 1880s visionary inventors demonstrated that electricity was able to do work, which enticed mining engineers who dreamt of sending power to hoists, compressors, and pumps, and other machinery through slender wires rather than through cumbersome and expensive steam pipes.[lxxi]

During the late 1880s and into the 1890s mining engineers working for profitable and well-capitalized Western mines in developed districts attempted to turn their dream into reality. Mining engineers made their first attempts to run machinery in locations that featured a combination of water and topographical relief where they could generate hydro-power. In 1888 the Big Bend Mine on the Feather River experimented with electricity, and the Aspen Mining & Smelting Company, in Aspen, Colorado, used electricity to run a custom-made electric hoist that served a winze underground. Two years later progressive mining companies in Telluride, and in Creede by 1892, attempted to adapt electricity to run machinery and illuminate the darkness. Electric plants were a rarity in the West until the late 1890s when a growing number of mining districts attempted to utilize the curious and promising power source.

Several factors came into play that excited interest in electrification during this time. First, the nation's economy and the mining West were recovering from the severe economic depression associated with Silver Crash of 1893, and mining companies once again had capital to work with. Second, electrical and mining engineers had made great strides in harnessing electricity for the unique work of mining. The earliest electrical circuits wired during the 1880s and early 1890s were energized with Direct Current (DC) which had a unidirectional flow, and during this time mining engineers were experimenting with Alternating Current (AC), which oscillated.

Neither power source, as they existed during the 1890s, was particularly well suited for Western mining. AC current had the capacity to be transmitted over a dozen miles with little energy loss, but motors wired to it were totally incapable of starting or stopping under load. Therefore AC was worthless for running hoists, large shop appliances, and other machines that experienced sudden drag, or that required variable speed. AC electricity was effective, however, for running small air compressors, ventilation fans, and mill machinery because they were constant-rotation machines that offered little resistance. DC electricity, on the other hand, had the capacity to start and stop machinery under load, but the electric current could not have been transmitted more than several miles without suffering debilitating power loss. Therefore DC currents had to be used adjacent to their points of generation. In addition, DC motors were incapable of running the massive production-class machines mining companies had come to rely on for profitable ore extraction.[lxxii]

In general electrical technology as it existed during the 1890s offered mining companies little incentive to junk even small pieces of sinking-class steam equipment. However, enough progressive industrialists and engineers saw the benefits that electricity offered to the mining industry to keep the movement going. As a result, in the mid and late 1890s a few capitalists formed electric companies that wired well-developed mining districts such as Cripple Creek and Central City, Colorado, Mercur, Utah, and several portions of California's Mother Lode. More companies formed in districts of similar magnitude during and shortly after 1900. The characteristics that these mining districts shared was that they were compact and limited in area, lending themselves to DC power distribution, and they encompassed a high density of deep, large, and profitable mines, which constituted a potentially significant consumer base. To further the demand for power in these districts, the electric companies leased motor-driven hoists and compressors to mining operations at discount rates. As a result small operations with little capital installed electric hoists and compressors amid their surface plants. Large mining companies used electric hoists underground to serve winzes, and they equipped their shops with motor-driven power appliances.

Around 1900 electrical appliance manufacturers had made several breakthroughs. Electricians had developed the three-phase AC motor, which could start and stop under load while using a current that could be transmitted long distances. The other major breakthrough consisted of the development of practical DC/AC converters, which permitted the use of

DC motors on the distribution end of an AC electric line. The net result was that electricity became an attractive power source to a broad range of electric consumers.

Still, most Western mining companies were not yet willing to relinquish mighty steam technology because even the new three-phase AC motors were capable of only driving sinking-class hoists and small compressors. In addition, voltage, amperage, and current had not yet been standardized among machinery manufacturers or among the various power grids in the West, which discouraged engineers from embracing the use of motors for critical mine plant components. Many pragmatic, professionally educated mining engineers felt that while electricity indeed offered benefits during the 1900s and 1910s, it was no where near ready to replace steam power.[lxxiii]

The rigors of mine hoisting proved to be one of the greatest obstacles electricity had to overcome, but by the 1900s mining machinery manufactures had developed a variety of small AC and DC models that were reasonably reliable. The early electric hoists were similar in design to sinking-class geared steam hoists, and they were manufactured by mining machinery makers with motors wholesaled from electric appliance companies such as General Electric. Most of the hoists consisted of a cable drum, reduction gear shafts, and motor fixed onto a rectangular bedplate. In many cases the *controller*, which served the same function as a throttle on a steam hoist, was also mounted onto the bedplate. A second popular electric hoist configuration consisted of a cable drum and a gear shaft fastened onto a main bedplate, with the motor bolted onto an extension projecting outward from the side. While electric hoists utilized bedplates similar to geared steam hoists, the performance rating for the bedplate size for electric models was less than it was for steam hoists.

Even though the electric hoists made during the 1900s were able to start and stop under load, they were very slow and had a limited payload capacity. Most of these hoists featured motors rated 75 horsepower or less. The early electric hoists had speeds under 600 feet per minute, payloads less than 3 tons including the weight of a hoisting vehicle, cable in the shaft, and ore, and their working depths were rated to around 2,500 feet.[lxxiv]

By the 1910s applications of electricity had progressed to the point where professionally educated mining engineers could not deny the potential savings in operating costs, and that the performance of electrical machinery was rapidly approaching that of all but the titanic direct-drive steam hoists. As steam machines such as hoists and compressors began showing wear after years and even decades of use, the engineers in charge of large and medium-sized mines began replacing them with electric models. Many mining operations were clearly demonstrating that electricity was more efficient than steam. One engineer asserted that in well-developed mining districts, a steam-driven compressor cost up to $100 per horsepower per year to run while an electric model cost only $50. The cost savings were probably even greater for hoisting.[lxxv]

Electric technology had come a long way by the 1910s, and many reputable professionally educated and even many self-taught mining engineers began to accept it at least for lighting, and even for running critical mine machinery. Mining operations getting underway during this time installed factory-made electric hoists while some older operations attempted to retrofit their steam models with motors. These electrical converts wisely maintained their steam boilers in an operable condition in the event the motor, or the entire electrical grid, failed, which occurred at times. Electrical engineers had standardized electric grids and motors in the West's mining districts for either 220 or 440 volts and 60 cycle AC current; other voltages and DC current had fallen out of favor by this time.[lxxvi]

Mining machinery makers had made the greatest advances with electric hoists during the 1910s. Not only had electrical engineers and machinery makers improved the performance and reliability of single-drum electric hoists, but also they introduced effective double-drum units for productive mines interested in achieving economies of scale through balanced hoisting. Within ten more years, except for remote and poorly capitalized operations, most of the mining West had adopted electric power for hoisting, as well as for running other types of mining machinery.

During the 1910s mining engineers had developed two basic electric systems they could choose from for production-class operations. They could have wired their machinery directly to an electrical substation connected to a power grid, or they could have first run the hoisting circuit through a rotary converter which had the potential to save electricity and moderate the demand on the system. The biggest problem large hoists presented to electric circuitry was that when they came under great load, such as beginning movement with a loaded cage, they siphoned a tremendous amount of power from other plant components, resulting in a brown-out. In response, electrical engineers in both America and Europe, which was also developing electric power at this time, introduce rotary converters that played a dual role in the hoist's circuitry.

The converter fed electricity to the hoist when needed, but it allowed the hoist motor to act as a generator when the hoistman shut off the power and used the motor's mechanical drag to lower the hoisting vehicle down the shaft. The electricity generated by the hoist motor, being turned by the descending hoisting vehicle, went to the converter and powered a motor there that set in motion a large iron flywheel. When the hoistman powered up his machine and raised another load from the depths of the mine, the hoist again drew full current, but the motor in the converter, kept in motion by the flywheel, reversed its role and became a generator that supplemented the power drawn by the hoist.

The mining industry used three basic types of rotary converters. These included the *Lahmeyer system*, the *Siemans-Ilgner system*, and the *Westinghouse system*, the latter of which was by far the most popular. Rotary converters were capital-intensive, and because electricity by nature was inexpensive, few mining companies saw the necessity of installing such machinery. However, a few heavily electrified mining companies operating their own generators found converters to be economical, and because one converter was able to serve several mines at once, some electric companies also found them to be cost-effective to wire into their grids. But in general rotary converters saw little application in the West.

Architecture

Once a mining company had proven the existence of ore the investors, who often had influence over management policy, fully expected the operation to perform throughout the year, during good weather and bad, until the ore had been exhausted. Attempting to comply with company wishes, mining engineers responded by using available capital to erect structures that sheltered important components of the surface plant against the summer sun and against arctic winter winds. To this end engineers understood that buildings served two purposes: mollifying the physical needs of the mine crew, and sheltering plant components that were intolerant of or performed poorly when exposed to adverse weather. The engineer and the mining company had a tacit understanding that the mine buildings also possessed the ability to inspire investors and prominent figures in the mining industry. Large, well-built, and stately structures conveyed a feeling of permanence, wealth, and industrial might while small and poorly constructed buildings aroused little interest from investors and promoters.

Building materials, architectural styles, and structure layouts for mine buildings in the West changed between the 1890s and the 1920s. Perhaps small mining outfits in remote areas realized the greatest gain from changes in conventional construction practices of mine buildings as the expanding network of roads and railroads reduced the costs of purchasing building materials. Regardless of a mine's location, the buildings erected by well-financed, profitable, and large mining companies tended to be substantial and big, while the buildings belonging to poorly funded and limited mining companies were crude, small, and rough.

Professionally trained mining engineers considered four basic costs that influenced the type, size, and constitution of the buildings they chose to erect. First, time had to be spent designing the structure. Second, basic construction materials had to be purchased and some items fabricated. Third, the materials had to be hauled to the site, and fourth, the mining company had to pay a crew to build the structure. Between the 1880s and around 1900 nearly all mining engineers in the West attempted to meet the above considerations by directing their carpentry crews to build wood frame structures and side them with dimension lumber. In a few cases small and poorly funded operations working deep in the mountains substituted hewn logs, but they understood that the log structures were intended to be impermanent, either to be replaced by dimension lumber should the mine prove a bonanza or totally abandoned should the mine go bust.

The introduction of steel and iron building materials to the Western mining industry in the1890s radically changed the structures erected by mining companies. A number of steel makers began selling iron siding for general commercial and residential construction nation-wide in the 1890s. While much of the siding was decorative, a few varieties were designed with industrial applications in mind. One of these types, corrugated sheet iron, found favor with the Western mining industry and its use spread like wildfire. Engineers increasingly made use of the material through the 1900s, and by the 1910s it had become a ubiquitous siding for all types of mine and many commercial buildings in the mining West. The advantages of corrugated sheet iron were that it cost little money, its light weight made it inexpensive to ship, it covered a substantial area of an unfinished wall, the corrugations gave the sheet rigidity, and it was easy to work with. These qualities made corrugated sheet steel an ideal building material where remoteness rendered lumber a costly commodity.[lxxvii]

The other significant use of steel in mine buildings occurred during the 1890s when a few prominent Western mines began to experiment with the use of girders for framing large buildings such as shaft houses, paralleling the rise in the construction of steel headframes. Architects began using steel framing to support commercial and industrial brick and stone masonry buildings as early as the mid-1880s, but Western mining companies found that wood framing met their needs as well and for less money. By the 1890s architectural steelwork had improved, and steel makers offered lightweight beams which mining engineers adapted to the framing of huge shaft houses. Further, engineers found that steel not only offered a sound structure able to rebuff the high winds of the West, but it often cost less money than the thousands of board-feet of lumber required to erect the massive and imposing buildings, and steel had the added benefit of being fire-proof. However, taking shelter in a steel building during violent lightning storms undoubtedly stirred at least a stoic concern among otherwise hardened miners.

The general forms, types, and layouts of mine structures followed a few general patterns, regardless of the building materials the mining engineer used for construction. During the 1880s and 1890s most mining engineers enclosed the primary surface plant components, usually clustered around the shaft, in an all-encompassing *shaft house*. The plant components associated with a tunnel or adit were enclosed in a *tunnel house*. These buildings contained machinery, the shop, the mine entrance, and a workspace under one roof. The buildings therefore tended to be large, tall, and unmistakable edifices in a mining district. Relatively small shaft houses in the West were constructed of stout post-and-girt frame walls, gabled rafter roofs, and informal or no foundations. Particularly spacious shaft houses required a square-set timber skeleton capable of supporting the roof independent of the walls. Regardless of the type of frame, carpenters clad the walls with board-and-batten siding or several layers of boards nailed either horizontally or vertically, and they used shakes for roofing material. During the 1880s and the 1890s, electric lighting was virtually unheard of, and mining engineers instead had carpenters install large multi-pane windows at regular intervals in the walls for lighting.

Most shaft houses built in the West conformed to a few standard footprints that the arrangement of the mine machinery influenced. Overall, the structures tended to be long to encompass the hoist, which the engineer had usually anchored some distance from the shaft, and they featured lateral extensions that accommodated the shop, a water tank, the boilers, and either coal or cord wood storage. Professionally educated mining engineers recommended that at least the boiler, and ideally the shop as well, be partitioned in separate rooms because they generated unpleasant soot and dust which took a toll on lubricated machinery such as compressors and hoists.[lxxviii]

The roof profile typical of most Western shaft houses featured a louvered cupola enclosing the headframe's crown and a sloped extension descending toward the hoist that accommodated the hoist cable and the headframe's backbraces. Tall iron boiler smokestacks pierced the roof proximal to the hoist, the stovepipe for the forge extended through the roof near the shaft collar, and the shaft house may have also featured other stovepipes for the stoves that heated the hoistman's platform and the carpentry shop. The tall smokestacks and stovepipes usually had to be guyed with baling wire to prevent being blown over by strong winds.

The mining engineer working at high elevations often had the shaft house interior floored with planks to improve heating. In some cases the shop and boiler areas, where workers dropped smoldering embers, hot pieces of metal, and nodules of fresh clinker were surprisingly also floored with planking, which presented an enormous fire hazard! Customarily the mining engineer designed the flooring to be flush with the top surfaces of the machine foundations, permitting the steam, air, and water pipes to be routed underneath and out of the way.

Shaft houses colossal enough to cover a bank of boilers, a large hoist, air compressor, and a shop were extremely costly to build and they required expensive upkeep. In addition, the heat generated by the shop forge, boilers, and a few woodstoves proved no match for the frigid drafts of winter. In response to the economic drain posed by large shaft houses, during the 1900s and 1910s many mining companies began sheltering key surface plant components in individual buildings. The appearance of the surface plants of many mines changed to consist of a cluster of moderate-sized buildings surrounding the exposed headframe.

Instead of a shaft house, at particularly large and well-equipped mines the engineers had carpenters enclose the hoist and boilers in a *hoist house*, the compressor in a *compressor house*, and the shop in its own building. The mine plant may have also featured a miner's *change house* also known as a *dry*, a storage building, a stable, a carpentry shop, and an electrical substation. Small and medium-sized mines often combined the hoist, boiler, compressor, and shop in one large hoist house, while the headframe and shaft collar remained exposed to the weather. It is important to note that sheltering the vital surface plant components in a single hoist house was standard for poorly-capitalized mines and prospect operations in the Great Basin and Southwest from as early as the 1870s, and the practice continued into the 1930s.

Wood frame and steel buildings consisted of structural materials that other mining operations, creditors, and district residents prized, and they were quick to remove a building for the lumber following a mine's abandonment. Further, federal tax laws levied assessments on the owners of property with improvements such as structures, and as a result private parties demolished mine buildings in hopes of avoiding payment. As a result, only a tiny fraction of the mine buildings that had dotted mining landscapes across the West prior to the 1930s have endured until today. Visitors seeking to identify the size, type, and shape of buildings at mine sites must turn to archaeological remains in the forms of foundations, footprints, and artifacts. Most mine buildings were impermanent and hastily built, so that thorough salvage efforts left scant remains behind.

In a few rare cases, mining engineers instructed their construction crews to lay either concrete or masonry wall footers, which can help the visitor in determining the footprint of a structure. Due to lack of funding and the general impermanence associated with Western mining, workers rarely built formal and lasting foundations. Instead, they built informal foundations consisting of dry-laid rock alignments or heavy timbers set in the ground. The visitor to historic mine sites may be able to identify the footprints of shaft houses, hoist houses, shops, stables, and compressor houses by abrupt changes in soil character and linear depressions where building walls had stood. Heavy foot and animal traffic, grease and oil deposits, forge clinker, dark soil with a high organic content, and differential soil weathering had the potential to result in the ground underlying a structure being different in appearance and texture from the surrounding soil or waste rock. To further aid visitors puzzling over historic mine sites, the soil differences created by structures affected revegetation patterns. Brush and grasses may outline a structure's footprint.

The assemblage of artifacts around the surface plant core may also help the visitor to identify the types and locations of mine buildings. Heavy concentrations of nails, window glass, lag bolts, stovepipes, and stovepipe flashing often were left after a wood frame building had been disassembled. Usually the artifact assemblages at mine sites active after around 1900 include at least a few pieces of corrugated siding. Some mining companies with limited funding used a variety of other forms of sheet iron siding to cover holes and gaps in mine buildings from the 1880s into the 1930s. Prior to the 1890s, mining outfits flattened the corrugated bodies of blasting powder kegs to obtain sheet iron, and between the 1880s to 1910s mining operations flattened square 5 gallon kerosene and gasoline cans. Last, the concentration of lumber fragments and light industrial artifacts such as small machine parts, electrical insulators, and nuts and bolts is often greater within the boundaries and immediately surrounding the location of a mine building than at short distances away.

The general construction methods and architectural styles of the 1930s changed little from the practices of the late nineteenth century. Like their predecessors, 1930s-era engineers designed stout structures that consisted of a dimension lumber frame and rafter roof, which laborers sided with corrugated sheet steel. Engineers continued to take advantage of natural light by designing buildings with multi-pane windows at regular intervals in walls, and they provided broad custom-made doors at important points of entry.

During the 1930s the use of flooring materials for well-built buildings became more common than during the Gilded Age. Engineers either floored principle structures with poured portland concrete, which had become an inexpensive material due in part to the proliferation of the truck, or they stood the buildings on proper foundations and used wood planking. Mining engineers at impoverished operations attempted to maintain a high level of quality by designing properly framed buildings, but they were forced to make due with plank flooring nailed onto joists placed on the ground, or they had to be satisfied with a floor of mother earth.

