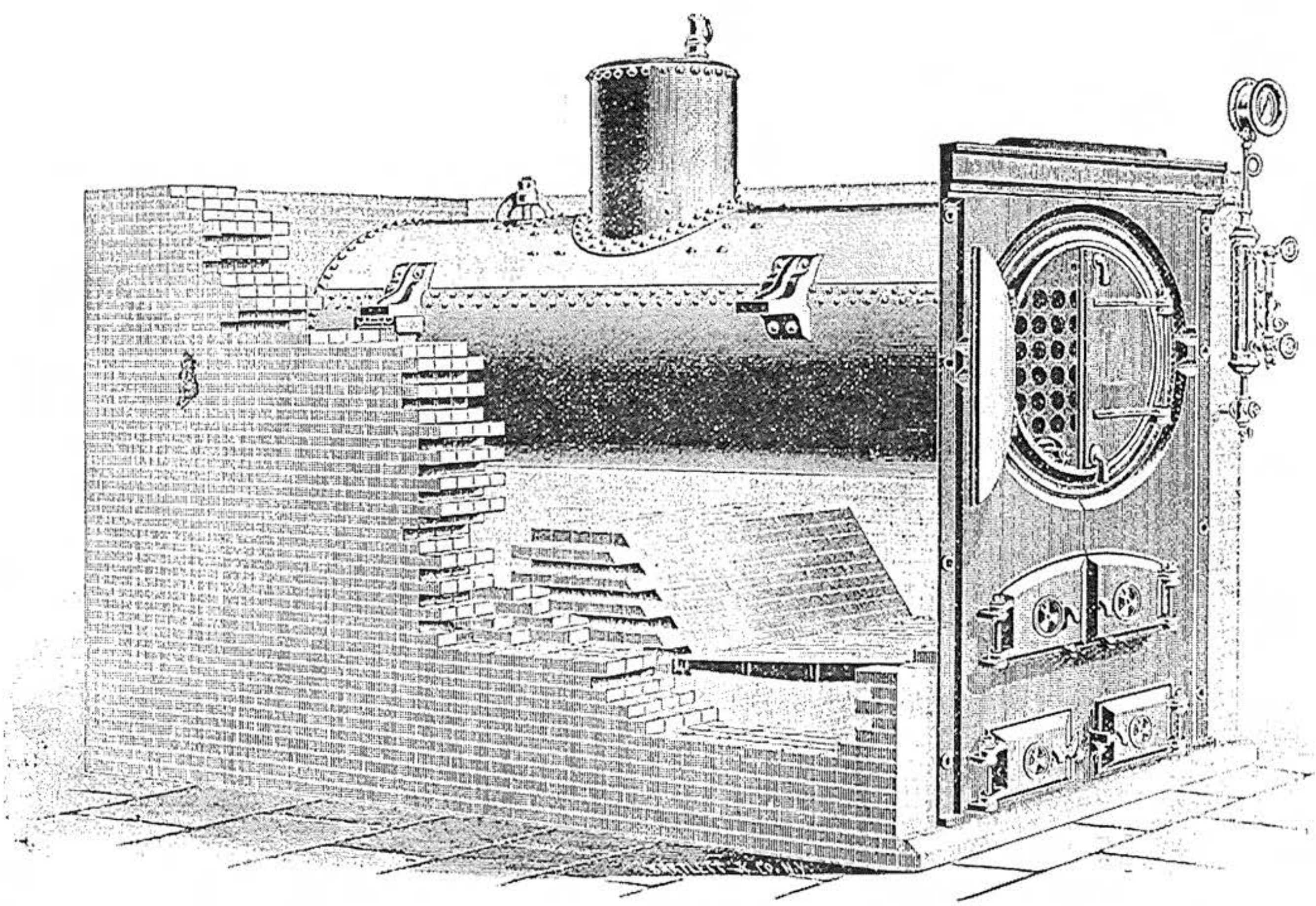
From Steam Engines to Electric Motors: Electrification in the Cripple Creek Mining District

By Eric Roy Twitty



During the latter half of the nineteenth century and into the twentieth, return tube steam boilers, such as the unit illustrated , were the single most popular sources for powering mine machinery. Some of the brickwork for the boiler illustrated has been cu t away to reveal details of the iron vessel. Source, advertisement, *Engineering & Mining Journal*, ca. 1900.

"The World's Greatest Gold Camp"