Depression-era buildings that had been erected by well-capitalized mining companies shared a few broad characteristics that, in addition to the construction features and materials noted above, separated them from the simple structures typical of lesser mines. Mining companies with funding tended to erect buildings that were spacious with lofty gabled or shed-style roofs. The materials the companies provided their workers included virgin lumber, virgin sheet iron, and factory-made hardware. The workers, often skilled in their trade, built lasting structures with a solid, tidy, and orderly industrial appearance. In most cases mining engineers emphasized function and cost in their designs and added little ornamentation, contrary to the large buildings erected during the Gilded Age.

Poorly funded mining outfits were economically forced to keep construction within a tight budget, and within their skills. These outfits could not afford first-rate construction materials and tools, they were not able to hire an experienced engineer or architect, and they lacked the funding to hire a skilled construction crew. As a result, the buildings that the small companies erected tended to be small, low, made with high proportions of salvaged materials, and poorly constructed overall. The buildings fabricated by small outfits were personal and unique to each operation, being a true expression of the outfit's nature, and assembled as the builder saw fit.

While large and well-financed mining companies customarily erected several buildings such as a hoist house, a compressor house, and a shop, the small and impoverished operations tried to save money by enclosing their crucial plant facilities in a single building. At shaft mines this structure usually consisted of the hoist house, or a combination shop and compressor house at adit mines. The construction of one building, with minor additions and extensions, minimized the outlay of precious capital and the time and effort required of miners to erect a structure. A compromise that many impoverished mining companies enacted involved moving entire buildings to the mine from abandoned operations nearby. In so doing a small mining company could have added to its assemblage of structures for little money. Mining outfits that engaged in this practice made little or no effort at altering the appearance of the relocated buildings, and these structures stand out today as being different in materials, construction, workmanship, and architectural style from the other vernacular buildings at the mine site.

The structures erected by poorly capitalized mining companies during the Depression can be divided into two categories. Some small outfits had at least a little capital and a crew with modest carpentry skills, and they built mine structures that consisted of a rough but sound frame, often of the post-and-girt variety, sided with salvaged lumber and scavenged sheet iron. These buildings appeared rough and battered even when relatively new, but they were fairly well-built and offered miners shelter against icy winter blasts and summer thunderstorms. Construction crews assembled the buildings with the materials they had on hand. They often sided the walls and roof with a patchwork of mismatched sheets of corrugated sheet steel in various stages of rusting. Miners salvaged doors and window frames from abandoned houses. Some structures even had mismatched walls, each face of the building having been sided differently from the others.

The quality of workmanship defines the second category of Depression-era mine buildings from the first. Buildings that fell into the second group appeared even rougher and had less structural integrity than the structures described above. The laborers frequently built such structures with no formal frame. Instead, they preassembled the walls, stood them up, and nailed them together, or established four corner-posts, added cross braces, and fastened siding to the boards. The builders may have used a combination of planks and sheet steel for siding, which was often layered to prevent being ripped apart by high winds. Many mining outfits favored the *shed* structural style, which featured four walls and a roof that slanted from one side of the building to the other, because it was simplest to erect.

The workers comprising small mining outfits constructed these buildings poorly for several reasons. First and foremost they sought to minimize costs and the effort of labor. Second, many workers at Depression-era mines were not the jacks-of-all trades that had characterized miners during the Gilded Age. Rather, they came from a variety of urban and rural backgrounds, and as a result they lacked carpentry skills and proper construction tools. Last, workers built shoddy structures because they wanted to fulfill an immediate need and anticipated abandoning the mine after a period of time. The architectural style of the mine buildings erected by such mining companies during the 1930s may truly be termed *Depression-era Western mining vernacular*.

One of the subtle factors that gives the buildings erected by impoverished outfits an overall beaten and ramshackle appearance is the use of unconventional building materials. As noted, Depression-era mining outfits extensively used salvaged lumber, recovered sheet steel, and in the mountain states raw logs still clad with bark. The visitor examining 1930s vintage mines today may note that the structures consist of lumber which, when considered on a piece-by-piece basis, contrasts from the other pieces in tone, grain, exact dimensions, and cut. The lumber and the siding will exhibit old nail holes, abandoned nails, and signs of differential weathering where it had previously been fixed onto another structure.

Mine workers assembled buildings with these types of materials as best as they could, but they often neglected to trim the boards and sheet steel to even lengths which greatly contributed to an overall rough appearance. They left the boards comprising roofs and walls uneven lengths, they left sheets of corrugated steel uncut only to bend them edges of the way, and they neglected to trim the posts supporting structures such as ore bins to a uniform length. Economic hardship, the fatigue it fostered, and the rag-tag workforce spawned by the Great Depression overrode the drive for regularity and order at the mine.

Aerial Tramways

In Creede, like other Western mining districts, prospectors had discovered many productive mines in impossible terrain. Some of the locations were so inaccessible that pack trains proved to be the only viable means of transporting in the materials of mining and hauling out ore. Unfortunately the carrying capacity of pack trains was severely limited, approximately 11 burros or donkeys required per ton of ore, which greatly inhibited a mine's production levels and, by direct association, profit. In some cases mining engineers spent lavish sums of capital to build circuitous wagon roads in hopes of mitigating transportation problems. However, the steep and winding wagon roads proved to be only somewhat better than pack trails, economically squelching what could have otherwise been a highly profitable operation.[lxxix]

In the greater West, mining companies began experienced these transportation-related problems as early as the 1860s when prospectors began finding tantalizing deposits of gold and silver in the rugged Great Basin and Rocky Mountains. At that time mining engineers dreamt of fanciful solutions to magically move great tonnages of ore to points of rail shipment, or directly to local reduction mills. One such engineer and mining machinery maker in San Francisco, Andrew S. Hallidie, was the first to turn fantasy into reality. Combining his knowledge of wire rope, his engineering skills, and familiarity with European mining technology, he hit upon an invention that solved the transportation problems presented by high mountains and impassable winter snows. In the late 1860s Hallidie developed and patented the first practical aerial tramway in the West. Hallidie's system consisted of a series of strong wooden towers featuring cross-members tipped with idler wheels that supported a continuously moving, endless loop of wire rope. The loop of rope conveyed a series of ore buckets that traveled a circuit between large sheave wheels at the top and bottom stations. The tram's wooden towers were built to heights dependent on the relief of the terrain in efforts to keep the pitch of the tramway consistent, and Hallidie ingeniously designed the system to move under gravity. The loaded buckets gently descended downslope, pulling the light empties back up to the mine.

Hallidie's design changed little from the 1870s until the 1910s. Empty buckets entered the tram terminal, they were loaded with payrock, whisked around the sheave wheel, and traveled down the line to the bottom terminal. In the top terminal, ore poured through a chute from a bin into the empty buckets while in they were in motion, and they continued down to the bottom terminal. When the bucket entered the bottom terminal a steel guide rail upset it, dumping the contents into a receiving bin underneath as it passed around the bottom wheel. A few feet past the ore bin, a group of laborers may have been busy loading empty buckets with dynamite, drill-steels, food, and forge coal to supply the miners at work high above.

By the 1880s enough mining companies had installed Hallidie aerial tramways to enable academic engineers to evaluate their economic worth and performance. The mechanical wonders remained unrivalled for moving large volumes of ore across untraversable terrain in districts such as Creede, but they possessed several undeniable limitations. The tramways had distance and elevation limitations of 2 miles and 2,500 feet, respectively. Longer circuits required very expensive transfer stations. Because the buckets were fixed to the wire rope, they had to be filled and unloaded while in motion, limiting their load and giving them the greater potential to wreak havoc with the system. When the grade traversed by Hallidie's tramway was less than 14 feet rise per 100 feet traveled, an expensive steam engine had to power the rope. Last, because the system relied on one rope to both carry and move the buckets, the weight capacity of each bucket had to be curtailed to minimize strain and ultimately the cataclysmic event of breakage.[lxxx]

With these problems in mind, Theodore Otto and Adolph Bleichert, two German engineers, developed an alternative system first employed in Europe in 1874. The *Bleichert Double Rope* tramway utilized a *track rope* spanning from tram tower to tram tower, and a separate *traction rope* that tugged the ore buckets around the circuit. The track rope was fixed in place and the buckets coasted over it on special hangers featuring guide wheels. The traction rope was attached to the ore bucket's hanger via a mechanical clamp known as a *grip*. Like Hallidie Single Rope tramways, *Bleichert Double Rope* tramways incorporated top and bottom terminal stations where the buckets were filled and emptied, and they too usually ran by gravity.[lxxxi]

Bleichert's system offered advantages that endeared the marvelous systems to academically trained technology-loving mining engineers. Even though Bleichert systems were up to 50% more expensive to erect than Hallidie tramways, they proved to be better for heavy production because they were able to handle greater payloads which resulted in higher production for the mining company. In addition, the grip fastening the buckets to the traction rope was releasable, permitting workers to manually push the buckets around the interior of the terminal on hanging rails, permitting them to fill the buckets at leisure without spillage. The double-rope system also permitted the entire tramway circuit to be extended up to four miles in length and work at almost any pitch.

Mining companies began experimenting with Bleichert Double Rope systems in the 1880s, ten years after Hallidie began manufacturing his marvelous aerial tramways. Due to superior performance, the popularity of Bleichert systems eclipsed the less expensive Hallidie tramways by the 1890s, when the use of tramways in Creede, and the rest of the West, surged. Still, many Western mining companies with limited production and moderate amounts of capital continued to install Hallidie systems after the turn-of-the-century.

Purchasing and installing aerial tramways was beyond the rough-and-ready skills of many mining engineers. The systems were complex and very expensive, they required economic and engineering calculations, and a state of mind bordering on the experimental and progressive. Even professionally trained mining engineers installing aerial tramways usually required direction from engineers dispatched by the tramway maker. While mining companies purchased basic tramway components from mining machinery makers such as A.S. Hallidie & Company, Park & Lacy, and Bleichert & Company, each set-up was a custom affair tailored to a specific mine's needs. Mining engineers and the builders of tramways assembled systems from fairly standardized technology, but rarely were two systems alike in the West.

Tramways offered mining companies the economic advantage of producing ore in economies of scale, but perhaps greatest of all in the eyes of engineers was the statement such a system made about the engineer himself, and about the mining company that backed him. The constant aerial parade of loaded ore buckets inspired management and investors alike, it spoke of prosperity and wealth, and was a mechanical fascination. The action inside the loading and unloading terminals was no less inspiring. A busy crew of mine workers uncoupled every bucket as it arrived, they pushed the empties over the hanging rail to the ore chutes where another worker filled them, and workers recoupled the buckets onto the ever-moving rope for the ride down.

Tramway systems were very materials-intensive and required substantial structures. As a result they almost always left characteristic forms of evidence at a mine site following abandonment. The basic components discernable to today's visitor include a top terminal near the adit or shaft, a bucket line featuring towers, and the bottom terminal located adjacent to either a road, railroad grade, or an ore reduction mill site. In many cases a visitor can evaluate the remains to determine whether the more efficient and costly Bleichert system, or the less-expensive Hallidie system serviced the mine.

Engineers recognized four basic types of tramway towers for both Bleichert and Hallidie systems. These included the *pyramid* tower, the *braced hill tower*, the *through tower*, and the *composite tower*. The pyramid tower consisted of four upright legs that joined at the structure's crest. The through tower resembled an A-shaped headframe consisting of a wide rectangular structure stabilized by fore and back braces, and the tram buckets passed through the framing. Composite towers usually had a truncated pyramid base topped with a smaller frame supporting a cross-member. The braced-hill tower was similar to the through tower, except it had exaggerated diagonal braces tying it into the hillslope.

Tramway towers for both Bleichert and Hallidie systems required stout cross-members to support the wire ropes at a distance that permitted the buckets to swing in the wind and not strike the towers. Hallidie systems, with their single wire rope and fixed buckets, needed only one cross-member that featured several idler wheels or rollers. Because the buckets were suspended from a long hanger fixed onto the cable, the cross-member was bolted to the top of the tower. Bleichert systems, on the other hand, required a stout cross-member at the tower top to support the stationary track cable, and a second cross-member 3 to 7 feet below to accommodate the moving traction rope. The second cross-member almost always featured either idler wheels or a broad steel roller.

Engineers found great challenge in attempting to design tram towers. They had to minimize the quantity of construction materials, yet create a tall structure that resisted a complex interplay of forces. Building a sound structure that met the last criterion was perhaps the most rigorous engineering goal. Tram towers had to withstand the sum of three basic stresses. The first was the downward pressure exerted by the weight of the cable and ore buckets. The second consisted of horizontal forces parallel to the cables created by starting and stopping the system. The third consists of sideways horizontal forces created by windshear on the towers, cables, and buckets. This last force was not to be underestimated in the rugged and mountainous West, and it had caused a number of major malfunctions at mines.

The choice of tower form and spacing was a function of topography, local weather, and the pitch of the line. Pyramid and composite towers could have been built higher that the other types, and they were the least costly. Hillslope towers were best for very steep terrain, and they, as well as through towers, gave greatest stability during severe weather. Engineers recommended using steel beams for construction, but this was far too expensive, and most mining companies in the West built with timber ranging from 6x6 to 10x10 inch stock, fastened with bolts. Where the bucket line traversed forested hillslopes, laborers had to cut a path through the trees.

Tramway terminals presented engineers with no fewer design problems than did the towers. Terminals had to be physically arranged to permit the input and storage of tons of ore from the mine, they had to facilitate transfer of the payrock into or out of the tram buckets, they had to resist the tremendous forces put on the sheave wheel by the traction rope, and in the case of Bleichert systems, they also had to anchor the track cables. Mining engineers designing small-capacity tramways attempted to solve all of the above problems literally under one roof, while the terminals for large-capacity tramways were enclosed in complex buildings.

Regardless of the type of tramway a mining company had installed, special accommodation had to be made for the sheave wheels in both terminals. They had to resist the significant horizontal forces of keeping the traction rope taught. The sheave in the top terminal was usually fixed onto a heavy timber framework anchored to bedrock and partially buried with waste rock ballast. The wheel was canted at the same angle as the pitch of the bucket line so that the cable did not derail, which would have resulted in a costly and potentially life-taking catastrophe. Typical sheave wheels, six feet in diameter for small systems and twelve feet for large systems, featured a deep, toothed groove for the rope, and they were fixed onto a heavy steel axle set in cast iron bearings bolted to the timbers. The teeth in the groove gripped the rope in the event that a terminal worker had to throw the brake and stop the system. Brake levers, usually installed in both terminals, were typically very long to provide great leverage, and they were located on a catwalk immediately over the wheel, or adjacent to the wheel at ground-level, both of which afforded the straining worker a view of the system he was attempting to stop. The lever controlled heavy wooden shoes that pressed with much force against a special flange fastened to the sheave wheel. These brakes may seem dubious to today's visitor when inspecting a tram station, but they were reputed to easily bring to a halt entire lines of full buckets.

Terminals for Hallidie systems featured the sheave wheel placed high in the framework to provide ample space to clear the hanging buckets, which passed directly under several ore chutes designed to fill them in motion. In most cases the chutes extended downward from ore bins located directly over the terminal, and in fact small terminals and ore bins shared a common stout structure. At the bottom terminal the sheave had be moveable to take up slack in the rope line. In many cases the wheel was fastened onto a heavy timber frame pulled backward by adjustable anchor cables or threaded steel rods. The wheel carriage also featured hardware that automatically upset the ore buckets, and they emptied their precious contents into an ore bin underneath the terminal.

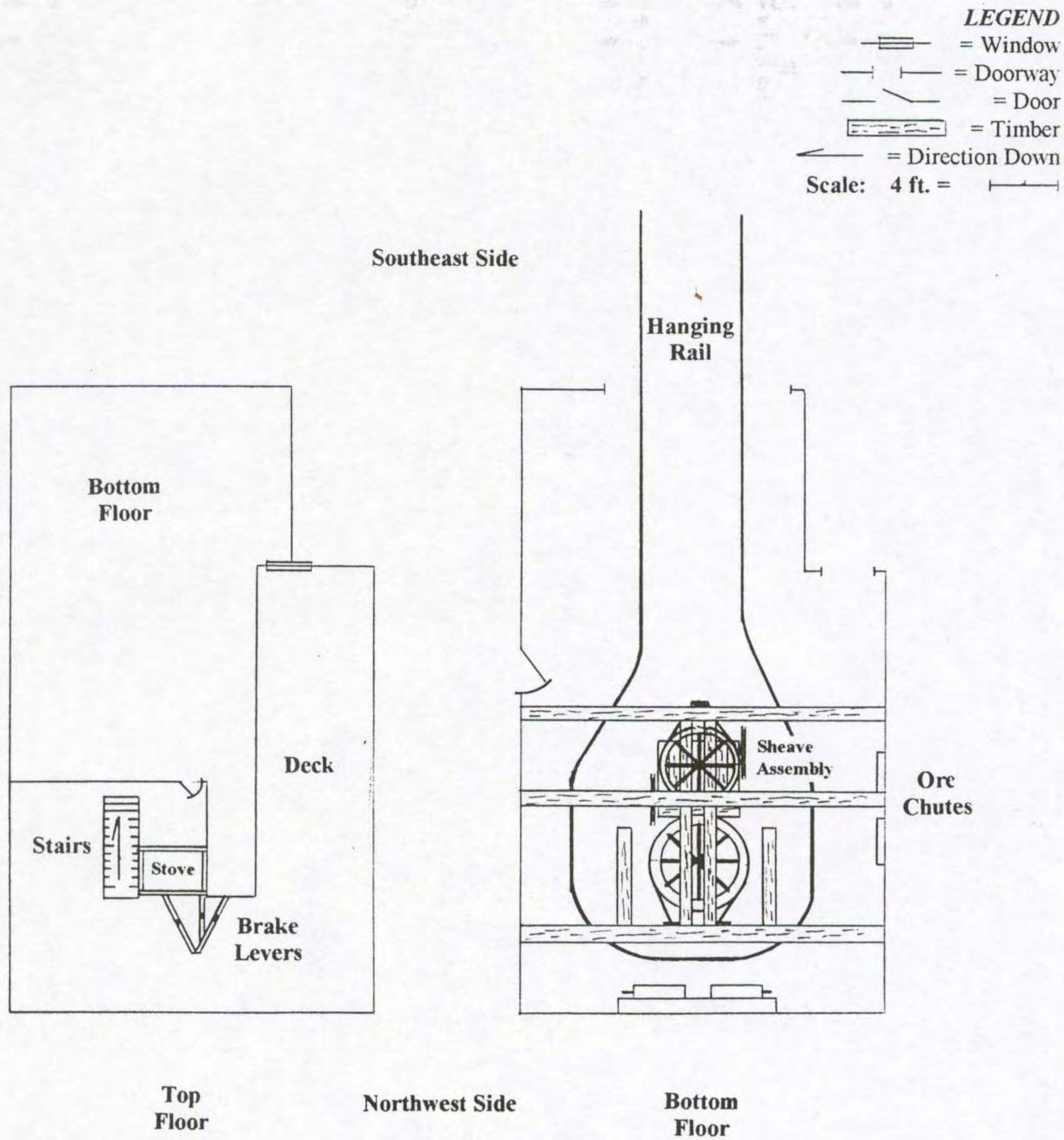
The tramway terminal at the lower haulage tunnel of the Bachelor Mine in the Creede Mining District in Colorado serves as an example of a large complex facility. Empty tram buckets coasted up into the terminal and were routed onto a hanging rail by a special fitting lashed over the track cable. Workers unfastened the buckets' grips and pushed them along the rail which curved around behind the sheave wheel framework. The bustling workers filled them at one of the terminal's three ore chutes, and pushed them on to refastening point. The terminal was spacious, it featured a centrally located woodstove, and the tramway brakeman stood on a platform over the sheave. The ore bins were located on two sides of the structure, and they received payrock from a feeder tramway descending from tunnels high up on the mountain, as well as material from the adjacent ore sorting house.