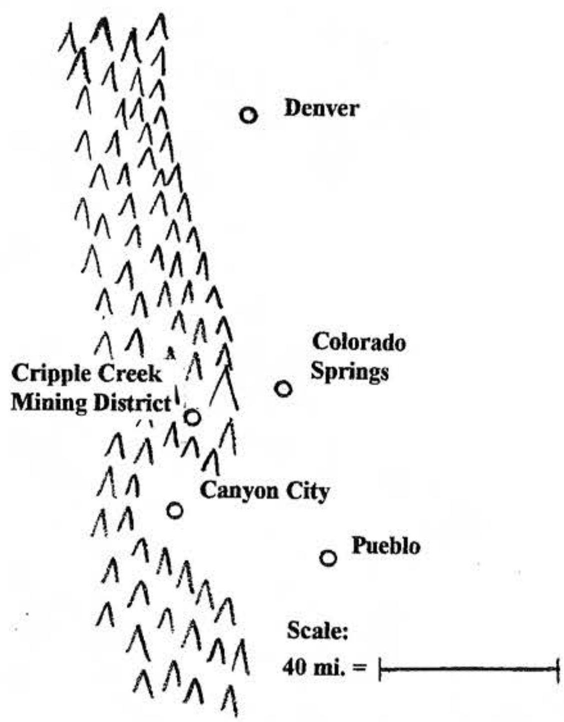
The Cripple Creek Mining District was without a doubt one of the world's greatest mining phenomena. Between the 1890s and approximately World War I miners drilled and blasted so much telluride ore that the district became the world's fifth largest gold producer, a record it still holds today. Many of the district's ore bodies ran deep, pitting profit-hungry mining companies, engineers, and miners against great odds. The deep mining, odd geology, and reservoirs of capital made the district a hallmark of then-current Industrial Revolution mining technology. Cripple Creek had been the proving ground for a number of experimental mining technologies, electricity being among them. Electrification of mining in the district has been a celebrated subject, modern-day historians and then-active promotors asserting it was instrumental in the district's mines. But was it?

During the 1870s and 1880s the name *Cripple Creek* did not yet hold meaning for the mining industry, and to those few people familiar with the region on the southwest flank of Pikes Peak, the name conjured images of tumbledown ranchsteads where life was slow. However, to local rancher Bob Womack, who gained experience prospecting near Idaho Springs, Cripple Creek held the promise of gold or silver ores, and when not punching his family's cattle, he searched for minerals. In 1878 Womack indeed found something: telluride float which assayed at approximately $200.00 per ton. Soon after, he found traces of placer gold near his ranch, but the limited quantity of gold made it merely a tease. Like most experienced prospectors, Womack knew the placer gold and telluride float had to be coming from a nearby source, and envisioning riches, he continue his search through the 1880s.

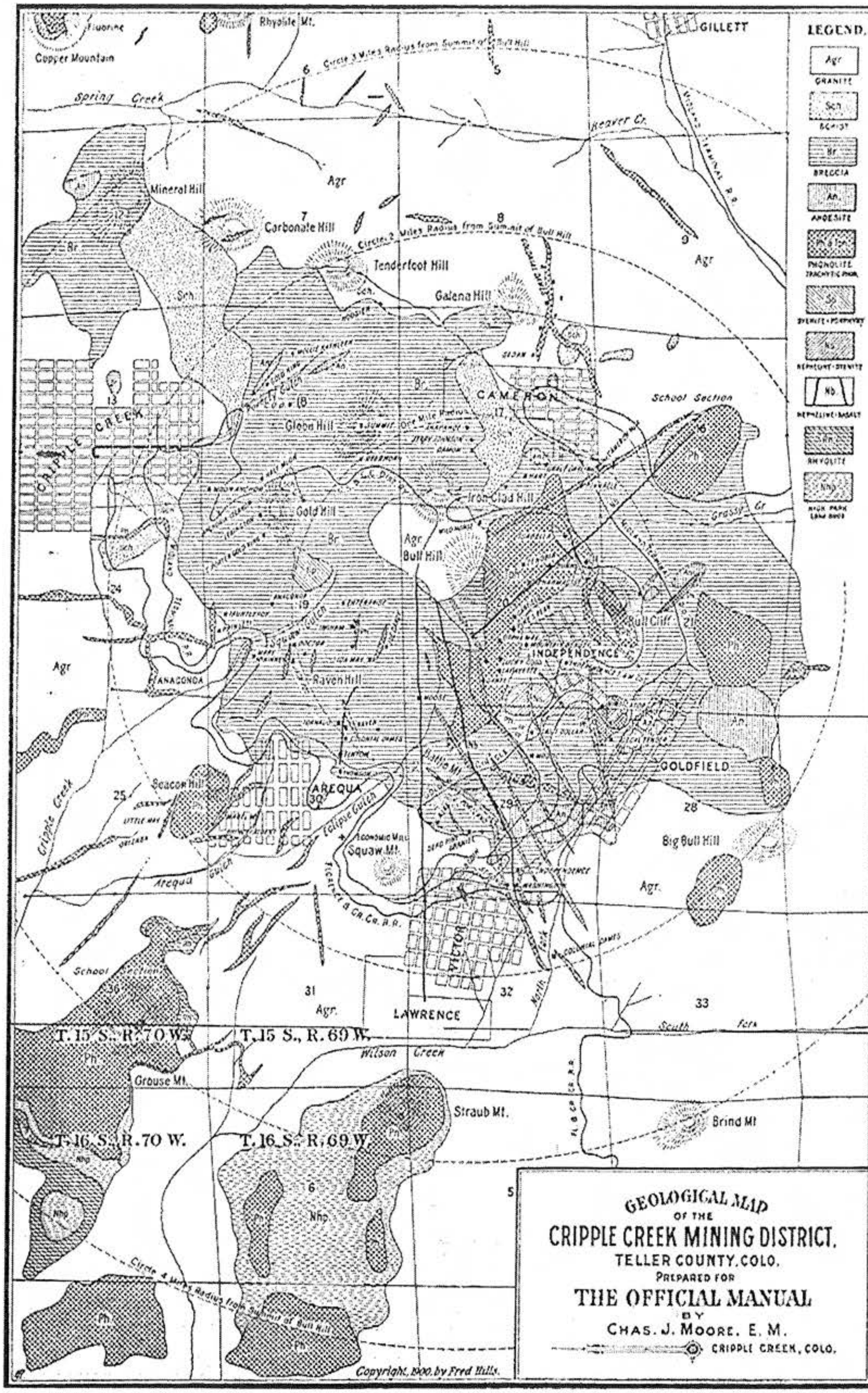
After more than ten long years, in 1890 Womack finally zeroed in on a source of ore in Poverty Gulch, east and upslope from present-day Cripple Creek. He sank a prospect shaft and struck what he named the El Paso Lode ten feet down.[1] Within a year other prospectors began to explore the area in earnest, some with success, and they christened the region the Cripple Creek Mining District. Not until some of the early claims proved their riches did the district become legitimate, and speculation and capital investment began to snowball. The year 1894 saw the district get its first rail connection, the Florence and Cripple Creek Railroad, and through the remainder of the 1890s Cripple Creek became the terminus of two other rail links with industrial centers down on the plains, lowering the cost of sending ore out to smelters and freighting in machinery and supplies.