As grand a solution as Hallidie and Bleichert tramways were for facilitating the procession of ore from a mine, they were too big and expensive for many small operations that possessed modest amounts of capital. Yet, rugged terrain and locations high on the sides of mountains presented no less a problem for these limited operations. The high relief and steep slopes also provided an answer to their dilemma of access. Rather than install the large and efficient but exorbitant tramways relished by academic engineers, the smaller companies strung up *single-rope reversible* aerial trams.

Well-engineered single-rope trams typically consisted of simple components. A fixed line extended from an ore bin located high up at the mine down to another ore bin below. A hoist at the mine wound and unwound a second cable that pulled a bucket. The cost of installing such a tramway was very low, but many engineers scorned them because these conveyances were slow and inefficient, relying on one vehicle moving back and forth between the bins.

The primary materials a mining company needed to build a single-rope tramway were abundant and inexpensive. A mine crew required two lengths of cable, lumber, a hoist, and a vessel hung from a pulley. In many cases mining companies, especially those with little capital, purchased a used steam hoist and an old upright or locomotive boiler, or a small gas hoists, and impoverished outfits used prospectors' hand-cranked windlasses or crab winches. The lines that mining operations strung up may have been retired hoist cables, and the bucket possibly fashioned from an ore car body, but proper ore buckets were preferred. The mining outfit often anchored the hoist high up at the mine to a sound timber foundation that they tied into bedrock, and they often anchored the ends of the track cable to timber deadmen buried in waste rock. Ramshackle though they might be, miners working high up on mountain sides would have agreed that the single-rope aerial tramways saved them immense aggravation and effort at bringing down their precious pay rock and sending up drill-steels, dynamite, and the occasional passenger.

Figure 4.33 Plan view of the upper Bleichert tramway terminal at the Bachelor Mine's lower tunnel. Tram buckets entered the structure on the rail in the upper left corner of the bottom floor, where a worker uncoupled it from the traction rope. He rolled the bucket around to the other side of the terminal and stopped it underneath the ore chute, filled it, and a second worker reconnected it to the traction rope. Engaging the band brake encircling the sheave could have stopped the tram. Author.



Ore Storage

While capitalists, mining engineers, and miners often held differing opinions as to how to set up and run a mine, all were in agreement that the primary goal was the production of ore, and lots of it. Most Western hardrock mines, of course, were failures, producing little or no pay rock and passing into history unknown. A few operations, however, proved to be profitable, and a tiny fraction made millionaires of their owners. Those mines with any measurable output of payrock usually included an ore storage facility as part of their surface plants, and operations that produced either miniscule amounts of payrock or were *dry holes* almost never featured ore storage facilities. Like most of a mine's facilities, ore bins and ore sorting houses reflected the financial state of the mining company, the mine's volume of production, and the type of ore the miners drilled and blasted.

Ore bins were functionally different from *ore sorting houses*, and the mining engineer based his choice on which structure he wished the company to erect on the type of ore being mined. Free gold, tungsten, and copper usually occurred in veins and masses that were fairly consistent in quality and rock type, and they warranted storage in an ore bin. The quality and consistency of silver and telluride gold, on the other hand, varied widely in any single given mine, and they required sorting, separation from waste rock, and rudimentary concentration in an ore sorting house. Both types of structures required a means of inputting ore from the mine, and a means of extracting it for shipment to a mill for finer concentration.

Mining engineers recognized three basic types of ore bins: the *flat-bottom bin*, the *sloped-floor bin*, and a structure which was a hybrid of the above two known as a *compromise bin*. Flat bottom bins, which generally consisted of a flat floor, high walls made of heavy planks, and a louvered gateway in one wall had a greater storage capacity per square-foot than the other two types of structures. However, laborers had to stand on the pile of shifting payrock and work in choking dust to shovel it out into a waiting wagon or railroad car. Sloped floor bins, on the other hand, were expensive to build, they required proper engineering, and they were conducive to automatically unloading the ore, which naturally flowed out of the structure through chutes. Compromise bins combined the above two designs, half of the floor being sloped and half being flat, to create a bin which automatically unloaded when full, and required shoveling when almost empty.[lxxxii]

Mining companies with substantial capital backing and heavy ore production often erected large sloped-floor ore bins. These structures were lasting, strong, and had a look of permanency, solidity, and they inspired confidence. Well-built sloped-floor bins, which cost more than twice to build than flat-bottomed bins, typically consisted of a heavy post and girt frame made with 8x8 inch timbers sided on the interior with 2x6 to 2x12 inch planking. The structures generally stood on foundations of posts tied to heavy timber footers placed on terraces of waste rock. To ensure the structure's durability in the onslaught of the continuous flow of sharp rock coming from the mine, construction laborers often armored bin floors with salvaged plate iron. Mines of a small order used sloped-floor bins consisting of a single-cell, for example 20 by 20 feet in area. Large productive mines erected long structures that included numerous bins to hold either different grades of ore, or batches of payrock produced by multiple companies of lessees working within the same mine.

Mining companies with limited financing and minor ore production erected flimsy flat bottom bins because such structures were inexpensive to build. Rarely did these ore storage structures attain the sizes and proportions of their large sloped-floor cousins because the walls were not able to withstand the immense lateral pressures exerted by the ore. Flat-bottomed bins had to contend with pressures on all four walls, while sloped-floor bins directed the pressure against the front wall and the diagonal floor.

By nature of the their function, ore bins and ore sorting houses had to be linked to the mine tunnel or shaft via a rail line for the input of fresh ore, and they had to provide for the removal of stored ore. Trammers and miners filled ore bins with precious payrock by pushing loaded ore cars from the mine, across a small trestle, and over the bin. To facilitate a rail connection featuring a level gradient, the rim of the ore bin had to be at the same elevation as the tunnel portal or shaft collar, and as a result mining engineers usually located sloped-floor bins, which tended to be rather tall, out on the flank of the mine's waste rock dump. Many flat-bottom bins, and some small, poorly built, flimsy sloped-floor bins, were located at the toe of the waste rock dump where stable ground lay. Trammers loaded ore into these holding structures by dumping the rock from the ore car into a chute that directed the rock into the open bin. Prior to the 1900s some mining companies extracting very limited quantities of ore countersunk small flat-bottomed bins into the waste rock dump near the adit portal. Such bins, often no more than 20 by 20 feet in area, were accessed by a mine rail spur curving off the main line, and the trammer merely pushed a loaded ore car to the bin's edge and disgorged the car's contents.

Ore sorting houses were generally more complex and required greater capital and engineering to erect than ore bins. The primary functions of ore sorting houses were both the concentration and the storage of ore. In keeping with gravity-flow engineering typical of mining, engineers usually designed sorting houses with multiple levels for the input, processing, and storage of ore. These structures usually featured a row of receiving bins located at the top level, a sorting floor under the receiving bins, and a row of holding bins underneath the sorting floor. Receiving bins always had sloped floors, and in most cases the holding bins below did too. In the cold and windy mountain states a gabled roof cupola sheltered the top level, and the sorting floor was fully enclosed and heated with a wood stove. Large and well-capitalized mines provided steam heat for the sorters. The holding bins at bottom were similar to the sloped-floor ore bins discussed above, and the structure usually stood on a foundation of heavy timber pilings, or a combination of pilings and hewn log cribbing walls.[lxxxiii]

Like the processes associated with ore milling, mining engineers utilized gravity to draw rock through ore sorting houses. The general path the ore followed began when the drilling and blasting team, the mucker, or shift boss, all working underground, characterized the nature of the ore they were extracting. They communicated their assessment of the ore's quality to the trammer via a labeled stake, a message on a discarded dynamite box panel, or a tag. The trammer subsequently hauled the loaded car out of the depths of the mine and pushed it into the sorting house, which stood on the flank of the waste rock dump. He emptied the car into one of several bins, depending on how impure the ore was. *High-grade ore* went into a small and special ore bin at one end of the structure, *run-of-mine ore*, which was not particularly rich but required no sorting, went into another bin at the opposite end of the structure. *Mixed ore* that was attached to or combined with considerable waste rock went into one of several bins located in the center of the ore sorting house. When released from the car, the mixed ore slid into a receiving bin that featured a heavy grate at the bottom known as a *grizzly*. The principle behind the grizzly was that the rich portions of telluride and silver ores fractured into *fines*, and the large cobbles that remained intact through the blasting, mucking, and unloading contained waste rock that needed to be *cobbed*, or knocked off by surface laborers. The valuable fines dropped through the grizzly directly into holding bins at the bottom of the structure, while the waste rock-laden cobbles rolled off the grizzlies and into holding chutes that fed onto sorting tables. There, laborers worked by daylight admitted through windows, and by kerosene or electric lighting to separate the ore from waste.

The visitor back in time viewing the scene on the sorting floor of a moderate-sized ore house would see a bustle of activity. Dusty wool-clad laborers, all wearing slouch hats and gloves hovered over a row of around four to six iron-clad sorting tables. A few workers would loosen the stoppings on chutes holding mixed ore until their tables were full of cobbles, then they sorted through the rock, occasionally using a hammer to knock off waste. The workers would drop the recovered ore through unguarded openings in the floor where it fell into holding bins below. They tossed waste rock onto the floor or swept it into ore cars parked on a rail line inside the structure.

Mining companies transferred stored payrock from the ore bins or ore sorting house into wagons or railroad cars for quick shipment to a mill. Most mines, even in well-developed districts, were not productive enough to warrant direct rail access, and they had to be served instead by teamsters, who, shouting and cracking their whips, maneuvered stout wagons directly underneath the ore chutes projecting out of the ore bins. When a wagon had been positioned, a surface laborer crept along a plank catwalk that linked all of the chutes, and he opened the gates which allowed the ore to pour forth. The types of chute stoppings on both early and late ore bins included louvered boards, iron gates raised by gearing, and a pivoting gate that opened when a laborer pulled down on a long lever. The louvered plank stopping proved to be most popular in the West because it cost least and was easiest to install.

The layout and nature of roads for large and productive mines differed from the roads at small mines. Most medium-sized and large mines were served by broad roads forming a circuit, or they featured spacious flat areas that granted a teamster plenty of room to pull his rig underneath the ore chutes and turn around once the wagon had been filled. Such traffic control facilitated the efficient movement of entire wagon trains. Inefficient dead-end roads, on the other hand, often served small mines. Where possible a wise teamster turned his wagon and team around and backed up into the loading area, and when turning room did not exist he had to unhitch his team while mine laborers manually turned the wagon around and loaded it with ore. Such roads were not intended to maximize the flow of materials. Rather, mining companies graded them in hopes of minimizing labor and the expenditure of capital.

Large and productive mines always hoped for rail service, because trains hauled much more ore for less money than ore wagons. However, except for operations in wealthy mining districts with developed rail networks, only mines rich enough were directly served by railroad lines. Even without direct rail service, the mere presence of a railroad in a mining district benefited all operations because the costs of shipping ore and the prices of machinery and other goods dropped significantly.

Overall, intact ore storage structures are a rarity in the West. Instead, the visitor to a historic mine site is often faced with remains. Large ore bins and ore sorting houses were usually complex buildings made of heavy timbers and lumber fastened with large nails, bolts, mortise and tennon joints, and iron tie rods. As a result, even after the structures had been disassembled or demolished, they usually left distinct traces. The most common evidence left by an ore bin or sorting house following its removal consists of groups of hewn log or timber foundation pilings projecting out of the flank of a waste rock dump. The pilings should be arranged in a rough rectangle and be situated adjacent to either a road or railroad grade. In a few instances the visitor may have additional evidence suggestive of an ore bin, including hewn log cribbing walls or dry-laid rock walls that served as foundations, and the eroded terraces of a waste rock platform which once supported the head or toe of the ore structure.

Flat-bottom ore bins may be somewhat more distinct that the clumps of timber pilings vaguely denoting the former location of a sloped-floor bin. The remains of a flat-bottomed bin may appear as an open-topped wood box embedded in the edge of a waste rock dump. Often the remains of flooring and plank walls are visible, but in instances where the building materials have been removed, the bin location may appear merely as a rectangular depression with a flat floor. Occasionally flat-bottomed ore bins stood on raised platforms made of waste rock which were retained by hewn log cribbing or dry-laid rock walls. Whether embedded in waste rock or free-standing, the outside edge of a flat-bottomed bin may be open, or it may feature the remains of an ore chute, either of which should have been adjacent to a road.

Because ore bins and ore sorting houses were materials-intensive, they usually left a distinct artifact assemblage. Invariably laborers dismantling an ore bin left behind relatively large quantities of intact and fragmented hewn logs, heavy timbers, and other types of dimension lumber in the approximate place where the structure stood. The laborers also left hardware such as lag bolts, heavy nails, large-diameter construction washers, iron brackets, and iron tie rods. The former locations of ore sorting houses, where mine workers spent a day’s shift, may also feature food items, stove parts, and small industrial items.

Magazines and Change Houses

Before leaving this chapter, we should consider several additional surface plant manifestations which may exist at historic mine sites. All were solutions to problems mainly large and productive mining operations in the West grappled with. A survey of any wealthy mining district would confirm that miners literally turned the earth inside out in the pursuit of riches, creating immense waste rock dumps at the mouths of tunnels and shafts. Extensive underground workings translated into waste rock dumps that in some cases were so large, they threatened to envelop structures and roads downslope and spill onto neighboring properties. As the dumps slowly grew, carload by carload, mining companies were forced to confront the containment of the spoils from their profits.

Under the advice and planning of engineers, large mining companies employed two solutions. Wealthy outfits anticipating long-term operation purchased adjacent claims both to gain mineral rights underground and to obtain the surface rights that permitted their operations to sprawl. The other solution that small and medium-sized outfits commonly enacted was to erect bulwarks of either log cribbing or dry-laid rock masonry to retain waste rock. Log cribbing tended to be the most structurally sound, consisting of a series of waste rock-filled cells ranging from 8 by 8 to 15 by 15 feet in area. Mining companies in the mountain states favored cribbing, while outfits in the arid Great Basin and Southwest favored rock masonry, which toppled over more easily.

Large mining operations that were bent on turning the earth inside-out for profit often employed dozens of mining crews underground to drill and blast. In the process of bringing down ore in the large quantities that made investors happy, the crews of miners consumed hundreds of pounds of dynamite per day. The mining company had to store enough dynamite to carry them through the several weeks spanning freight deliveries, and all-too-often they stacked 50 pound boxes, the standard shipping container, in shaft houses, compressor houses, storage sheds, and in vacant areas underground. Worse, during cold months, which spanned much of the year at high altitude, mine superintendents had boxes of dynamite stored near boilers, in blacksmith shops, and near hoists where it remained in a thawed and ready state, so they hoped. Such storage practices were absolutely dangerous at mines that kept on hand large volumes of dynamite. In response mining engineers had construction crews build explosives magazines where storage could have been carried out in a more controlled and orderly manner.

Well-built magazines came in a variety of shapes and sizes, but they all shared the common goal of concentrating and sheltering the mine's supply of explosives away from the main portion of the surface plant. Academically trained mining engineers felt that magazines should have been bulletproof, fireproof, dry, and well-ventilated. They also felt that magazines should have been constructed of brick or concrete and if of frame construction, the walls needed to be sand-filled and sheathed with iron. These structural features not only protected the explosives from physical threats, but also they regulated the internal environment which was important, especially in summer. Extreme temperature fluctuations and pervasive moisture had been proven to damage fuse, caps, blasting powder, and most forms of dynamite. This in turn directly impacted the miners' work environment, because degraded explosives created foul and poisonous gas byproducts that vitiated mine atmospheres. In extreme cases degraded caps, fuse, and dynamite misfired when in the drill-hole, meaning they failed to explode, until a miner attempted to extract the compacted mess a little too vigorously with a drilling spoon. Dynamite exploding in the faces of miners in this way was a leading cause of death and injury in the mining West.

Regardless of direct and obvious safety hazards and degradation of the explosives, many small and medium-sized mining companies stored their explosives in very crude and even dangerous facilities. Engineers, often self-educated, had crews erect sheds sided only with corrugated sheet-iron that offered minimal protection from fluctuations in temperature and moisture. In other cases small capital-poor operations took even less precaution and stored their explosives in sheet-iron boxes similar in appearance to doghouses, in earthen pits roofed with sheets of corrugated iron, or they used abandoned prospect adits. Lack of funding appears to have been a poor excuse for improper storage practices, because most operations had the ability to erect fairly safe, inexpensive vernacular dugout magazines. Large mining operations, on the other hand, found it within their means to build proper magazines.

Proper magazines manifest as stout masonry or concrete buildings around 12 by 20 feet in area with heavy arched roofs and iron doors in steel jambs. Usually these magazines have been erected a distance away from the main portion of the mine's surface plant. In other cases mining engineers had construction crews built a concrete, masonry, or timber-lined bunker with a stout iron door. Well-built vernacular magazines, on the other hand, often appear similar to root cellars. Generally they take form as a chamber workers excavated out of a hillside, often 8 by 10 feet in area, and roofed with earth, rubble, and rocks. Timber posts support the roof beams, and the front wall may have been made of timbers, planks, logs, or dry-laid rock masonry. The front of the structure usually features a vernacular wooden door set into a wooden jamb. The interiors of well-built magazines had shelves for boxes of dynamite, while miners merely stacked the boxes up in vernacular magazines.

The last principle surface plant component the visitor to today's historic mine sites may encounter pertains to particularly harsh climates, such as at Creede. Miners working underground had to contend with highly humid, warm, still air, and dripping water. During their shift in such an environment, they became sodden. While this condition was not a problem on warm summer afternoons, it was potentially life-threatening during freezing winter days. Miners who may have already contracted pulmonary illnesses risked significant degradation of their health while en route back home. One response that companies undertook on behalf of wet and cold miners was the installation of *change houses* near their shafts and tunnels. There, miners removed their filthy, damp work clothes, washed if they felt so motivated, and put on clean, dry clothes. These change houses, often incorporated into other mine buildings, also served as warming rooms for the mine's surface workers.[lxxxiv]

Ore Milling

The ore produced by mines throughout the West, including those at Creede, was considered by mining companies to be a raw product, at best. Gold, and especially silver ores, usually consisted of a natural blend of metals mixed in with host rock. Silver ores were rarely pure, and they were instead compounds that included to varying degrees lead and zinc. The finished product derived from the ores that investors and metals buyers sought was purified metal, known as bullion. To produce bullion, the blend of metals had to be separated from the host rock, separated into their individual constituencies, and purified. This process was accomplished in specialized facilities known as mills and smelters.

Mills and smelters differed in the processes that the workers used to separate the metals from the host rock, known as *gangue*. Mills were able to produce metals from simple gold and silver ores by physically reducing the rock to a slurry, then chemical treating the slurry to extract the metals. Ores that consisted of complex compounds of silver and industrial metals, on the other hand, required the additional processes offered by smelters, which included roasting to drive off sulphide minerals, melting the mass, separating the metals, and refining them.

Mining companies rarely possessed sufficient capital nor produced enough ore to warrant the erection of a dedicated smelter. Instead, they shipped their ores to custom smelters, which extracted the metals for a fee. The shipping charges and smelting fees often constituted a heavy expense, and in response, well-capitalized mining companies attempted to save money by building *concentration mills* near their workings. Concentration mills relied on mechanical and some chemical processes to reduce the ore, separate the metalliferous materials from the gangue, and prepare the resultant concentrates for shipment to a smelter for final roasting and refining. In so doing, mining companies accomplished many of the steps smelters charged fees for, and they did not have to pay to ship the worthless waste usually integral with raw ore. Concentration mills were not equipped, however, to produce finished bullion.

The reduction mills typically built by mining companies were modest and equipped to handle limited tonnages of rock. By the time the Creede district boomed, milling technology was fairly uniform and the processes well-understood by engineers. While each mill was a custom-built facility, engineers usually incorporated standard machines and appliances suited for concentrating silver compound ores. Because the ore underwent a series of stages of physical reduction and concentration, engineers typically erected mills on terraced ground to permit gravity to draw the rock from one process to the next. Large mills usually required stone masonry and concrete terraces to support the building and the heavy machinery, while earthen terraces and substantial beamwork were sufficient for small mills.

The upper-most portion of a concentration mill consisted of several receiving bins which contained raw ore brought from the mine. The milling process began when mill workers fed rock from the bins into a *coarse crusher*, intended to reduce the material to cobbles ranging from 1 to 4 inches in size. Most mills favored jaw crushers to accomplish this, while a few large operations employed gyratory crushers. The crushed material passed into a screen system designed to permit acceptably small rocks to proceed to the next process, while returning oversized rocks back to the crusher. By around 1900 engineers favored using *trommel screens* or *shaking screens* to sort the rock. A trommel consisted of a concentric series of cylindrical screens that rotated, allowing fine material to drop through, while the oversized cobbles rolled out of an open end.[lxxxv]

At simple mills, the rock then proceeded to a *fine crusher* for further reduction. For much of the Gilded Age, millmen favored using the traditional *stamp mill* for fine crushing. The stamp mill consisted of heavy cylindrical iron shoes fitted onto the ends of a battery of between 2 and 5 iron rods known as stems. A camshaft raised the stems, which were over 8 feet high, and let them freefall in a staggered order. A heavy beam frame braced the ironwork, and a canvas or rubber belt passed around a bullwheel to provide the battery with power. The stamps dropped onto ore that millworkers had fed into a cast iron battery box bolted onto a laminated wood base. The stamp battery reduced the rock to a sand slurry, which proceeded to the next mill process once it passed through fine classification screens. Mills equipped for simple ores featured mercury-coated tables fixed underneath the discharge ports for the stamp battery, and the mercury amalgamated with the silver and gold in the sand. However, this proved futile with complex ores.

By the 1890s machines known as *crushing rolls* came into favor for pulverizing certain types of ores. A set of crushing rolls featured two heavy steel rollers with a gap between. As the rollers rotated under great power, they pulverized the rock until the fine material was able to pass through the gap. Machinery manufacturers offered crushing rolls with different gaps between the rollers to produce fines of varying grades. When an engineer desired a grade consisting of minute particles, he arranged a series of rolls with ever-closer gaps between the rollers, each machine reducing the material incrementally. Before the pulverized rock could proceed to the next process, it had to pass through another set of screens.[lxxxvi]

Tube mills and *ball mills* offered the finest grinding. Each appliance consisted of a large cylinder which millworkers partially filled with rock slurry and a little water. The cylinder slowly rotated, and iron rods in tube mills or iron balls in ball mills, tumbled in the chamber. Over time this action further pulverized the slurry within. Both types of grinding appliances saw use beginning around 1900, and millmen used them to reduce partially concentrated metalliferous fines. By the 1930s ball and tube mills were used in place of crushing rolls and stamp batteries.

After machinery reduced the rock to a desired size, usually ranging from the consistency of sand to dust, it entered the concentration phase. By the time mining was in full swing at Creede, millmen selected from a variety of appliances to process complex silver ores. The *Wilfley table* was by far the most popular concentration appliance, and it saw heavy application at Creede. The Wilfley table consisted of a tabletop, approximately 10 feet long and 6 feet wide at one end, and 5 feet wide at the other, coated with linoleum and thin wood riffles. The tabletop was mounted at a slant on a spring-loaded iron frame, and the machine imparted a jerky oscillation, which permitted the heavy metalliferous fines to gravitate to the bottom riffles, while the light gangue remained on the highest riffles. Mining machinery makers offered several variants of the Wilfley table, and each featured a slightly different tabletop, but all operated according to the same basic premise. The finest material at the bottom riffles may have passed on to additional tables for finer concentration, the *middlings*, which collected in the center riffles, may have returned to the fine crushing stage, while mill workers threw the gangue was away.[lxxxvii]

Millmen used two other types of appliances for concentrating metalliferous fines. The *jig* was an old appliance, but it saw use well into the twentieth century. The jig consisted of a heavy, iron-lined wooden trough featuring cells with screens placed above their floors. Plungers reciprocated in the water-flooded cells, and their action forced heavy, fine metalliferous particles to work through the lighter material, kept partially in suspension, and through the screens. Wilfley tables often subsequently processed the fines produced by jigs. *Vanners*, developed in the 1880s, utilized vibration and gravity to separate metalliferous fines from gangue. The vanner featured a broad rubber belt kept wet with water jets. Like the Wilfley table, the belt mechanism was slanted and assembled on a spring-loaded iron frame which vibrated vigorously. The heavy fines sifted through the material and adhered to the belt, while the water jets washed the gangue downward. The belt slowly advanced and dropped its coating of fines into a trough below. As with the jig, the fines produced by vanners were processed afterward by Wilfley tables.[lxxxviii]

Most of the ore reduction and concentration processes required water to mobilize the material being worked, and to allay dust. However, excess water became a problem for concentration. Engineers installed various *dewatering devices*, which ranged from conical and pyramidal settling boxes to *Dorr thickeners*. Mill workers introduced watery slurries into settling boxes, where the fines accumulated and were drawn out through spigots in the bottom for concentration. The Dorr thickener, devised for high volumes of material, featured a tank, at least 20 feet in diameter, with a conical floor. Radial arms rotated slowly within the slurry and they forced settled fines toward the tank's center, where the material passed through a large spigot.[lxxxix]

Gravity drew the metalliferous fines from one reduction and concentration process to the next. However, each step had to make allowances for returning inferior material back for reprocessing, be it for reduction or concentration. This meant defying gravity and sending heavy material uphill. To accomplish this, millmen used either a bucket line or a spiral feed. Bucket lines were often a series of closely spaced sheet iron pans stitched to an endless canvas belt, and they scooped material from one bin and deposited it into another. Spiral feeds, which were effective for moving fines short distances, typically featured an auger that rotated in a sheet iron shroud. As the auger turned, it moved the material upward and deposited it into a bin. Material handled in such a way had to be moist enough to act as a solid. When too dry, the pulverized rock created dust, and when too wet, the machinery could not move it.

Supplying power to all of the machinery located throughout a mill presented engineers with a considerable problem. Convention of the day dictated that when workers built a mill, they suspended overhead driveshafts from bearings bolted high in the building's frame. The drive shaft featured broad pulleys, and canvas or leather belts passed from them to drive pulleys on each mill machine. During most of the Gilded Age, steam engines powered the overhead driveshafts via more belts, and when electricity began to experience popularity after 1900, engineers substituted motors for the steam engines. Electricity came early to Creede, and while the power source was not well-suited for operating many types of machines used at mines, it was conducive to running mill appliances. Most of Creede's mills relied on motors for power, and some had steam engines for backup.

Today, mill sites typically possess characteristic telltale evidence, even after the machinery and building components were removed. Mill building foundations often appear as a group of terraces on a hillside with roads at the head and toe. The terraces may feature machine foundations, plank decking, residual crushed rock, and structural and industrial artifacts. The engineer usually designed the mill processes to extract the *mill tailings*, which are the powdered gangue, at every step of reduction and concentration, and eject them from the facility. The tailings left the mill in the form of a slurry and were piped into the nearest waterway when nearby, or deposited in a dump downslope. Tailings often also abound in and around the mill remains. While determining exactly which machines a mill included can be difficult, most concentration facilities followed the series of processes outlined in this section.

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CHAPTER 5

THE HISTORY OF THE CREEDE MINING DISTRICT

Silver is Discovered

For centuries the San Juan Mountains were the exclusive domain of the Ute Indians. Rugged, remote, and inhospitable, Spanish, then American explorers examined the piedmont areas surrounding the mighty range, but few ventured deep into the mountains. Rumors circulated that the Spanish had mined silver in the mountains as early as the late 1700s, and if so, their impact was limited. Then, in 1865, the Utes saw their isolation and peace begin to erode. A party of prospectors led by Charles Baker penetrated deep into the Animas River drainage in search of placer gold. The party encountered minor amounts of the metal near present-day Silverton, and while they did not locate economic quantities of gold, the prospectors' impact was great. The Baker party reported that the San Juan Mountains held great promise for mining, and they proved that the area could be accessed. During the next 10 years other prospecting parties imitated Baker, and in addition to placer gold, they sought hardrock gold and silver, which the San Juans offered in abundance. Their success in finding riches stimulated mining, which led to the growth of settlements such as Silverton, Ouray, Telluride, Lake City, and Rico. Due to the remoteness of the San Juans, and because of the threat posed by angry Ute Indians, mining developed slowly.

The Utes were not hostile at first. They understood that Whites were interested in minerals and not in extensive settlement, and they permitted prospectors to search the high country unmolested. However, as more Whites arrived in the early 1870s, conflict seemed eminent. When faced with the disaster of another Indian war, the federal government employed the typical strategy in which it coaxed the Indians into signing a treaty. In 1873, Felix Brunot, President of the Board of Indian Commissioners, held negotiations with Chief Ouray, and hammered out the Brunot Treaty. According to the agreement, the U.S. Government paid the Utes $25,000 for 4,000,000 acres of mineral-bearing land, and the Utes retained the right to hunt on the ceded territory. With the treaty in effect and the threat of hostile Indians mitigated, isolation became the main impediment to mining in the San Juans. To facilitate the region's development, Colorado road-builder Otto Mears, freight companies, and mining interests all contributed to the development of a network of roads, some barely passable even after completion, between the many settlements in the mountains.[1]

Ironically, the area that became Creede lay just several miles north of one of the most heavily traveled routes into the deep San Juans. Prospectors, freighters, and other travelers followed the Rio Grande River on their way to Lake City and the Silverton area, unaware of the riches that lay near Wagon Wheel Gap, which served as a way stop. Further, the Denver & Rio Grande Railroad graded a line through South

Fork, 20 miles south, increasing traffic along the Rio Grande.

After the Brunot Treaty had been negotiated, parties of prospectors felt less inhibited and they fanned out, searching remote and inaccessible areas of the mountains for ores. In 1876, one group including John C. McKenzie and H.M. Bennett, examined the area that became Creede, which was unsettled at the time. After considerable prospecting they discovered silver ore west of where the city of Creede would stand, and they staked the Alpha claim. The party failed to rouse interest in their find, and, still holding optimism for the area, returned on subsequent prospecting forays. In 1878 McKenzie discovered another ore body and staked the Bachelor claim, named after his marital state. Little did McKenzie suspect, as he erected his claim posts, that he was standing on one of Colorado's richest and longest ore veins. After prolonged failure to stimulate interest and arouse investors, Creede's first successful prospectors sold the Alpha in 1885 to brothers Richard and J.N.H. Irwin. McKenzie optimistically retained title to the Bachelor. After attempting to work the ores in arrastes, and after further futile searches, the various parties gave up.[2]

In 1889, 13 years after McKenzie and Bennett first drew attention to the area, another party of prospectors encountered bonanza ore. In May, Nicholas C. Creede, E.R. Taylor, and G.L. Smith located the Holy Moses claim on Campbell Mountain, which they named after their exclamation of astonishment and surprise at the strike's richness. Nicholas Creede, for whom the district is named, was no ordinary prospector. Creede was born William Harvey in Fort Wayne, Indiana in 1842. He fell in love with a young woman, and during their courtship she left Harvey for his brother. Harvey may have even married his beloved. Horrified, Harvey left home and changed his name to Nicholas C. Creede. The young Creede arrived in Colorado in 1870, lured by the sirens of mineral wealth. Creede successfully prospected in the Collegiate Mountains, and he had better luck than other hopefuls in the range's Silver Creek area. There, he sold an ore-bearing claim for a little money, and within a short time the purchasing company began turning a handsome profit. Creede felt that he had been taken, and vowed never to sell low again.[3]

Creede's demise was tragic. After locating the Holy Moses claim, the party of prospectors interested an investment syndicate including mining and railroad magnate David H. Moffat, U.S. Army Captain L.E. Campbell, and Denver & Rio Grande Railroad general manager Sylvester T. Smith. The business trio not only supplied capital to develop the property, but they hired Creede to serve as their professional prospector. Their decision to retain Creede proved wise, because he subsequently staked the Ethel claim, and in 1891 he located the fabulous Amethyst Mine. Creede sold a share of each of his finds to his employers, but remembering his lesson learned in the Collegiates, he kept a substantial portion for himself. Creede had accomplished what other prospectors only dreamed of. He encountered mineral wealth several times and profited handsomely from each. Within a short time Creede retired in Pueblo, then moved to Los Angeles in 1893 to enjoy the mild, dry, sea-level climate. A storm was brewing for Creede in the East, however. By 1897 Creede's estranged wife, of whom little is known, had learned of her spouse's good fortune, and she made it known that she was planning on coming out West to live with Creede. When Creede learned of his wife's intent, he panicked, and in his despair he took an overdose of morphine.[4]

The word of Creede's find began spreading through Colorado, and prospectors traveled to the King Soloman district, as the area was then known, in 1890 to examine the potential. Several new-comers and seasoned prospectors made further discoveries, lending to the growing curiosity. Veteran prospectors Dick Irwin and Nick Crude, who served as one of Kit Carson's scouts, encountered silver and lead ore near the old Alpha claim. In 1891 a party of prospectors including Theodor Renniger, Ralph Granger, Julius Haas, and Eric Von Buddenbock, subsisting on a $25 grubstake, set up camp and began their search for wealth. The party encountered samples of float along the banks of West Willow Creek and followed the lead upslope. Unsure of what they had found, the prospectors asked Creede to examine their strike and pass judgement. Creede immediately recognized the richness of the ore, and urged the prospectors to stake claims, which they did under the name Last Chance. Inspired by the party's find, Creede calculated the orientation of the ore body, traveled a short distance north, and staked the Amethyst claim. The Last Chance and Amethyst mines became the district's wealthiest operations.[5]

Creede and his party of prospectors interested the Moffat syndicate in the Holy Moses in 1891. The district was largely unknown to the mining world at that time, and Moffat probably surmised that he and his associates were presented with a mining investors' dream. Moffat's syndicate had the opportunity to buy a cluster of fabulous mines at low prices, before attention from the mining world drove prices up. The Moffat syndicate's interest in Creede's claims lent legitimacy to the area and served as a crack in the dike retaining the waters of further investment.

Shortly after Creede and Moffat's deal for the Soloman, Renniger and his party acquired investors for the Last Chance. Julius Haas sold his share in the claim to the other three prospectors for $10,000. Renniger and Von Buddenbock sold their shares to investors Jacob Sanders and S.Z. Dixon for $50,000 each. Like Creede, the last of the Renniger party, Ralph Granger, refused to completely sell out, even when offered $100,000. Granger, Dixon, and Sanders interested Willard Ward and silver magnate Henry O. Wolcott in the property, and the men formed the Last Chance Mining Company. The activity in the district had finally drawn the attention of the mining industry. The conservative mining periodical *Engineering & Mining Journal* described the finds as "immense", lending fuel for a rush.[6]

Reports of the Creede district's wealth began rippling first through Colorado, then through the West, and finally to other parts of the nation in 1891. Mining industry workers, professional miners, roustabouts, and hopefuls ventured to the new area, causing the area's population to soar. Most of the newcomers stopped over in one of several camps near the Rio Grande River, and many continued several miles up to the high country to stake claims. By 1891 prospectors had determined that the best ore was concentrated in three vein systems, the Amethyst, Holy Moses, and the Alpha, discussed in the geology section above.