The district's peak occurred around 1900 when the population reached a pinnacle of 50,000 people and production hit an all-time high of $18,000,000 for the year[2]. Shortly after World War I, production slumped as ore reserves dwindled, and the population left to chase new jobs elsewhere. Mining in Cripple Creek maintained a twilight status through the 1920s as only the larger operations produced ore, almost all of the smaller mines having closed.

The Great Depression at first killed most of the remaining mines, however, when President Franklin Delano Roosevelt signed into law the Gold Reserve Act in 1933, which set the minimum price of gold at $35.00 per ounce, the increased value coupled with the droves of unemployed spelled reinvigoration for Cripple Creek. Although many mines were reopened and rehabilitated, the district was a mere shadow of



Geographical location of the Cripple Creek Mining District relative to Denver, Colorado. Source: Author.



Geological map of the Cripple Creek Mining District showing principle towns, mines, and topographical features, circa 1900. Source: Hills, Frederick *The Official Manual of the Cripple Creek District, Colorado, U.S.A.* Fred Hills, EM, Colorado Springs, CO 1900 p32.

its past glory. By act of Congress the mines were forced to close in 1942 for their lack of war-time contribution, which was their death-knell. After the war only a fraction of those running in the 1930s reopened, and most of these lasted less than ten years, to fall silent forever.

During its skyrocket to riches and glory, Cripple Creek became a magnet for miners thrown out of work by the Silver Crash of 1893, and it buoyed Colorado's claim to mining fame, and the state's mining-dependent industries. Prospectors carpeted the Cripple Creek Mining District with claims as they dug thousands of prospect pits and sank hundreds of shallow shafts. Running high on hopes, hundreds of mining companies engaged in deep underground exploration, and more than a hundred fortunate operations drilled and blasted tons of ore in well-paying mines. The district, awash in money, had awakened Colorado Springs from a deep slumber, it electrified the West's mining industry, and made millionaires.

Sinking Plants & Permanent Plants

Every prospector and mining company that developed a mineral claim beyond the infantile prospect pit had to erect facilities to support driving of underground workings. These facilities, known as surface plants, ranged from simple operations powered by hand-labor to some of the largest, most awesome collections of structures and machines the Industrial Revolution had to offer.

All surface plants of western metal mines had to address four basic needs of driving underground workings. First was providing a spacious, stable entry underground. Second was maintaining and manufacturing equipment and tools. Third was moving shot rock out of the underground workings and miners and supplies in. Fourth was ventilation. Generally, miners sank shafts on vertically oriented ore bodies, such as those which concealed Cripple Creek's riches. In addition, a shaft was frequently the only option in districts blanketed with individual mining claims. All shafts required a hoisting system for raising rock out of and lowering men and materials into the workings.

Mining engineers have categorized surface plants as either being geared for sinking a shaft, or designed to facilitate ore production. Sinking plants, referred to by mining engineers as *temporary plants*, tended to be simple, and they utilized small, inexpensive pieces of machinery which were easy to install and dismantle. Plants geared for production, which mining engineers referred to as *permanent plants*, usually represented long-term investment, and were intended to rapidly move high volumes of rock out of and materials into the shaft, maximize energy-efficiency, provide for materials and ore storage, and include easy access to the mine.[3]

Mines featuring temporary plants tended to rely on inexpensive technologies which were by nature inefficient for meeting the needs of driving underground workings. Miners and shop workers usually labored by hand to repair and manufacture tools, for moving materials, and for drilling blast-holes. When the air in the underground became intolerably foul, mining companies induced ventilation in prospect shafts with passive means, such as using wind socks to direct natural drafts. When engineers upgraded a mine plant for production, they mechanized its components to lower long-term operational costs and to expedite materials and rock handling. Production-class hoists tended to be large and powerful machines; miners drilled blast-holes with compressed air-powered rock drills, and when a natural air flow could not be induced in a mine, mechanical blowers supplied fresh air. Traditionally, hissing, monstrous boilers and chuffing steam engines powered the array of machinery. Steam was the workhorse of the Industrial Revolution, and mining was no exception. Nearly all production plants and many sinking plants intended for deep work utilized steam machinery, especially hoists, because of their superior performance to other sources of power.