East and West Willow creeks served as the principal gateways to the Holy Moses and Amethyst veins, respectively, and camps naturally sprung up at the creeks' confluence. Prospectors had established the camp of Creede on East Willow Creek as early as 1890, the camp named Jimtown grew along the main trunk of Willow Creek approximately one mile downstream, and South Creede sprang up downstream from Jimtown. Crude's Camp, also known as Sunnyside, rose to the west near the Alpha ore system. Each town became a commercial center, attracting merchants, the offices of brand new mining companies, and local government. Tides of miners and prospectors coming from and going to the workings ebbed and flowed through the settlements.[7]

The Creede district's four main camps were typical of the West's boomtowns spawned by mining rushes. The inhabitants focused on making money, and as a result the development of social and physical infrastructures became a secondary priority. Architecture was also a secondary consideration. At first, the camps consisted of a mix of wall tents, log cabins, and rough frame buildings, all with limited floor space. Yet, businesses such as saloons, hotels, and mercantiles abounded. Like other Western mining settlements, Creede's camps grew in topographically inappropriate places. Except for Sunnyside, the other camps were located in the deep and constricted canyon of Willow Creek, which presented traffic problems and the threat of flooding. By 1891 the population of the camps along Willow Creek soared from several groups of prospectors to approximately 1,000 inhabitants.[8]

The prospecting and mining activity on the Amethyst and Holy Moses veins was as frenetic as that in the burgeoning settlements below. Prospect operations, in varying stages of development, extended for over two miles along both veins. Prospectors had blanketed the ground with claims, which restricted the available surface space for each operation. As a result, prospectors and miners explored their claims at depth predominantly through vertical and inclined shafts, instead of adits. Parties of prospectors using primitive hand windlasses worked in the shadows of advanced, heavily equipped steam operations. All sought bonanza ore.

Great distances and a terrain that can be described as treacherous, at best, separated the settlements along Willow Creek from the workings on the veins above. Miners and prospectors found it most convenient to live at or near their operations, instead of making the twice-daily trek. Not only would a commute by foot or horseback have consumed too much time and energy, but also such travel bordered on impossible in adverse weather, especially during the winter. As a result, several small camps formed. When the search for ore gave way to extraction, mining companies erected boarding houses at their mines for the same reasons.[9]

Creede's boom peaked in 1892 and 1893. The Denver & Rio Grande Railroad graded a line up the Rio Grande River from its main track at South Fork to the settlement known as South Creede. The D&RG RR later extended the rail line to North Creede. During the boom, trains were bringing up to 300 immigrants per day to the district, and the population of the Willow Creek settlements swelled to 8,000. During this time Jimtown and

South Creede merged to form the town of Creede, and the original Creede, located on East Willow Creek, became North Creede.[10]

The dramatic increase in population and economic activity fostered a need for a formal local government. The problem with representation lay in the fact that the Creede district overlay the intersection of Saguache, Hinsdale, and Rio Grande counties. In 1893 Mineral County was carved out of the three counties. Ironically, the town of Creede was not the original county seat. The honor went to the townsite of Wason, located on the Wason Ranch south of Creede. The residents of Creede were outraged, and they thought Martin Van Buren Wason, a powerful local rancher and transportation mogul, pirated the county seat, and after a considerable fight, they moved it to Creede.

Not only did the Creede boom offer possibilities to those seeking mineral wealth and jobs at the mines, but the lawlessness and abundant money presented opportunities for gamblers and criminals. People of mythic proportion, both honest and crooked, called early Creede home. Prize fighter Jack Dempsey started his boxing career while a boy in Creede. Bob Ford and Bat Masterson both operated saloons and gambling houses in town, and Poker Alice practiced her questionable card games in Creede. Gambling shark Bob Fitzsimmons had a statue of a man cast in concrete, and buried it in the mud of Farmers Creek. One of his underlings "discovered" the seemingly petrified man, and Fitzsimmons used it for publicity. But Jefferson Randolph "Soapy" Smith was the most notorious criminal to live in Creede. Smith earned his nickname in Denver by playing a con game in which he inserted a $20 bill under the wrapper of a bar of soap and mixed it in with a bushel of ordinary bars. For a small sum of money, he permitted individuals to select one bar from the bushel in an effort to retrieve the salted bar that Smith had buried. Curiously, few people ever won playing Smith's game. By the early 1890s, Smith had become a well-known and clever gambler, and was respected in the underworld. Seeing Creede as an opportunity, Smith established himself there, and became involved in local politics which he tied into his ring of organized crime. He reigned for several years, trying to walk a fine line between Creede's honest citizens and his shady syndicate. Smith appeased both sides by permitting gambling, some of which was crooked, as well as prostitution, while squashing petty crime and overt lawlessness. Smith left Creede in 1893 following the death of his friend, Joe Simmons, and in the face of the economic depression caused by the Silver Crash.[11]

Silver ore began pouring out of the district's principal mines by 1892, and the towns along Willow Creek began to exhibit signs of mature industrial communities. In the town centers, the ramshackle architecture of the earliest inhabitants gave way to large, stately frame buildings. Six sawmills, operated by the Creede Lumber Company in surrounding forests, supplied lumber. In 1892 Lute Johnson founded the *Creede Candle*, and the famous Cy Warman established the *Creede Chronicle*. The *Candle* published newspapers until 1930. Creede hosted the district's first school, and the town of Creede was officially incorporated. New comers and some of the district's original prospectors, such as C.F. Nelson, sat on local governmental panels. Destruction visited Creede in

1892, when a significant portion of the town burned, and the area near Willow Creek succumbed to flood waters. Activity in the towns continued unabated, however, until the fateful year of 1893.[12]

To many residents, the experience of life in early Creede was nothing less that exciting. Above the noise, traffic, bustle, talk of mineral riches, and money, stood optimism and the romance of Western mining. This environment spurred Cy Warman to write the famous poem capturing the essence of early Creede:

CREEDE

Here's a land where all are equal –
of high and lowly birth –
A land where men make millions,
dug from the dreary earth.
Here the meek and mild eyed burro
on mineral mountains feed –
It's day all day, in the day-time
And there is no night in Creede.

The cliffs are solid silver
with wond'rous wealth untold;
And the beds of running rivers
are lined with glittering gold.
While the world is filled with sorrows
and hearts must break and bleed,
It's day all day, in the day-time
And there is no night in Creede.[13]

During the early 1890s the mines on the Amethyst Vein also began showing signs of maturation. The large operations drew a growing workforce, and they required an infrastructure for fuel, water, and transportation. The town of Bachelor, named for the Bachelor Mine, sprang up on a grassy area at the vein's south end, and the town of Weaver grew deep in West Willow Creek's canyon near the vein's mid-point. Mine workers and merchants serving the area's mines established Bachelor in 1891, and they platted the townsite in 1892. By 1893 the town hosted 8 stores, 10 saloons, assay offices, boarding houses, and several hotels and restaurants. The town center was small, but the residences and boarding houses associated with the numerous mines, up to several miles away on the Amethyst Vein, were included, peaking the population at a questionable 6,000. Because the town kept a fire engine on hand, Bachelor's most significant fire claimed only several business buildings.[14]

The town of Weaver never attained the size or degree of formality that Bachelor experienced. At its peak, the town consisted of a collection of rough frame and log cabins, and a few wall tents, located at the confluence of two deep canyons. Miners and workers of the Amethyst and Last Chance companies, and teamsters constituted the bulk of Weaver's population. The town hosted a school, which reflects the strong presence of an industrial working population. Bachelor and Weaver both thrived until the disastrous year of 1893.

Figure 5.1 Jimtown as it appeared around 1891. The view is southeast, and the Rio Grande River valley lies in the background. The district's first prospectors called the rough settlement home. Courtesy of Colorado Historical Society (F-4850 S0025673).

Figure 5.2 In the early 1890s the city of Creede, known then as Lower Creede, was a tangle of merchants, hostlers, restauranteurs, prospectors, speculators, and freighters weaving their way amid construction and traffic. Courtesy of Colorado Historical Society (William Henry Jackson 30655 S0025189).

The Mines

The towns of Creede, North Creede, Bachelor, and Weaver would have remained primitive camps were it not for the rich mines on the Amethyst and Holy Moses veins. Between 1891 and 1893 the Creede district's principal mines included the Bachelor, the Last Chance, the New York, and the Amethyst, all of which penetrated the Amethyst Vein. The Holy Moses, the Soloman, and the Ridge mines, also exceedingly wealthy, lay along the Holy Moses Vein. Of this group, the Amethyst and Last Chance mines stood out as the top producers.

The Moffat syndicate owned the rich Holy Moses and Amethyst mines. When the Moffat syndicate purchased the Holy Moses, it formed a mining company with L.E. Campbell as general manager, and it secured the services of a competent mining engineer who equipped and developed the property. Thirty workers and miners erected a surface plant and drove exploratory drifts and crosscuts to block out ore. To the Moffat syndicate's delight, they encountered 18 inches of native silver and galena ore which assayed at $1,000 per ton. Production began, and miners brought 30 tons of ore to the surface per day. By 1893 the value of the ore had dropped to $100 per ton, which was still a handsome return.[15]

Senator Thomas Bowen, a San Juan mining magnate, purchased the King Soloman Mine and the Ridge Mine from C.F. Nelson, he organized a mining company, and put these properties into production. Like the Holy Moses Mine, miners began developing the King Soloman, and in 1892 they too struck phenomenally rich ore.

On the Amethyst Vein, the Moffat syndicate formed the Amethyst Mining Company to work Creede's spectacular find. During the mine's early operating period, Senator Thomas Bowen and L.D. Roundebush bought into the company. The syndicate hired a capable mining engineer who followed standard convention when he developed the property. The engineer equipped the mine with a sinking plant, which he upgraded once miners had blocked out sufficient ore. In 1892 the engineer had mineworkers erect a large shaft house enclosing a new steam hoist and an 80 horsepower boiler. By this time miners were producing 35 tons of ore per day, and to accommodate this, and the greater volumes anticipated, the mining company financed the construction of an innovative and efficient ore handling system. Miners input raw ore from the mine into an ore sorting house on the surface. There, workers separated waste and deposited the concentrated ore into several holding bins. An aerial tramway transported the ore from the ore sorting house across 2 miles of the most hostile terrain down to another set of holding bins serviced by the D&RG RR at North Creede. This ore handling system permitted the mine to produce ore in economies of scale.[16]

The Wolcott syndicate owned the fabulous Last Chance Mine. Henry O. Wolcott was a lawyer, eventually a senator, a promoter of Colorado business, and a member of Denver's elite. The Wolcott family made its fortune in Colorado silver through rich mines in the central portion of the Rockies, and through Colorado business and finance. Henry's brother, Senator Edward O.

Figure 5.3 In 1892 the Moffat syndicate financed the erection of a production-class surface plant at the Amethyst Shaft. In the view, which faces south, workers have completed a return tube steam boiler, visible at photo-center, and they are preparing to assemble the steam hoist. The hoist's components lie to the left of the boiler. After the workers installed the machinery, they enclosed the facilities in a shaft house. The Last Chance Mine is the complex of buildings at the upper left, and the New York Mine is at top center. Courtesy of Colorado Historical Society (S0025678).

Figure 5.4 View south of the Last Chance Mine during the winter of 1893. The shaft house is the prominent building at right, and the blacksmith shop stands in front. The covered trestle supported the track for dumping waste rock. Much archaeological evidence left by this operation currently remains at the site. Courtesy of Colorado Historical Society (F-24096 S0025675).

Wolcott, heavily influenced Colorado business and politics. The Last Chance Mining & Milling Company secured the services of a competent mining engineer, like the Amethyst operation. The engineer probably installed a sinking plant to facilitate mine development, but once this was complete, he had mineworkers painstakingly erect possibly the most extravagant production-class surface plant in the district. To achieve ore production in economies of scale, the engineer equipped the mine with a massive direct-drive double drum steam hoist, which raised and lowered two hoisting vehicles in a three-compartment shaft. The surface plant also included an air compressor, several return tube boilers, a spacious shop, and a massive ore sorting house. Freight wagons hauled the ore to the rail line in North Creede.[17]

The Moffat syndicate, which now included Senator Thomas Bowen, purchased the Bachelor Mine from J.C. McKenzie for $20,000 in late 1891 or early 1892. The Bachelor Mine, which lay south of the Last Chance operation, did not experience production until 1892. Miners began developing the property through a tunnel, which prospectors had driven 350 feet during the previous year or two. Miners expanded the underground workings and erected a relatively simple surface plant. The mine would become a substantial producer at a later time.[18]

In 1892 A.E. Reynolds purchased the Commodor Mine from McKenzie, and he acquired the New York Mine. A.E. Reynolds was not as well-known as other Colorado mining moguls, however, he invested heavily in San Juan mines, and his capital made many operations in the region possible. The New York Mine occupied ground upslope from and west of the Last Chance property. In fact, the New York claim overlapped a portion of the Last Chance claim, which led to litigation between Reynolds and the Wolcott syndicate. The mine's owner hired an engineer who erected a modest surface plant to facilitate exploration during 1891, and in March of 1892 miners struck rich ore. Unlike many mining Western mining companies, Reynolds was reluctant to see his profits go to lawyers instead of his own coffers. As a result, he formed a cooperative merger with the Last Chance Mining & Milling Company, and the interests consolidated their holdings.[19]

Colorado's silver barons were handsomely rewarded for their investments in Creede's mines. Within a year the mines produced $4,200,000 in silver, 50% of which came out of the Amethyst, and 30% of which came from the Last Chance. And to their delight, production increased during 1893.[20]

In marked contrast to the Creede district's principal mines, the other operations on the Amethyst and Holy Moses veins remained in a primitive state between 1891 and 1893. Nearly all of the additional operations consisted of deep prospects equipped with conventional temporary or sinking-class surface plants. Most of the mining companies on the Amethyst Vein were either searching for or had just encountered ore in 1892, but had not proven the vein's extent. Most operations of similar magnitude on the Holy Moses Vein would prove to be worthless. Because the topographical relief on the south portion of the Amethyst Vein varied, prospecting outfits were able to explore their claims through adits, which required less capital. The topography overlying the vein's north portion, however, was relatively flat, necessitating that prospect outfits sink shafts to search for ore.

During the early 1890s the prospects at Sunnyside, in the western portion of the district, appeared to hold great promise. The strikes made by John C. McKenzie and H.M. Bennett at the Alpha in 1876 led to a close inspection of the area by prospectors during Creede's early boom, and several claims with showings of ore were developed in 1892. The Kreutzer-Sonata Mine, the Monon Mine, and the Sunnyside were the most significant operations. However, bonanza ore failed to materialize, and the excitement on the Amethyst and Holy Moses veins eclipsed the activity at Sunnyside. Further, the Silver Crash of 1893 snuffed out what little interest existed in the marginal properties. Sunnyside would attract attention again at a later time.

Progressive mining engineering and technology came early to Creede. In 1892 John W. Flintham, manager of the Denver Consolidated Electric Light Company, realized the potential electric market that Creede presented. He organized the Creede Electric Light and Power Company and ordered a construction crew to build a small electrical generating plant along the D&RG RR right-of-way in Creede. The plant consisted of a dynamo turned by a steam engine, which was powered by a return tube boiler, all enclosed in a 24 by 95 foot frame building. Creede's plant was modest and capable of generating only enough power to energize electric light circuits and run some simple mine machinery. Despite its modesty, Creede's plant was important to the mining industry, because it was one of the first generating plants erected in the West. More than 20 years would have to pass before the mines in Creede would see electrification to any great extent.[21]

The surface plants erected by prospecting outfits to support work in adits typically consisted of a simple blacksmith shop, a mine rail line, a timber dressing area, and often an associated residence. The surface plants associated with shafts included a hoisting system, which ranged from the hand windlasses erected over shallow shafts, to horse whims, to steam donkey hoists, to stationary sinking-class steam hoists and portable boilers. Most of the district's prospect operations never progressed beyond their sinking class surface plants for economic and for technological reasons, discussed below.[22]

During the Creede district's first boom, the mines and the needs of the work force fostered an enormous demand for food, dynamite, tools, and machinery. By 1892, the district's principal mines began producing ore in economical volumes, which had to be delivered to the D&RG RR railhead in North Creede. Pack trains were far too costly and inefficient to manage the district's freight. The need to move the materials of mining required the establishment of a transportation infrastructure throughout the district capable of accommodating wagons. By the mid 1890s all of the principal mines, most of the substantial prospect operations, and the townsites were accessed via roads. The network was probably created by a combined effort. Workers employed by individual mining companies completed feeder roads, and construction contractors funded by subscriptions contributed by the district's businesses and mining companies graded main thoroughfares.

The roads between the towns on Willow Creek and the mines up on the

Amethyst Vein handled an enormous volume of traffic. The grades in West Willow Creek's canyon proved especially treacherous, both during construction and while in use. An old-time resident of Weaver recalled how a construction crew was blasting a road above the town, probably to the Amethyst Mine. During one particular incident, the blast sent a boulder rolling downslope, and it bounded toward town. Just as a sick man rose out of bed for a drink of water in a cabin below, the boulder crashed through the roof and crushed the bed in which he had just been laying. While run-away wagons and other accidents were not uncommon on the steep grades to the mines, the worst road in the district was the "Black Pitch", between Weaver and North Creede. Despite precautions such as wheel locks and strong harnesses, wagons broke loose and plunged into the ravine, occasionally killing teamster and team.[23]

The teamsters who plied Creede's roads were described as being rough and rowdy. Most lived in either Creede or Weaver, and they made approximately two round trips per day between the ore holding bins at North Creede and the mines. Teamsters served all of the mines on both veins, except for the Amethyst and Holy Moses mines, which relied chiefly on their aerial tramways to haul ore.

All of the supplies hauled up to the mines, and all of the ore that flowed down from them had to pass through the town of Creede. Local cattle king Martin Van Buren Wason understood this. In fact, he forecasted the need for a central artery to Creede, and graded a toll road to the promising camp in 1891 in expectation of reaping a handsome profit. The road to Creede was not Wason's first experience with toll roads. Wason was born in New Hampshire and became a sailor at an early age. He weathered the dreaded Cape Horn during several sailing voyages, and he spent much time in Central and South America. While in these remote lands Wason served as a captain on a pearl boat, he became a rancher in Argentina, and mined gold in Central America. Wason returned to the United States via California in 1870, and there he acquired a small herd of fine horses. In 1871 he drove his herd, accompanied by Vaqueros, through parts of the West until he arrived in Colorado. On his way from Poncha Springs to the San Luis Valley, Wason arrived at Otto Mears' toll gate on Poncha Pass. Having insufficient money to pay the necessary toll, he was forced to retreat and sneak around the gate by traveling a wide arc through the surrounding mountains. This included making numerous trips to transport supplies and disassembled wagons. When Wason established a ranch on the Rio Grande, he remembered his dependence on toll roads and graded his own, in hopes of making a profit. Wason's road, used by immigrants and freighters bound for mines in the deep San Juans, extended from Wagon Wheel Gap at the south, past his ranch, and terminated north. He linked the road to Creede with his original trunk line.[24]

Wason's greed led to protracted problems with the mining community. He had workers erect a toll gate on his road and charged wagons 75 cents to pass, which was an exorbitant fee. The citizens, and especially the mining companies, were justifiably outraged, and they considered the road to North Creede to be a public thoroughfare. Their outrage reached uncontainable proportions in 1892, and they hung a dummy of Wason in effigy. Wason, fearful, hired Jesse H. Stringley as a guardian. Stringley carried a six-gun and a badge, but the gunfighter was arrested on the grounds of impersonating an officer of the law, and defrocked. Sentiment against Wason continued to be strong, and he was unprepared when the powerful mining interests brought their political and economic might against him. As the mining interests went, so went Creede. F.M. Osgood, M.J. Connolly, Mike Regan, and L.C. Lowe appealed to the Hinsdale County Commissioners to force Wason to turn the road over to public domain. The commissioners, upon investigation, discovered that Wason's underlings had levied tolls against all wagons, and not merely those laden with ore, as his contract with the county had specified. Wason's toll officers were arrested, and in their absence, under the cover of night, some of Creede's men, probably teamsters, dismantled and removed the toll gate. It vanished without a trace. Creede's war against Wason was won, but not entirely over. When Creede attempted to remove the new Mineral County Seat from Wason's under-populated townsite, Wason retaliated by threatening to resurrect the toll gates. The officers of the big mines took political and economic aim at Wason, and he backed down. The war ended when Colorado's governor purchased the road in 1899 for $10,000.[25].

Mining at Creede Collapses

The excitement, the search for wealth, and the conversion of the wilderness into an industrial landscape was just beginning to reach a crescendo when the Silver Panic of 1893 struck. Ever since hardrock mining began in the West, the price of silver has fluctuated in response to natural market forces, and in response to the implementations and revocations of federal price supports. Western senators, such as Creede's Henry and Edward Wolcott, and Thomas Bowen, were instrumental in instituting price support programs. The Bland-Allison Act of 1878 mandated that the Federal Government purchase silver at a guaranteed price, which caused the value of the semi-precious metal to rise to $1.15 per ounce. In direct result, mining in the San Juans intensified. A decrease in the price of silver in 1886 severely hurt mining. In 1890 the Western senators again pushed for price supports and passed the Sherman Silver Purchase Act, which boosted the price of the white metal to $1.05 per ounce. The artificially high price affected Creede, because silver barons such as David H. Moffat, Senator Thomas Bowen, the Wolcotts, and A.E. Reynolds began campaigns to acquire and develop the mines.[26]

The silver tide ebbed in the West in 1893 when reformists repealed the Silver Purchase Act. The price of silver plummeted from around $1.00 to 60 cents. Mining in Colorado, New Mexico, Nevada, and Idaho completely collapsed. The ripple affect caused a panic that overcame at first the West, then other parts of the nation, resulting in an economic depression. Western silver towns, including Creede, were devastated, and Colorado’s silver miners faced the challenge of having to seek alternative modes of employment. Lucky for them, Cripple Creek, which was a gold-producing district, was under development and in need of skilled miners. The silver barons lost fortunes, and the less affluent mining investors lost all.[27]

Twilight overcame the Creede Mining District. By the end of 1893 a significant portion of the district's population migrated elsewhere, and only the Amethyst and Last Chance mines continued to operate, albeit at low levels. All of the district's other mines and prospects were either totally abandoned or idle. The towns of Bachelor and Weaver, directly dependent on the Amethyst Vein's mines, lost nearly all of their residents and businesses. Creede and North Creede also lost much of their residents, and the D&RG RR dramatically curtailed rail service. However, Creede possessed two factors unique to other silver mining districts also in economic duress. First, the Amethyst and Holy Moses veins contained amazingly rich ore capable of providing income even at silver's abysmally low prices. Second, the mines' owners were adamant about profiting from their investments. The key to success, they determined, was to produce ore in unprecedented volumes. They employed technology and engineering to achieve production in economies of scale, drastically reducing the cost of mining.

By March of 1894 the Creede Mining District began a slight recovery. Several mines in addition to the Amethyst and Last Chance properties resumed operations, employing a total of 500 mineworkers. During 1894 and 1895 optimistic investors resumed exploration and development of several properties on the Amethyst Vein, which would ultimately net them profits. The Del Monte Mining Company began to deepen its shaft and explore its claim, which lay southeast from the Last Chance Mine. David Moffat, W.B. Felker, Byron E. Shear, and W.H. Byrant used the hard times experienced by investors during the economic depression, and they purchased the Happy Thought Mine, north of the Amethyst Mine, and in 1894 they financed a resumption of shaft sinking on the property. Last, O.H. Poole funded the installation of a sinking class plant and the erection of a 10 stamp mill at the Park Regent Mine, located at the north end of the Amethyst Vein. Most of the miners working at these operations lived in boarding and bunkhouses on-site.[28]

As the national and state economies recovered in the several years following the Silver Crash, mining in Creede resumed. All of the principal mines reactivated, and work resumed at some of the developed prospect operations. The principal producing mines on the Amethyst Vein at this time included, from south to north, the Bachelor, the Commodor, the Del Monte, the New York, the Last Chance, the Amethyst, the Happy Thought, the White Star, and the Park Regent. The principal active mines on the Holy Moses Vein included the Soloman, the Ridge, the Holy Moses, the Outlet, and the Phoenix. In all, the number of principal mines active after the Silver Crash increased.

Figure 5.5 The big operations on the Amethyst Vein resumed mining by 1895. The Amethyst Shaft complex lies at lower left, the Last Chance Mine is right of center, and the New York Mine is at top right. Compare this photo with Figure 5.3. The view is approximately the same. The numerous smokestacks at the Amethyst Shaft indicate that the mining company added several boilers to the power plant. Note the women and children standing at lower right. Courtesy of Colorado Historical Society (F-1134 S0025676).

Figure 5.6 In 1895 O.H. Poole had the Park Regent Mine's facilities upgraded. Mine workers assemble lumber and a return tube boiler shell (left of center) in preparation for construction. This north view depicts the mine's shaft house and a portion of the associated residential complex at left. Courtesy of Colorado Historical Society (F-29362 S0025674).

Engineers Come to the Rescue

Mining engineering played a key role in the resumption of profitable mining at Creede in the late 1890s. On an individual scale, the district's mining companies improved their surface plants to facilitate the production of greater volumes of ore at a lower cost per ton. The Amethyst Mining Company installed a larger hoist and set of boilers, which permitted rapid hoisting speeds from greater depths. The Bachelor Mining Company hired a crew of miners to develop its vein through a series of tunnels, permitting the extraction of ore simultaneously through several levels. To efficiently move the great tonnages of pay rock to the railhead at North Creede, Bachelor engineers erected an aerial tramway similar to those that operated at the Holy Moses and Amethyst mines. The Happy Thought Mine installed a bigger hoist like the Amethyst. Many of the large mines which did not have air compressors to power mechanical rockdrills installed the machines to expedite the drilling and blasting process underground.[29]

Another engineering tactic that some of Creede's large mining companies exercised involved milling the ore locally. In the late 1890s and early 1900s the Soloman, the Ridge, the Happy Thought, and the Amethyst mining operations erected small ore reduction mills near their mines. The idea was not to produce refined silver bullion, but to reduce and concentrate the metals content, and ship the concentrates to a smelter. Prior to the erection of these mills, Creede's mining companies exported all of its raw ore to smelters at Pueblo and Denver, Colorado, to Joplin, Missouri, and probably to Omaha, Nebraska. The smelters crushed and concentrated the raw ore, then extracted and separated the metals. To turn a profit, the smelting companies levied a per-ton charge for processing. By concentrating the ores on-site, Creede's mining companies not only saved a portion of the smelters' processing fee, but they saved shipping costs, because the heavy, worthless waste rock was removed.[30]

O.H. Poole erected the first concentration facility at Creede when he installed a 10 stamp mill at the Park Regent Mine in 1895. Poole's mill, however, was a failure. Poole relied on two batteries of stamps to pulverize the ore, and another mechanical process to concentrate the slimes. The machinery that Poole selected was inappropriate for Creede's silver and lead ore. The mining engineers working for the district's large mining companies had theoretical and practical experience with milling silver ores, and they designed effective facilities. The standard treatment for Creede's ores began with reduction by a primary jaw crusher. Cornish rolls, which were pairs of heavy iron drums, and ball mills pulverized the rock fragments. The rock may have passed through up to three sets of rolls or ball mills, each designed to further reduce the crushed rock. The fines produced by the rolls were sent to concentration tables, which used gravity to separate waste from metal-bearing materials. The tables consisted of iron frames bolted onto the mill floor, and table tops designed to vibrate. The table tops lay at a slight pitch and they featured riffles, and as they rapidly vibrated the light waste floated upward and the heavy

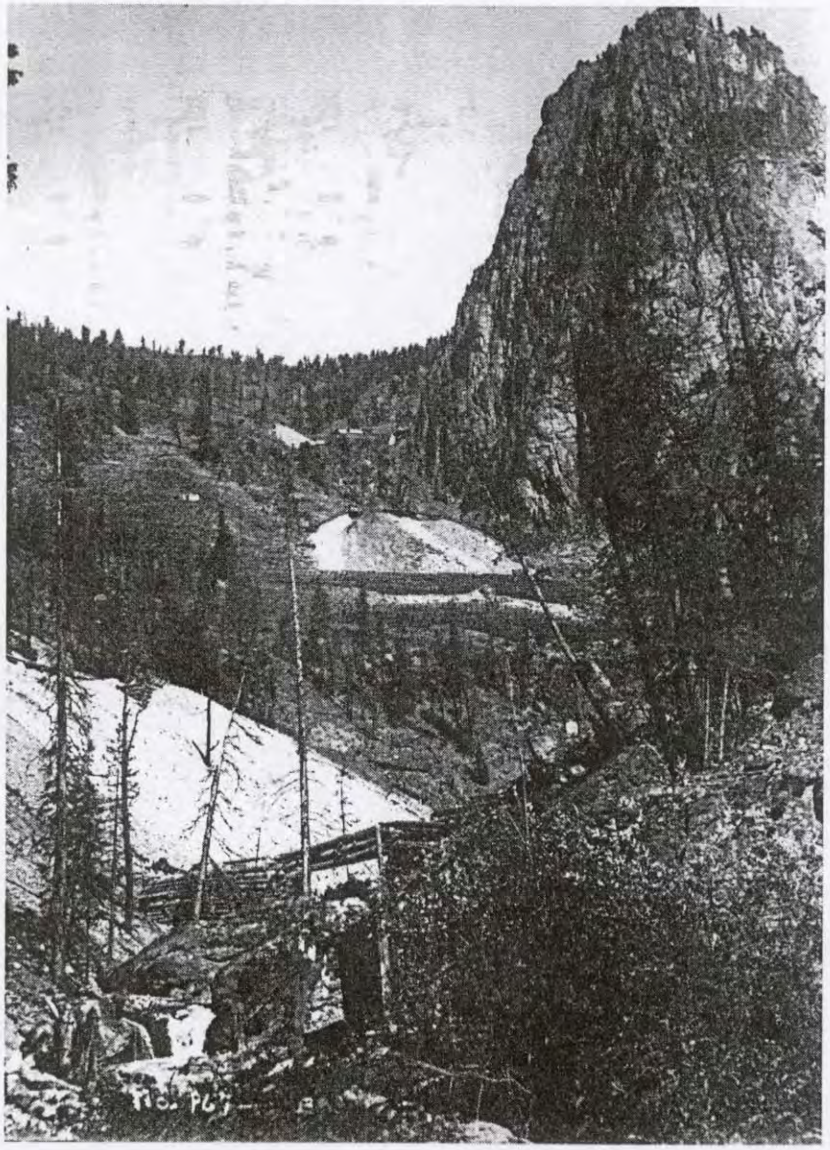

Figure 5.7 The Bachelor Mining Company developed its property through two principal tunnels. The lower tunnel, defined by the waste rock and log cribbing walls near photo-center, served as a haulageway. The upper tunnel is denoted by a small waste rock dump above. The waste rock dump at lower left belongs to either the Nelson Tunnel, or the Commodor Tunnel No.5. The photo was taken in the late 1890s, and many of the structures at the Bachelor dating to this era remain. Courtesy of Colorado Historical Society (S0025670).

metal-bearing fines worked their way downward. Creede's mills may have included a series of such tables to further refine the concentrates produced by previous tables in the circuit. The mills' end product consisted of shipping-quality concentrates.

The mills erected by Creede's big producers followed the technological convention of the day, and their sizes and assemblages of equipment were relative to the mining company's volume of production and capital. The Amethyst Mill included several circuits for processing ore, while the Happy Thought Mill consisted of one circuit. Modern electric motors powered the Happy Thought Mill, and electric motors backed up by a steam engine powered the Amethyst Mill. The mills' engineers used common means to transfer power from the motors to the mill machinery. The motors and steam engines turned overhead drive shafts mounted in the buildings' rafters, via canvas belts. Additional belts extended from the drive shafts to the mill machinery. The engineers also followed convention when they designed the mills to rely on gravity to transfer the materials from one step in the concentrating process to the next. To achieve this desired gravity flow, all of the mills were built on terraced hillsides.[31]

In 1901 the Moffat interests added the Humphreys Mill to Creede's roster of concentration facilities. The Humphreys Mill was by far the district's largest, and it represents another attempt to save money by concentrating the ore locally. Engineers applied state-of-the-art technology when they designed the mill and selected the appliances. Like traditional mills, the Humphreys facility used gravity to move the rock between stages of reduction, and it included several independent circuits for concentrating ore. The mill, located on the west bank of West Willow Creek at North Creede, began operating in 1902 and it treated ore hauled out of the Nelson Tunnel. While construction workers were completing the mill, D&RG RR track gangs graded a spur line to the mill's base so that finished concentrates could be shipped by train. Engineers erected a hydroelectric plant by the mill to supply power for drive motors. However, they miscalculated the degree to which West Willow Creek's flow fluctuated, and to their chagrin, the creek slowed to a trickle in the winter of 1903. In response, the engineers installed a backup steam plant to see the mill through future winters. The Humphreys Mill operated for well over 10 years, returning the initial investment plus profits to the mill's financiers.[32]

In addition to improvements made to individual mines and the installation of ore reduction mills, the mining interests of Creede applied engineering on a broad scale to boost the volume of production and lower the costs of mining. The mines on the Amethyst Vein faced the problems of a high water table, poor ventilation, and an increase in operating costs with depth. In 1892, when the district was enjoying its first boom, Charles F. Nelson, who discovered the Soloman Mine, organized the Nelson Tunnel Company with the intent of remediating these problems for at least some of the mines. Nelson served as the company's director, A.W. Brounell acted as president, and J.S. Wallace was treasurer. Nelson held visions of using the tunnel as a prospect bore to search for deep ore, of using the tunnel as both a drain and enormous ventilation duct for the mines, and as a haulage way for ore trains. Nelson also promoted the minor benefits of his proposed tunnel, such as serving as an escape route in instances of fire, and acting as a platform from which mining companies could develop deep ore. Nelson proposed establishing a portal and surface plant on West Willow Creek below the Bachelor Mine, and driving the tunnel along the Amethyst Vein. David Moffat's and Henry Wolcott's mines were at once interested. The cost of the project would, of course, be enormous. Nelson expected to cover the costs by charging subscription fees, and levying a toll per ton of ore hauled through the tunnel.[33]

The Bachelor Mine possessed the first workings that the Nelson Tunnel would encounter, and so Moffat's Bachelor Mining Company naturally was the first operation to subscribe. Nelson had mineworkers erect a surface plant consisting of a well-equipped shop, an air compressor that powered mechanical rockdrills, and a generator driven by a Pelton water wheel, on waste rock 400 feet east of the tunnel portal. Miners managed to drill and blast 1,500 feet before the Silver Crash of 1893 brought the project to a halt. This distance brought the tunnel within the Bachelor ground, where tunnel workers encountered ore. Work on the tunnel resumed after the economic depression, and when the tunnel reached 2,100 feet in length, Nelson's contact was fulfilled.

The rate of progress and the discovery of ore were crucial to the success of Nelson's tunnel concept. The Last Chance, New York, and Amethyst mines offered subscriptions when the Wooster Tunnel Company formed around 1897. The Wooster company leased a right of way through the Nelson Tunnel, and contracted to drive a drift from the extant tunnel north to the Last Chance, New York, and the Amethyst properties. Using 4 heavy piston drills, miners advanced the tunnel 6 feet per shift, and in 1899 they first reached the Last Chance workings, then the Amethyst workings.

Even though the Wooster Tunnel had reached the vicinity of the Amethyst and Last Chance properties, the company required time to make the final connections. Because water was very costly to pump from deep workings, the Amethyst and Last Chance mines allowed the lower passages to flood. This presented the Wooster engineers with a problem. To avoid a life-taking inundation in the tunnel upon breakthrough, the water in the deep workings had to be drained. An engineer had the bright idea of using diamond drills, which were in the developmental stage in the late 1890s, to bore long-holes into the sumps of the Last Chance and the Amethyst shafts. In 1900 trained drillers from the Sullivan Drill Company arrived and began boring holes toward the Last Chance Shaft. In the process, they struck a subterranean body of water pressurized to such a degree that a jet of water forced the drill away from the tunnel face. Much to the disappointment of the engineer in charge, Mr. Rowley, the hole penetrating the Last Chance Shaft failed to yield the volume of water that he anticipated. After inquiry at the Last Chance Mine, he discovered that a great quantity of silt and mud had accumulated in the shaft's sump, forming a barrier. To free the mass, Rowley packed an iron tube with 50 pounds of dynamite and used drill-steels to push it through the long-hole into the Last Chance Shaft. After the charge detonated, a tremendous volume of water jetted through the hole. Once the Last Chance shaft was drained, the process was repeated for the Amethyst Shaft.[34]

Figure 5.8 In 1902 David Moffat's syndicate completed construction of the Humphreys Mill on West Willow Creek at North Creede. The mill concentrated ore brought out through the Nelson Tunnel, and the concentrates were shipped via rail to smelters in the Midwest. Horses drew ore trains along a rail line that entered the upper-most structure. Workers sorted the ore, and sent recovered payrock into holding bins at the top of the mill proper. Machinery crushed the ore and separated waste from metal-bearing fines. The structure at photo bottom was an electrical generating plant. In 1902 electricity was a novel power source. The view is west, and the Nelson Tunnel, not visible, lies up the canyon to the right. Courtesy of Colorado Historical Society (S0025678).