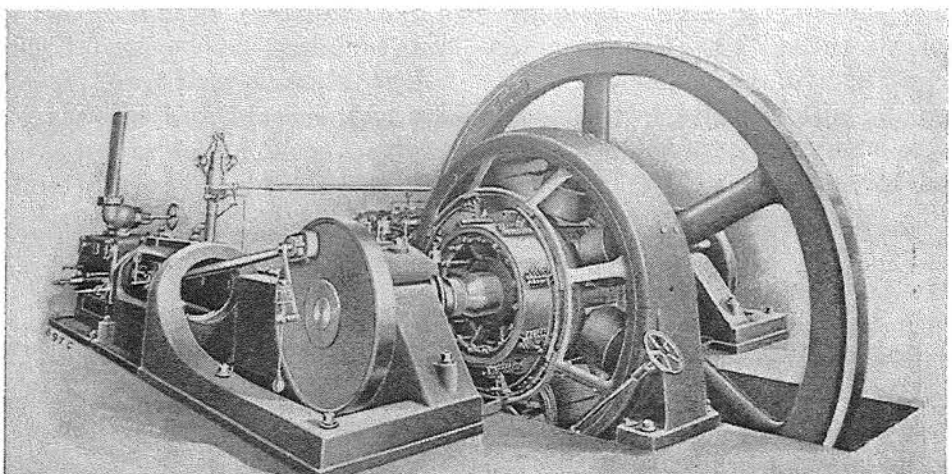
In the 1890s two forms of power for mine plants began showing signs of mounting a challenge to the supremacy of steam. The first was the internal combustion engine, the other electricity. Internal combustion engines, the most common of which ran off gasoline or diesel fuel, were found capable only of powering sinking-class mining machinery. Electricity, on the other hand, held great promise.

Turning on the Power: Electrification and Cripple Creek

The introduction of electricity to mining came well before the development of Cripple Creek. In

1881, while Bob Womack wandered the hills around Cripple Creek in search of the source of his telluride float, mining engineers at William A. Clark's famous Alice Mine & Mill in Butte, Montana checked over the electric lighting they had just installed. Satisfied, they threw the main switch, and the first electric circuit strung through a western mine showed signs of life as bulbs glowed with a cold yellow light. Progressive engineers in major mining regions in the West quickly perceived the potential offered by electricity. According to their thoughts, would it not have been more efficient to conduct energy through wires to electric motors for running mine machinery, than it was to deliver tons of coal or cord wood to their constantly hungry boilers? In an 1892 issue of *Engineering & Mining Journal*, William Saunders observed that "Compared with other means by which power is transmitted, it [electricity] has many advantages which are sure to give it a prominent place as an economic agent".[4] To engineers seeking to maximize ore production and minimize costs, it seemed electric power was too good to be true; all that was needed to electrify a mine was a generator, wiring, and electric motors, and the obsolete boilers and steam engines could have been sent to the scrap heap. However, in the 1880s and early 1890s electric power was, in fact, too good to be true; the technology was not yet ready to withstand the rigors of hardrock mining, let alone meet the demands of less taxing industries. In reality, motors manufactured during this time were weak and incapable of starting under load, a fundamental requirement for use with mine machines, and Direct Current (DC) was the only available current, which could not be transmitted far without significant power loss.[5]

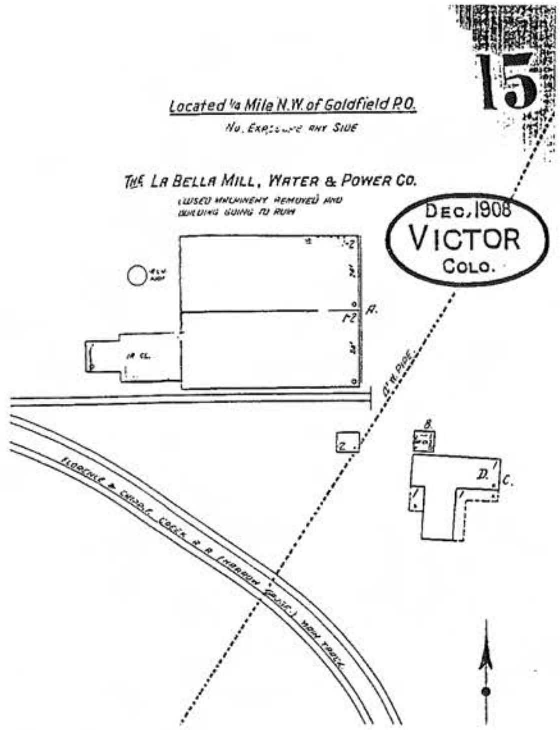
In hopes of adapting electric power to the rigors of the mining environment, engineers began experimenting with electric-powered mining machinery during the mid and late 1880s. Unknown to each other, in 1888 both the Aspen Mining and Smelting Company in Aspen, Colorado and the Big Bend Mine on the Feather River in California's Mother Lode became the first western mines to run machinery with electric motors.[6] Aspen's application included use of a DC trolley car motor to power a hoist installed over a winze, which was an underground shaft. The San Juan Mountains in Colorado, where the volume of water and steep mountain sides were conducive to hydro-electric generation, hosted the next application of electric power for western mining at Telluride in 1890, and at Creede in 1892. By 1897 a ground swell of western mining districts began to experience scattered, virtually experimental electrification projects