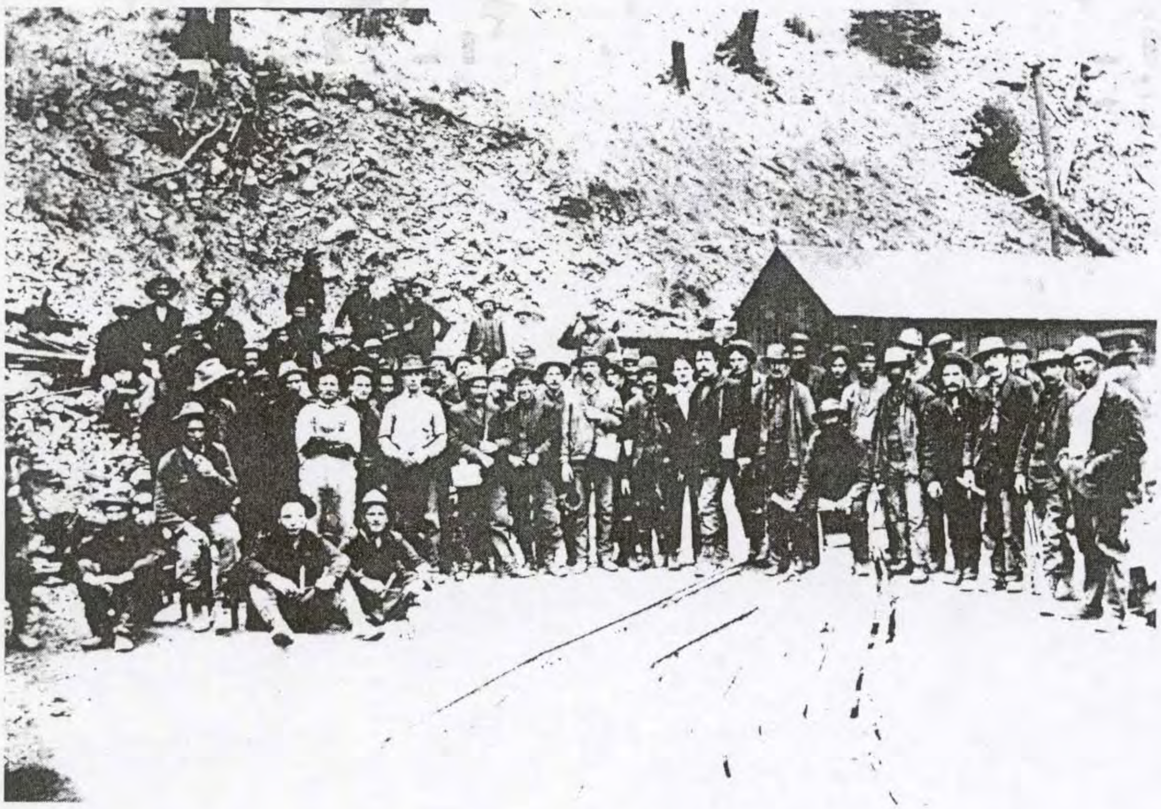

Figure 5.9 The view captures miners at the portal of the Nelson Tunnel, probably in the late 1890s. All have the garb typical of Western miners, including felt hats, tin lunchpails, and the ubiquitous candlesticks. Several Hispanics appear to be among the miners at left. The crew stands on plank decking erected over the banks of West Willow Creek. The building at right is the blacksmith shop. Courtesy of Colorado Historical Society (F-4809 S0025671).

Impressed with the success of the Nelson and Wooster tunnels, the mines farther north along the Amethyst Vein subscribed to another tunnel designed to undercut their workings. In 1900 the Humphreys Tunnel commenced from the end of the Wooster Tunnel. The financing and logistical arrangements for the Humphreys Tunnel were similar to those of the Wooster company. Miners drilled and blasted the passage around the clock for two years, and by 1902 the Humphreys Tunnel had reached the Park Regent Mine, which was the northern-most operation on the Amethyst Vein. The aggregate length of the three tunnels totaled 11,000 feet, and all major operations except for the Commodor Mine enjoyed decreased pumping and transportation costs, improved ventilation, and the discovery of new ore. Mining companies found that the savings achieved through the tunnel system offset the cost of the subscription and the $1.00 per ton of ore passing out the mouth of the tunnel.[35]

When construction workers erected the Humphreys Mill, they graded a mine rail line to the Nelson Tunnel's surface plant, and they built a flume alongside the track which supplied part of the mill's water needs. The tunnel served as part of a large system in which ore was mined and sent directly to be milled at North Creede, on the banks of West Willow Creek.

The owners of the Commodor Mine thought that the Nelson Tunnel Company’s subscription rates and toll per ton of ore were too costly, and they elected to drive their own haulage way in the late 1890s. The Commodor Mining Company hired an engineer who selected the site for a surface plant and a tunnel portal on the Manhattan claim, only several hundred feet up West Willow Creek from the Nelson Tunnel. However, the Bachelor Mine lay between the proposed tunnel site and the Commodor claim, presenting the problem of trespass. Other locations for the proposed tunnel were out of the question, due to restricted nature of West Willow Creek’s canyon. The Commodor Mining Company negotiated with the Bachelor’s owners and secured the right to drive the tunnel through their ground, probably for a royalty.

The Commodor interests hired a mining engineer who put a crew to work erecting a surface plant and a crew of miners to work drilling and blasting the tunnel. The surface plant consisted of a shop, an air compressor, and a return tube boiler. By 1900 miners had driven the Manhattan Tunnel, later known as the Commodor No.5, 4,000 feet to the Commodor claim, where they blocked out ore with raises and drifts. After the tunnel was complete, it served as the Commodor’s principal haulage way, and the upper tunnel was abandoned, except as an entry to the upper workings.[36]

The Bachelor and Commodor companies were on good terms, which facilitated the Commodor’s right of access through the Bachelor’s ground. In 1900 the two companies became even closer when the Moffat Syndicate purchased a controlling interest in the Commodor. The mining industry subsequently recognized the two mines as being one entity, and miners linked the underground workings with numerous passages. As a result, the upper-most tunnel on the Commodor claim became known as Tunnel No.1, the Manhattan Tunnel became known as Tunnel No.5, the Nelson Tunnel was unofficially termed No.4, and Tunnels No.2 and No.3 pierced the ground upslope. In the combined effort to extract ore efficiently, the mine's engineer installed a Pelton wheel at the Commodor No.5, which turned a generator and an air compressor, and the top two tunnels were abandoned.[37]

The Creede district experienced steady production until 1907, when a recession forced most of the mines to temporarily close. After the economy recovered, mining continued. During this time, the application of engineering and technology had a significant impact on the population of the district. Because mining was intense between around 1896 and 1910, the towns of North Creede and Creede thrived. The need for workers at the Amethyst Mill and on the Amethyst tramway ensured that Weaver maintained a small population. However, the completion of the Nelson, Wooster, and Humphreys tunnel series rendered the surface plants on the surface above the Amethyst Vein obsolete. The Nelson Tunnel became the principal access to the mines, and the population of miners and teamsters shifted from the town of Bachelor, which included the disbursed bunk and boarding houses at the mines, down to Creede. Only a few residences up high were maintained. In 1900 approximately 1,150 people lived in Creede and North Creede, 343 people lived in and around Bachelor, and 84 lived in Weaver.[38]

Between 1896 and 1910 most of the mining companies had focused their efforts on developing and extracting the known ore deposits. By around 1910 these bodies began to show signs of exhaustion, and within several years many of the marginal mines closed. Not only did the district suffer from depleted ore bodies, but other silver-lead mining districts such as Joplin, Missouri, Leadville, Colorado, and some of those in Idaho were presenting significant competition, which kept metals prices low. As Creede's mines closed, people left the district. The populations of Creede, North Creede, and Bachelor decreased dramatically between 1905 and 1915. By 1910 Weaver became almost totally deserted.

Contrary to the trend of the implosion of mining on the Amethyst and Holy Moses veins during Creede's second boom, activity spread to several outlying areas on the fringes of the district. As the economy improved during the late 1890s and early 1900s, investors became interested once again in the prospects at Sunnyside. An unknown mining company developed the old Corsair property, and they began shipping silver ore during 1902 and 1903. Captain Free Thoman, who owned the Sunnyside Tunnel, interested investors Albert Damm, Jeff McAnelly, Perry Learnard, and M.H. Akin of Fort Collins in his operation. They supplied capital, which Thoman used to drive a tunnel 750 feet, where miners encountered a small ore vein. The Kruetzer-Sonata and Monon properties saw further exploration, and they eventually produced a little ore.

Two more promising prospects far up West Willow Creek also attracted attention around the turn-of-the-century. Miners began sinking a shaft on a promising lead on the Captive Inca property in 1903, and another company drove a tunnel on the Equity claim. The Captive Inca proved to be worthless and it was abandoned by 1912, however the Equity Mine produced ore for several years beginning in 1912.[39]

The outbreak of World War I benefited Creede's faltering mining industry. The war fostered a heavy demand for industrial metals, creating a profitable environment for Creede's mining companies. While the high metals prices resuscitated mining, the renewed activity was nothing like that of years past. The need to handle greater tonnages of ore than before while cutting production costs convinced the mining operations to spend capital on advanced technology. Electrification was the most cost-effective improvement that the mining companies could effect. While Creede boasted of being served by one of West's earliest power plants, until the 1910s electric technology was not advanced enough to significantly benefit mining. However, when Creede experienced its World War I revival, the technology was sufficiently advanced.

In 1917 a new power plant was built in Creede, possibly by the Creede Tribune Mining Company, which leased the Amethyst Mine. The plant was a state-of-the-art affair, and it consisted of four Heine water tube boilers which powered a massive 500 horsepower steam engine and 225 kilowatt dynamo. A second engine and dynamo were kept on stand-by. The mining operations on the Amethyst Vein used the electricity underground to power small hoists and ventilation fans, and to light stations. The Amethyst Mine proved to be the greatest beneficiary of electricity. In 1918 the Creede Exploration Company leased the mine and installed an electric hoist and motor-driven compressor at the shaft to facilitate work above the Nelson Tunnel level.[40]

The American Smelting and Refining Company, part of the Guggenheims' industrial metals mining and milling empire, organized the Creede Exploration Company in 1918 to lease several of the properties along the Amethyst Vein and extract what little ore remained, and to search below the Nelson Tunnel level for more deposits. During previous years the Moffat syndicate's engineer had miners drive a central shaft within the Commodor workings, and it penetrated ground below the Nelson Tunnel level, which Creede Exploration used for deep exploration. In 1918 or 1919 miners unwatered the shaft and equipped it with a double drum electric hoist which worked two skips. After several futile years of searching, ASARCo gave up on deep ore. Uneconomical quantities had been found, but they were too poor in content. Faced with worthless properties, ASARCo sold its holdings to individual mining companies.[41]

During the 1890s, when rich ore lay in the ground, mining companies purchased claims, hired crews of miners, and extracted ore under the umbrella of their corporate structures. The depletion of rich ore, the inefficiencies of large company structures, and high operating costs discouraged such an operating strategy after around 1900. The growing trend in Creede, as well as other Western mining districts, was for the mining companies to cease operations and lease either the entire mine to a second-party company, or lease portions of the ore body to individual miners. The payment schedule included either a royalty per ton of ore, or a flat fee. This scheme shifted the burden of minimizing operating costs from the mine's owner to the lessee. Under this system, lessees had every incentive to minimize the capital that they put into the operation since they had no allegiance to the mine itself, and they extracted the maximum ore in minimal time. While lessees were able to make a profit where large, cumbersome mining companies could not, their tactics proved problematic for the long term state of the mine. Lessees rarely conducted exploration for new ore bodies because it was "dead work", as they termed it. They also avoided investing in maintenance and the long term well-being of the mine's infrastructure. It was under this environment that mining in Creede continued during the 1910s.

During World War I mining and leasing companies were producing ore from the other mines on the Amethyst Vein. The Mineral County Mining & Milling Company extracted ore from the Happy Thought property, which they concentrated in the Humphreys Mill. A succession of lessees profitably worked the Last Chance ground, and more lessees mined the Park Regent and the Del Monte properties. In 1915 Norman Corson organized a company that did well mining the Bachelor ground. During the 1890s and 1900s the Moffat and Bowen interests had gutted their mines on the Holy Moses Vein, and interest in these properties lagged. The only mine on the Holy Moses Vein that possessed profitable ore during World War I proved to be the King Soloman. The leasing outfit William Wright & Co. profitably extracted ore and milled it at the Soloman Mill until 1918.[42]

The demand for industrial metals was high enough, and milling technology sufficiently advanced to make the ores at Sunnyside and at the Equity Mine, high up West Willow Creek, economically viable. After successful exploration, lessees A.B. Collins and H.R. Wheeler brought the Monon Mine into production in 1916. In 1918 the Manitoba Leasing Company took over operations at the Monon and profitably extracted ore until 1921. The Creede Equity Mining Company began drilling and blasting ore in the Equity Mine in 1918 and quit in 1919.[43]

Decline

The declaration of armistice in 1918 halted war-related industrial production, which caused metal prices to tumble. Mining at Creede once again became unprofitable, and the district fell on hard times. The end of the war proved to be the death knell for the marginal properties, and the end of surface prospecting along the Amethyst and Holy Moses veins. By 1920 all mines but the Bachelor had become completely quiet, many never to be worked again. With the subsidence of activity, irreversible decay set in. The surface plants of nearly all mines fell into total disrepair, and shafts and tunnels became unstable, except for the Nelson, Commodor, and Bachelor operations.

The few miners that remained in Creede glimpsed a ray of hope in 1922. Western senators has passed the Pittman Act, which mandated that the federal government purchase silver at $1.00 per ounce, in hopes of bolstering a failing Western mining industry. The principal mining operations in Creede geared up for production, and activity at the Bachelor, Commodor, Del Monte, Happy Thought, Last Chance, and New York properties resumed with vigor. All work was conducted through the Nelson and Commodor No.5 tunnels. The Ethel

Leasing Company reopened the Soloman on the Holy Moses Vein. The high price for silver stimulated some prospecting, and knowledgeable district residents searched new ground. A find was made near Windy Gulch northwest from Creede, and local interests concluded that it was lead-silver-zinc vein missed by the prospectors of years past. The Pittman Act expired in 1923, and Creede entered another dark period. Some mining activity continued, however. The Commodor Mine continued to produce, and lessees spent a short time in 1925 exploring the Bachelor ground. In 1925 E.J. Lieske, Dr. Thomas Howell, and C.N. Blanchett formed the Bulldog Leasing, Mining, and Milling Company to explore and develop the new vein discovered above Creede. The property already featured a tunnel 1,050 feet long, which they drove further. The operation collapsed in 1926.[44]

The last significant mining endeavor of the 1920s occurred at the Amethyst Mine. The company's leading engineer determined that economic ore still lay in the upper levels of the Amethyst and surrounding properties. Hauling the ore out, however, would have constituted a great cost. After years of neglect, the Nelson Tunnel and the raises and chutes necessary for transferring the ore needed expensive improvement. The surface plants and shafts of the Amethyst, Last Chance, New York, and Happy Thought mines were in a hopeless state. The engineer elected to drive a new haulage tunnel from the company's property at Weaver on West Willow Creek, instead of effect the required improvements. In 1928 miners began work on what then they named the Sloane Tunnel, later known as the Amethyst Tunnel. The passage provided easy access to the Amethyst and surrounding properties, and it permitted mining of low-grade ore shunned by earlier operations as being uneconomical. The tunnel saw only two years of service before mining at Creede once again ceased.[45]

Paradox: Boom During the Great Depression

Ironically, under the presidency of one of the World's greatest mining engineers, Herbert C. Hoover, the Crash of 1929 brought the nation to its economic knees. The subsequent Great Depression destroyed what little was left of mining in Creede. The victory of Franklin Delano Roosevelt over Hoover in 1932 for U.S. President set in motion a chain of events that spelled a revival of mining in the West, including Creede, on a scale not seen since the close of the Gilded Age. In an effort to devalue the U.S. dollar, in October of 1933 Roosevelt enacted a plan in which the Federal Government bought gold at relatively high prices. When price declines began to interfere which this scheme, Roosevelt and Congress passed the Gold Reserve Act early in 1934, which set the minimum price for gold at $35.00 per ounce. In 1934 Roosevelt signed the Silver Purchase Act into law, which monetized silver and set the price for the metal artificially high. Creede experienced a boom unlike anything seen since the Gilded Age. Most of the principal mines on the Amethyst Vein, the Soloman Mine on the Holy Moses Vein, and the few producers at Sunnyside underwent further exploration and production.[46]

Lessees began exploring the Bachelor, Commodor, and Amethyst mines, and they initiated production shortly afterward. Miners accessed these three properties through the Bachelor tunnels, through the Commodor No.5, and the new Amethyst Tunnel, respectfully. The Nelson Tunnel, which was long-neglected, was no longer used. Miners began drilling and blasting pockets and small stringers of ore in the gutted Amethyst Vein's hanging wall. Because capital remained scarce during the Depression, miners working deep underground revived the old practice of hand-drilling, while miners working for the large operations, such as at the Commodor and Amethyst mines, had the luxury of using mechanical rockdrills. Miners completed nearly all other work underground with hand-labor. In addition to work underground, small companies leased the rights to sort through the waste rock dumps associated with the large mines for low-grade ore tossed out by earlier operations as uneconomical.