The La Bella Mill, Water, & Power Company plant had three generators directly coupled to 1000 -horsepower steam engines, which were very similar to the titanic machine shown in the photo. The steam engine on the left turned the generator located in photo - center, and the flywheel on the right gave momentum to the unit's high -speed rotation. Source: *The Practical Management of Dynamos and Motors.*

Table 1 Electrification in the West by Year

Mining District	Year	Information Source
Aspen Mining & Smelting Co. Aspen, CO.	1888	*Engineering & Mining Journal* 1/23/90.
Big Bend Mine, Feather River CA.	1888	*Mining & Scientific Press* 9/22/00.
Red Mountain Mining District, CO.	1889	Smith, P.David *Mountains of Silver* Pruett Publishing Co., Boulder, CO 1994 p176.
Telluride, CO.	1890	*Engineering & Mining Journal* 7/23/92.
Creede, CO.	1892	Mumey, Nolie *Creede: History of a Colorado Silver Mining Town* Artcraft Press, Denver 1949.
Standard Consolidated Mining . & Milling Co., Bodie, CA	1893	*Engineering & Mining Journal* 5/13/93.
Rock Springs Coal Mine Rock Springs, WY.	1893	*Engineering & Mining Journal* 4/29/93.
Coeur d'Alene, ID.	1895	Wyman, Mark *Hard Rock Epic* University of California Press, Berkeley, CA 1979 p103.
Central City, CO.	1890s	Bancroft, Caroline *Gulch of Gold: A History of Central City, Colorado* Sage Books, Denver, CO 1958 p321.
Amador Mining District, CA.	1897	Grimsley, G.P. "Electric Power Plants in the Mining Districts of Northern California" *Engineering & Mining Journal* Aug. 31, 1901 p270.
Sutter Creek, CA.	1897	Ibid.
Ione, CA.	1897	Ibid.
Angels Camp, CA.	1897	Ibid.
Diamond Hill Gold Mine, MT.	1897	*Engineering & Mining Journal* 9/25/97.
Mercur, UT.	1898	*Engineering & Mining Journal* 6/25/98.
Cape Floyd, UT.	1900	Gibson, George II "Electricity in Mining" *Engineering & Mining Journal* 3/1/02.
Comstock/Virginia City, NV.	1901	*Engineering & Mining Journal* 2/9/01.
Owyhee, ID.	1901	Wyman, Mark *Hard Rock Epic* University of California Press, Berkeley, CA 1979 p103.
Silver City, ID.	1902	Ibid.
Lake County, San Juans, CO.	1902	*Engineering & Mining Journal* 8/30/02.
Mariposa, CA.	1902	*Engineering & Mining Journal* 2/2/02.
Goldfield, NV.	1905	Wyman, Mark *Hard Rock Epic* University of California Press, Berkeley, CA 1979 p103.
Leadville, CO.	1906	Renz, Robert "The Electrical Equipment of the Yak Tunnel" *Engineering & Minig Journal* 5/25/07.



When the *Sanborn Map Company* surveyed the Cripple Creek District's electric facilities in 1907, the La Bella plant had a l-ready closed. Sanborn's map depicts La Bella's empty building.

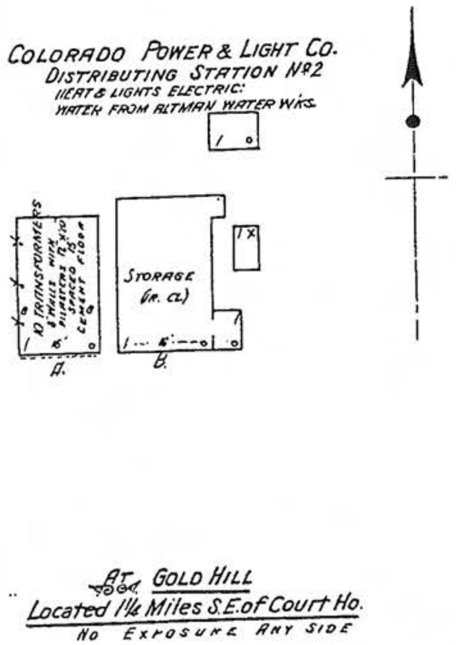
The Cripple Creek Mining District was swept up by the wave of electrification in western mining in 1896 when engineers ceremoniously opened the gates of the Lake Moraine Power Plant penstocks, located high on Pikes Peak.[7] The Lake Moraine plant was small and its financiers, the wealthy Woods brothers, never expected it to generate electricity for use throughout the district. Rather, they transmitted its power to their Columbine Tunnel, which extended west from their Gold Coin Mine in downtown Victor to Eclipse Gulch, for lighting, to run an electric locomotive, and to power electric rock drills. The tunnel, thousands of feet long, served as the conduit for tramming ore and waste rock from the Gold Coin Mine.

Although the electric drills were a failure, the locomotive and lights were a success, and they forwarned of things to come. Hot on the heels of the Woods brothers, the Colorado Electric Power Company erected a steam generating plant in Canyon City on the Arkansas River and strung a transmission line approximately 30 miles north to Cripple Creek, and energized the district in 1898.[8] Colorado Electric's plant consisted of three Hamilton-Corliss engines turning generators, which were supplied steam by a battery of Heine water tube boilers, the latest and most efficient in boiler design. The financiers of Colorado Electric simultaneously graded the "Highline" interurban electric street car railway through the mining district to be a principle revenue-generating electricity consumer.

Within a year the Canyon City plant faced significant competition for electrical service in the Cripple Creek Mining District when the La Bella Mill, Water, & Power Company, financed by David Moffat, fired up the boilers in its steam generating plant adjacent to and southwest of Goldfield in 1899.[9] Moffat, a Colorado railroad, banking, and mining magnate, owned interests in a number of Cripple Creek mines. The length and breadth of La Bella's circuit rivaled that of the Colorado Electric Power Company, and it was used to power the "Lowline" street car service, for lighting, and for light industrial work. The heart of La Bella included three McIntosh, Seymore & Company 1000-horsepower steam engines which turned General Electric generators, powered by a bank of six Babcock & Wilcox boilers fed coal by automatic stokers. The La Bella plant also housed two Corliss duplex compressors delivering compressed air through plumbing to mines on Battle Mountain and in the Vindicator Valley for drilling.[10]

In 1900 the Woods Brothers began building their Skaguay hydro-electric plant on Beaver Creek 10 miles east of Victor, and they brought it on line a year later. Skaguay's circuit served the south portion of the mining district, including all of the Woods' properties.[11]

Although much of the Cripple Creek Mining District had been wired for electric power by the turn of the century, there were not enough customers to support the three power companies. The La Bella plant was the first of the three power companies to suffer the consequences of the intense competition. In 1907 it folded, and the Vindicator Mining Company purchased the plant and converted it into a small ore reduction facility ironically run by electricity from one of La Bella's competitors. Skaguay was the next plant to experience the repercussions of competition. To buttress the hydro-electric facility against possible failure, the Woods Brothers formed



The *Sanborn Map Company* serves as the only reference for little-known aspects of Cripple Creek's electric grid. In this case Sanborn documented one of Colorado Electric Power Company's transformer stations on Gold Hill.

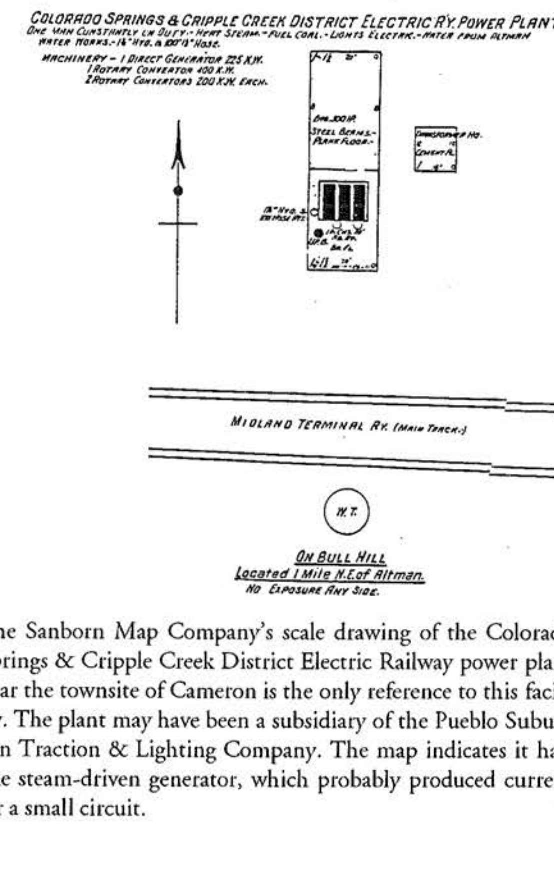
an alliance with the Pueblo Suburban Traction and Lighting Company, which ran a line from its steam-generating plant in Pueblo 60 miles southeast, to Cripple Creek via Skaguay.