Table 5.1: Summary of Mining on the Amethyst Vein

Mine Name	Relative Size	Location on Vein	Operating Years of Surface Plant	Operating Years of Property
Amethyst	Very Large	Central	1891-1920	1891-1920; 1928-1929; 1934-1950s.
Annie Rooney	Small	Central-South	1891-1892	1891-1892
Bachelor	Very Large	South	1878; 1885; 1891-1893; 1895-1923; 1925-1929; 1934-1940; 1944	1878; 1885; 1891-1893; 1895-1923; 1925-1929; 1934-1940; 1944
Commodor	Very Large	South	1891-1893; 1895-1910s; 1916-1920; 1923-1929; 1934-1940; 1944-1983	1891-1893; 1895-1910s; 1916-1920; 1923-1929; 1934-1940; 1944-1983
Del Monte	Medium	South-Central	1891-1893; 1890s	1891-1893; 1895-1900s; 1916-1923
Happy Thought	Large	Central	1891-1893; 1894-1907	1891-1893; 1894-1917; 1922-1923; 1928
Last Chance	Very Large	Central	1891-1893; 1895-1896; 1898-1910s	1891-1893; 1895-1896; 1898-1920; 1923; 1937
Nelson Tunnel	Very Large	South	1892-1893; 1896-1929; 1935	1892-1893; 1896-1929; 1935; 1945-1950s.
New York	Medium	South-Central	1891-1893; 1895-1902	1891-1893; 1895-1902; 1900s-1915; 1923; 1934-1940
Park Regent	Medium	North	1892-1893; 1895; 1898-1912	1892-1893; 1895; 1898-1912; 1916-1917
Sunnyside	Small	South-Central	1892-1893	1892-1893
White Star	Small	North	1892-1893; 1890s	1892-1893; 1890s-1917

Figure 5.10 By the late 1930s the surface plant associated with the Commodor Tunnel No.5 was expansive and consisted of a variety of facilities. The mine was one of the district's biggest Depression-era operations. The view is down and east from the Bachelor Mine. Author.

Figure 5.11 During the Great Depression the Amethyst Tunnel became another of the district's biggest operations. The view is north. West Willow Creek flows down through the center of the photo. The tunnel portal is in the background left of center, and the structure at right is an ore sorting house. The Amethyst Shaft lies in the upper left. Author.

Table 5.2: Summary of Mining on the Holy Moses Vein

Mine Name	Relative Size	Location on Vein	Operating Years of Surface Plant	Operating Years of Property
Holy Moses	Very Large	Central	1891-1893; 1895-1910; 1934; 1953-1958	1891-1893; 1895-1910; 1934; 1953-1958
King Soloman (Soloman)	Large	South	1891-1893; 1895-1918; 1922-1923; 1934; 1945; 1950-1952	1891-1893; 1895-1918; 1922-1923; 1934; 1945; 1950-1952
Outlet Tunnel	Medium	North	1890s; 1956-1958	1890s; 1956-1958
Phoenix	Small	North	1891-1893; 1900; 1951-1960s	1891-1893; 1900; 1951-1960s
Ridge	Medium	South	1891-1893; 1890s-1900s; 1943-1949	1891-1893; 1890s-1900s; 1943-1949

Table 5.3: Summary of Mining on Upper West Willow Creek

Mine Name	Relative Size	Location on Vein	Operating Years of Surface Plant	Operating Years of Property
Captive Inca	Medium	South	1902-1905	1902-1905
Equity	Medium	North	1900s; 1912; 1918-1919; 1927-1929; 1953	1900s; 1912; 1918-1919; 1927-1929; 1953

Table 5.4: Summary of Mining on the Alpha-Corsair Ore System

Mine Name	Relative Size	Location on Vein	Operating Years of Surface Plant	Operating Years of Property
Corsair	Medium	South	1883; 1901-1904; 1922; 1925; 1933-1934; 1939	1883; 1901-1904; 1922; 1925; 1933-1934; 1939
Kreutzer-Sonata	Medium	North	1892-1893; 1926	1892-1893; 1926
Monon	Medium	South	1890s; 1916-1921; 1925; 1938-1940; 1953	1890s; 1916-1921; 1925; 1938-1940; 1953
Sunnyside Tunnel	Medium	Central	1892-1893; 1901	1892-1893; 1901

When miners had proven that ore still existed in these mines, investors eager for profit began a campaign to acquire the principal mines on the Amethyst Vein. In 1935 the Emperius Mining Company purchased the Commodor and Bachelor mines and the Nelson Tunnel. In 1937 Emperius leased the Last Chance and New York properties, and in 1939 it completed its game of Monopoly when it purchased the Amethyst Mine. Ore extracted from the upper levels of the New York and Last Chance were hauled through the Last Chance No.2 Tunnel, located near the abandoned Amethyst Shaft. Miners brought ore extracted from the lower levels of the above two properties through the Amethyst Tunnel.[47]

Within a year Emperius invested capital to locate additional ore veins, which the company's engineers were sure lay to either side of the Amethyst Vein. During the following years miners in fact encountered new ore, which ensured the company's continued profitability. Then, in 1938 Emperius miners discovered the OH Vein, which was the most significant find since the initial discoveries of ore in the district. Previous mining companies on the Amethyst Vein shortchanged themselves by focusing time and effort on gutting the known ore bodies and neglecting exploration, leaving the discovery of the OH ore body to miners drilling and blasting four decades later.[48]

Because Creede's ores possessed a lower value than times past, Emperius continued to emphasize production in economies of scale. The company ensured that the surface plants at the Commodor and the Amethyst mines were fully equipped. Miners working underground used rockdrills when driving exploratory workings in hardrock, and they drilled by hand when working in softer ores. Miners used other pieces of power equipment such as electric and compressed air hoists at winzes and to scrape blasted ore out of stopes with drag lines. Mules, which were inexpensive to maintain, pulled trains of ore out of the Commodor and Amethyst tunnels. The surface plants of both of these operations, and the Last Chance No.2 Tunnel, included large ore sorting houses where mine workers manually concentrated the ore and separated out waste.

Like times past, mining men in Creede sought to mill the ores locally in hopes of saving the shipping and processing fees associated with exporting payrock to distant smelters. In 1937 T.P. Campbell, W.B. Jacobson, and a man named Mr. Weber organized Creede Mills, Incorporated, which erected a flotation mill south of the town of Creede. While the flotation process was not new to mining in 1937, Creede's past mills had not applied the concept. The process reduced the ore to a slurry, as other mills had done, and it relied on oils and foaming agents in tanks to "float" the pulverized metalliferous fines away from the waste. The mill proved successful, and Emperius added it to its Creede empire in 1940.[49]

The resurgence of mining stimulated by FDR's programs reversed the trend of the exodus from the dying Creede district. In 1930 the town's population dropped to around 334, and during the following decade it increased to 587. The proliferation of the automobile and truck permitted miners in the 1930s to live in Creede and commute to the centers of activity at the Commodor and Amethyst tunnels. Except for a few isolated residences, the townsites of Bachelor and Weaver had been long-abandoned. The Creede business district experienced another fire in 1936, which would have probably precipitated the town's final abandonment, were it not for the profitable mining.[50]

Table 5.5: Population of the Creede Mining District, 1890-1960

Population Center	1890	1892	1900	1910	1920	1930	1940	1950	1960
Mineral County	Not Extant	Not Extant	1,913	1,239	779	640	975	693	424
Creede	1,000	8,000	938	711	500	334	587	433	424
North Creede	Part of Creede	Part of Creede	235	122	Part of Creede	Part of Creede	Part of Creede	Part of Creede	Part of Creede
Bachelor	0	0	343	179	0	0	0	0	0
Weaver	0	0	84	0	0	0	0	0	0

(Data collected from: Schulze, 1976 and from Nolie, 1947:59)

Unlike World War I, the outbreak of World War II curiously did not foster a district-wide resurgence of mining in the Creede district, despite the need for war-related industrial metals, but interest increased, none-the-less. On the Amethyst Vein, Emperius miners continued drill and blast ore deep within the Commodor, Bachelor, and Amethyst properties, and they may have continued to work the lower levels of the Last Chance ground through the Amethyst Tunnel. In response to anticipated production, in 1943 Emperius invested much capital reconditioning unsound portions of the Commodor No.5 Tunnel, and in 1945 the company did the same to the Nelson Tunnel, which had been neglected for decades. In 1945 the New Ridge Mining Company reopened the old King Soloman, after 11 years of inactivity, and another group of lessees reopened the Ridge Mine in 1943. Reopening both properties on the Holy Moses Vein required considerable capital, because the King Soloman had been idle since 1934, and Ridge was abandoned in the 1910s. The mines that were active at Sunnyside during the Great Depression had closed in the 1930s, probably due to the exhaustion of economic ore. In 1940 the partnership of Larson & Soward leased the mine, conducted some exploration, extracted a little ore, and shut their operation down.[51]

The Last Boom-Bust at Creede

Mining at Creede experienced a boom-bust cycle yet again following the end of World War II. War-related production slowed, and the price for industrial metals sagged. The ore bodies in the old mines were becoming truly exhausted and exploration conducted by both Emperius and by partnerships failed to discover new ore. The end of mining at Creede seemed to be in sight. However, the economic boom of the 1950s created a strong market for industrial metals once again, and improved milling technology made ores of even lower grades economical. Not only did this prolong the lives of Creede's active mines, but a wave of partnerships and lessees closely examined many lifeless but formerly productive properties.

During the late 1940s the Emperius Mining Company was the only significant operation active at Creede. In times past Emperius extracted ore from various levels in the Commodor, Bachelor, Amethyst, and Last Chance properties. Following the post-war slump in metals prices, the company curtailed its operations and used only the Commodor, Nelson, and Amethyst tunnels. The company abandoned all other surface facilities.

The wave of interest in Creede's mines began rising in 1950. The long-idle mines on the Holy Moses Vein attracted the most attention. In 1950 the Mexico Mining Company leased the King Soloman property and conducted underground exploration. The TOC Development Corporation assumed the lease and produced $20,000 in ore by 1952. In 1951 the Outlet Mining Company reopened the Phoenix Mine, conducted exploration, and by 1956 had extracted an impressive $500,000 in lead and silver. In 1953 the Sublet Mining Company leased the Holy Moses Mine, and it leased the Outlet Tunnel in 1956, where the outfit conducted underground exploration. The lessees began shipping ore from the Holy Moses in 1954. In light of the success miners were experiencing with some of the district's long-abandoned properties, lessees and investors became interested in the prospects at Sunnyside and those on upper West Willow Creek. Lessees reopened the Equity Mine in 1953, which lay abandoned since 1929. They proved unsuccessful and the mine closed permanently. Another group of hopefuls reopened the Monon Mine also in 1953. They encountered small veins which were rich enough to pique their interest, but not sufficient enough to be profitable. The lessees chased the ore stringers for the next five years before they finally gave up.[52]

Mining in Creede experienced one last contraction in the late 1950s. All of the operations that were active during the 1950s shut down permanently, except for the Outlet Mining Company which continued underground exploration at the Phoenix Mine, and the Emperius Mining Company which continued to profit from the seemingly endless bodies of ore under the Commodor and the Amethyst properties.

During the 1960s the culture of the Creede Mining District entered a dichotomous state. The people, the economy, and the physical landscape retained characteristics derived from 70 continuous years of underground mining based on traditional Gilded Age methods, while the modern world was beginning to exert a substantial influence. The Emperius Mining Company continued to work the Commodor and the Amethyst properties, and the Bulldog Mine, long idle, began production. Improved technology permitted a greater tonnage of ore produced per miner, but both mining companies continued to drill and blast using traditional methods. Both mining companies began to use heavy equipment, such as bulldozers and front-end loaders, instead of hand-labor on the surface. On the other hand, Creede’s economy began to enjoy a higher income from tourists that in times past, and the culture began changing to accommodate the passers-through. During the 1960s a movement began in which tourists ventured from urban and suburban centers to historic mining towns to commune with the material culture of the American West.

Creede, with its dozens of intact historic mine sites and ghost towns, was well prepared to satisfy the waves of tourists. The transition from mining to tourism accelerated during the 1970s.

The end to mining in Creede finally came in the 1980s. After almost a century of mining, all of the mines shut down. Exhaustion of ore was partly to blame, the skyrocketing costs of underground operations were heavily at fault, and competition from mining operations in other countries and the associated low metals prices contributed heavily. Mining constituted a significant portion of Creede's cultural fabric, and the closing of the mines was a hard blow to the area. However, Creede survived well because tourism continued to grow, and the town served as the region's commercial and economic hub. Despite Creede's transition from one of America's greatest silver mining districts to a historical destination that draws tourists from across the West, the cultural fabric created by almost 100 years of mining remains intact. The heritage that is Creede's, as well as that of a special time and place in American history, lives on through the people, the town of Creede, and the surrounding historic mine sites.[53]

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CHAPTER 6

CONCLUSION

The Creede Mining District holds a place of importance in national, state, and local history. Creede has been described as one of America's the most significant silver producing districts, and its mines made significant contributions to the fortunes of powerful and influential mining investors and politicians such as Thomas Bowen, Henry O. and Edward O. Wolcott, David H. Moffat, and A.E. Reynolds. Because these men were heavily invested in profitable silver mines, including those at Creede, they put great energy into a national policy that favored the silver mining industry and Western business. The ripple effect of their actions, and the actions of other politicians with similar interests, caused economic cycles which reverberated throughout the West, and ultimately the nation. Federal silver price supports and the revocation of such policies caused boom-and-bust cycles that stimulated settlement and industrialization of the mining West when silver prices were high, and required the population to be transient when low prices forced mines to close. The cycles ultimately impacted the nation's economy, exemplified by the Silver Crash of 1893 and the associated depression.

The excitement over the immense ore veins at Creede fomented one of the West's last great mining rushes. The potential for staking a rich claim at best, and securing a well-paying job at the least, acted as a siren calling to miners, businessmen, and investors across the nation. In response, people immigrated to Creede from hardrock mining regions across the West, as well as from Michigan, Missouri, Wisconsin, Canada, and Europe. At its peak, the rush to Creede began to eclipse the excitement at Cripple Creek, which was one of the other great districts of the 1890s. Were it not for the devastating Silver Crash of 1893, Creede may have overshadowed Cripple Creek for many more years.

Creede served as a proving ground for innovative mining and industrial technologies, as well as an example of the application of accepted, conventional mining methods and practices. The prominence of the district, the problems associated with mining an immense vein, the investors' wealth, and the need to produce ore in economies of scale contributed to the use of advanced technology. Creede hosted one of the West's earliest municipal and industrial electric grids at a time when steam power reigned supreme. To achieve production in economies of scale, many of the district's prominent mines made use of aerial tramways at a time in mining history when the devices were uncommon and expensive feats of engineering. The mines at Creede also saw the application of advanced drilling technology. During the late 1890s miners began using stoper drills to bore blast-holes into the ceilings of stopes and raises. The use of stopers at this time is significant for several reasons. First, stopers manufactured during the 1890s and 1900s were one of the first commercial versions of the hammer drill, which replaced then-conventional piston drills and evolved into today's jackhammers and rockdrills.

Second, the stoper was one of the first light-weight and inexpensive drills portable and operable by one man. The piston drill, which weighed up to 350 pounds and required a crew of two to operate, was the convention among mining companies until the 1910s, when hammer drills became popular. The large mines at Creede saw early application of diamond drilling around 1900 for deep sampling, and engineers in the district used them for the unheard-of practice of boring drain-holes into the sumps of several flooded shafts. Like hammer drills, diamond drills were still in the developmental stage during this time, and they proved themselves successful at Creede.

During the 1890s mining engineers bored the Nelson Tunnel for 2 miles under the claims on the Amethyst Vein, linking many prominent mines together in hopes of reducing production costs and solving some of the problems of mining. The tunnel served as a massive drain and ventilation duct, and it became the principal access and haulage way to the mines, which caused a geographical shift in the district's population. Boring the Nelson Tunnel, linking it to the principal mines on the Amethyst Vein, and equipping it for haulage, ventilation, and access to encompassing underground workings required sound engineering practices. The Nelson Tunnel converted the individual mines on the Amethyst Vein into an interrelated system.

The Creede Mining District holds historical importance on a state level. During the 1890s, Creede was a center of mining excitement second only to the world-renowned Cripple Creek. Creede fueled Colorado's economy for four decades, except for a brief period during the Silver Crash of 1893. Economic stimulation came from gross ore production, from capital poured into the district from outside the state, and from immigrants moving to the district. To that end, Creede drew a workforce consisting of a variety of ages, ethnicities, and experiences, adding color to Colorado's population. Creede's investors influenced state politics, including the strong reaction to the growing wave of unionism. Creede's mining companies shipped their ore for processing, and much of it went to smelters at Denver and Pueblo, which supported industries in those areas. And in a contrary way, the mines at Creede consumed thousands of tons of coal to feed boilers, blacksmith forges, and stoves. Most of the bituminous coal and much of the anthracite coal came from within the state, which supported mining and settlement at Trinidad, Crested Butte, Florence, and the Front Range. Creede proved to be important to the state of Colorado during the Great Depression. When President Franklin Delano Roosevelt signed the Silver Purchase Act in 1934, Creede experienced a revival which supported hundreds of workers and their families. On a broad scale, the return of silver mining helped see portions of Colorado's population through the Depression. Last, Creede's abandoned mine sites continue to draw tourists to Colorado, which support the state and local economies.

The Creede Mining District also holds a place of importance because many of its historic elements are intact and retain integrity. The district retains cultural geographic integrity in terms of its settlements, mine sites, and transportation arteries. Many of the settlements and historic mine sites feature examples of Gilded Age and Depression-era industrial, commercial, and residential architecture. The towns of Creede and North Creede and the townsite of Weaver possess little-altered historic commercial and residential buildings in an intact ambiance.

Perhaps Creede's most significant cultural resource is its historic mine sites. Many of these sites feature a combination of intact archaeological and architectural elements ranging in age from the district's earliest boom years up to the 1970s. While many of the mine sites have been stripped long ago of their buildings and machinery, the remaining archaeological evidence often clearly reflects the physical constitution of the surface plants, dates of operations, the natures of the operations, and associated residences. The archaeological record also includes buried deposits such as trash dumps, cellars, and privy pits which have the potential to enhance our current understanding of life and culture in Western mining districts. The large mine sites include many standing buildings ranging from small explosives magazines to offices to massive ore sorting houses. The aerial tramway terminals and sorting houses are ponderous, well-engineered structures unique to Western mining. On an individual basis such structures are rare, and the assemblage of these structures possessed by the Creede district is exceptional. When all of Creede's historic mine sites are considered in sum, they provide fuel for the examination of patterns related to mining. For example, the assemblage of sites reflect both changes and constants in underground mining methods and technology employed from the Gilded Age up to the 1970s. The site assemblage includes many examples of mines arrested in states ranging from small, poorly developed prospects to massive, industrialized operations. The assemblage of mine sites are both proximal to historic townsites, and they include individual residential complexes. As whole, the mines and residential complexes can illuminate settlement patterns.

The Creede Mining District possesses many reasons that favor preservation and future cultural resource analysis. Today, other historic mining districts are loosing integrity to development, gaming, and environmental remediation, making Creede all the more important to Mineral County, the state of Colorado, and the United States. The historic resources at Creede constitute a rare example of a heavily capitalized, wealthy, and well-engineered mining district, and an example of a time and place in history quite different from today's culture and economy.

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