In 1911 the Chicago engineering firm of H.M. Byllesby purchased the Canyon City, Pueblo, and Skaguay plants and consolidated them as the Arkansas Valley Railway, Light, & Power Company.[12] The new company continued to offer the same services to Cripple Creek as its predecessors, but at reduced rates as a result of the consolidation. Within ten years the Standard Gas & Electric Company purchased the generating plants from Byllesby and ran them as the Southern Colorado Power Company.[13] With heavy electrification in the Florence coal fields, Pueblo's heavy industry, and, at long last, mines in Cripple Creek, the power distributor's importance grew through the 1920s and into the 1930s.

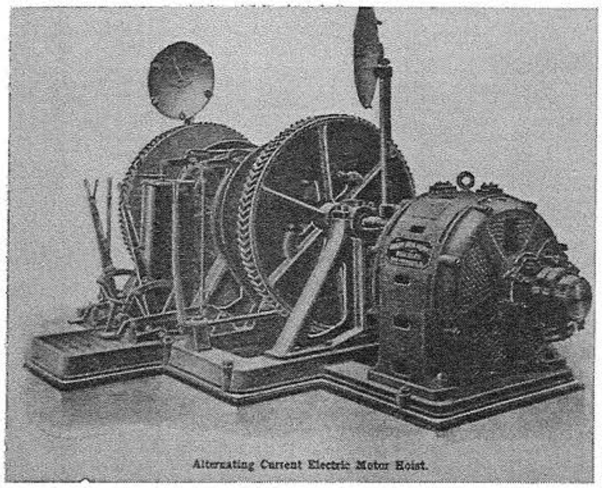
The Technology & Economics of Electricity

Stoked with faith and a futuristic optimism, many mining and electrical engineers heavily promoted electric machinery during Cripple Creek's boom. They claimed it to be superior to the steam technology, which powered the mining industry until the 1910s. Electric motors were advertised as being quiet, compact, reliable, easy to fix, and economical in terms of power consumption. Yet not all engineers agreed. T.A. Rickard, one of the nation's foremost mining engineers during this period, stated in 1904 that the opposite was true; the durability, serviceability, and reliability of steam components would make them competitive for some time to come.[14] In reality, motors manufactured during Cripple Creek's boom required constant care and maintenance, they were not of unquestionable reliability, and they could only be troubleshooted by specialized electricians. Motors suffered most under wet conditions, which was a fundamental element of many a mine's environment.[15] The realities of applying motors to mining differed from the claims of pro-electricity mining engineers.

If these factors were not enough to discourage mining companies from the use of electrical machines, the state of the technology was. Generators, currents, motors, and circuitry was nascent, quasi-



The Sanborn Map Company's scale drawing of the Colorado Springs & Cripple Creek District Electric Railway power plant near the townsite of Cameron is the only reference to this faci lity. The plant may have been a subsidiary of the Pueblo Subu rban Traction & Lighting Company. The map indicates it had one steam-driven generator, which probably produced current for a small circuit.



The electric hoist depicted in the photo is similar to those used in Cripple Creek during the boom era. This model is a single drum unit geared to an electric motor. Electric hoists of the 1890-1920 vintage were slow, they had a limited payload capa c-ity, and their motors required much servicing. Source: *Mining & Scientific Press* July 9, 1904 p25.

experimental, and unstandardized. By the turn of the century, electrical engineers and inventors were working with five basic types of electrical circuits, and of those they experimented with adapting 110 volt lighting circuits, 450-550 volt electric railway circuits, and 50 volt arc lighting circuits for industrial work such as mining. The two which held the greatest promise were 450-550 volt DC, and 450-550 volt Alternating Current (AC) currents. By the 1890s engineers and entrepreneurs had accomplished much work in adapting DC current to industrial work, but the problem with DC current was that it had to be used close to the generation source because it suffered energy loss through transmission. Such performance was not conducive for electric distribution in mining districts such as Cripple Creek, where great distances had to be traversed by transmission lines.

Alternating Current current held greater promise for running mining machinery than DC, in part because AC could be transmitted great distances. However, during the 1890s AC currents had proven worthless for mining because AC motors were incapable of starting and stopping when coupled to machinery, and their speed was invariable, which was exactly the performance demanded by mining.[16] At last, by 1900 a multiphase AC circuit, one utilizing three or more wires instead of two, had become commonly available for industrial use, allowing motors to start and stop under load. An electric current and suitable motors capable of acceptable performance had finally arrived. However, ten more years would pass before electrical technology would unconditionally meet the needs of mining. Until improvements were realized, mining companies looked askance at electrical machinery.

The second major factor that discouraged mining companies from converting to electrical machinery revolved around the economics of running a mine. Developing a claim from a prospect pit to a real mine required capital and reliable machinery capable of withstanding the unforgiving environment of hardrock mining. Electricity had been applied mainly on an experimental basis for only ten years by the time the power was turned on in Cripple Creek, whereas steam had proven effective since hardrock mining began in the West in the 1860s. During the 1890s, electric power had been successfully applied to sinking-class machines, but not to production-class machines, which large mines relied on to maximize tonnage. Naturally, most mining companies opted to

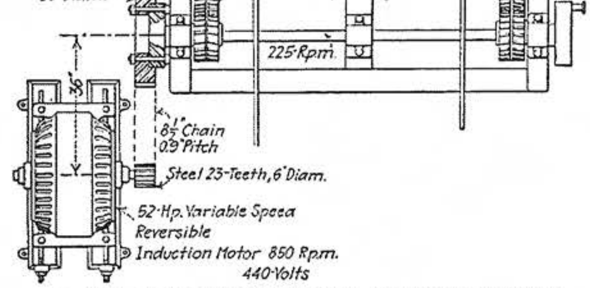


FIG. 257.—STEAM HOIST ARRANGED FOR ELECTRIC DRIVE.

Circa 1910 schematic drawing illustrating how to adapt an electric motor to drive a geared steam hoist. According to the drawing, the steam linkage has been removed and an electric motor installed on the right side. Source: *Details of Practical Mining* McGraw-Hill Book Company, New York, NY 1916 p326.

equip their plants with the conventional, proven steam technology. This mindset perpetuated the installation of steam plants in Cripple Creek and other mining districts through the 1910s.

The steam plants erected by mining companies represented a considerable capital expense. During the 1890s when mining companies were developing many of Cripple Creek's mines, the average cost of a steam hoist, a boiler, and installation was approximately $1,000, and the heavy production-class hoists and the additional boilers required to power them cost much more.[17] Once the mining companies installed hoists, compressors, and boilers, they were then saddled with debt, whether they prospered or failed. Under these circumstances mining companies had no economic incentive to junk an operational steam plant and accrue additional costs replacing it with electric machinery, which might not even perform as well.

Mining companies did have an economic incentive to replace steam-powered mine equipment with electric machinery, but only after the steam versions wore out and became unreliable. But because nineteenth century machine manufacturers prioritized longevity and durability, steam hoists and compressors were built to last, which meant slow, piecemeal replacement.

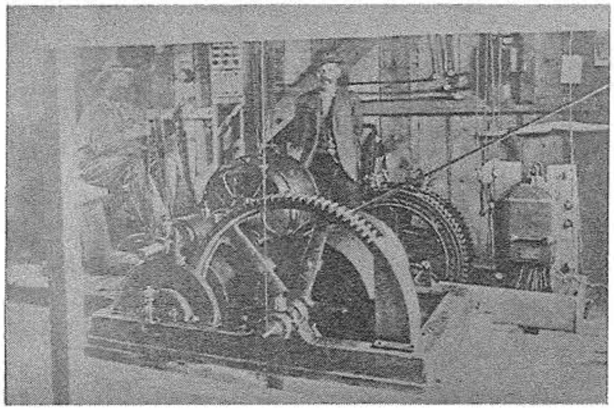
During Cripple Creek's boom, the district's original power company officials tacitly understood the mental and technological obstacles they faced in trying to groom a substantial customer base. While refuting the pro-steam mindset proved difficult because of its intangibility, they attempted to assuage the economic side of the problem. Accordingly, each company assembled a pool of electric mining machines, including hoists, pumps, and drive motors, which were rented to miners engaged in erecting surface plants. The three power companies hoped mining companies, especially those with little capital, would find that renting equipment with little or no deposit would be less costly than purchasing and installing steam plants, and they would then become electric consumers. Basically, because mining companies in Cripple Creek were not embracing electrical technology, the power companies attempted to remove the economic risks from installing electric machinery.

The outcome of this system was not quite as anticipated. In Cripple Creek the greatest body of capital-poor companies consisted of groups of lessees. As was common in many western mining districts, the owners of Cripple Creek's mines often leased their properties to groups of independent miners who contracted to work mines. Generally, paying mines were worked by the parent company. Some mine owners erected surface plants on their properties which made life financially easier for lessees, but where the machinery was lacking, it was up to lessees to provide it. The electric companies in fact provided a cheap source of energy on a monthly payment basis for struggling miners who hoped to strike ore.

By facilitating the rental system, the electric companies significantly benefited the mining district as well as themselves, in an unexpected way. Lessees often could profitably work low-grade ore that was uneconomical for a large company. By making affordable machinery available to the lessees, the electric companies extended the life of the district and, hence, their own existence. Mines which companies would have closed as unprofitable were worked for years by lessees. The electric companies also indirectly benefited the district, and again themselves, by powering ore reduction mills, which could process ore at a lower cost than with steam. Mill workers in turn worked previously uneconomical low-grade ore, which meant prolonged life for the mines.[18]

Despite the success lessees achieved with electric machinery, most mines in Cripple Creek did not embrace the new technology. Instead, they continued to order steam equipment as many as twenty years after the Canyon City plant went on line in 1898. Surface plant machine installations in the Cripple Creek Mining District compiled from the *Engineering & Mining Journal (E&MJ)*, the *Mining & Scientific Press (M&SP)*, *Sanborn's Insurance Maps*, and other sources reveals a gradual switch to electric appliances, the change being more liberal for compressors, pumps, and shop machinery than for hoists. *Sanborn's Insurance Maps* comprise a unique and distinct historical record of the layout and machinery of mine plants. Sanborn produced precise scale maps detailing the types of machinery and sources of power of individual mines as well as mining towns.

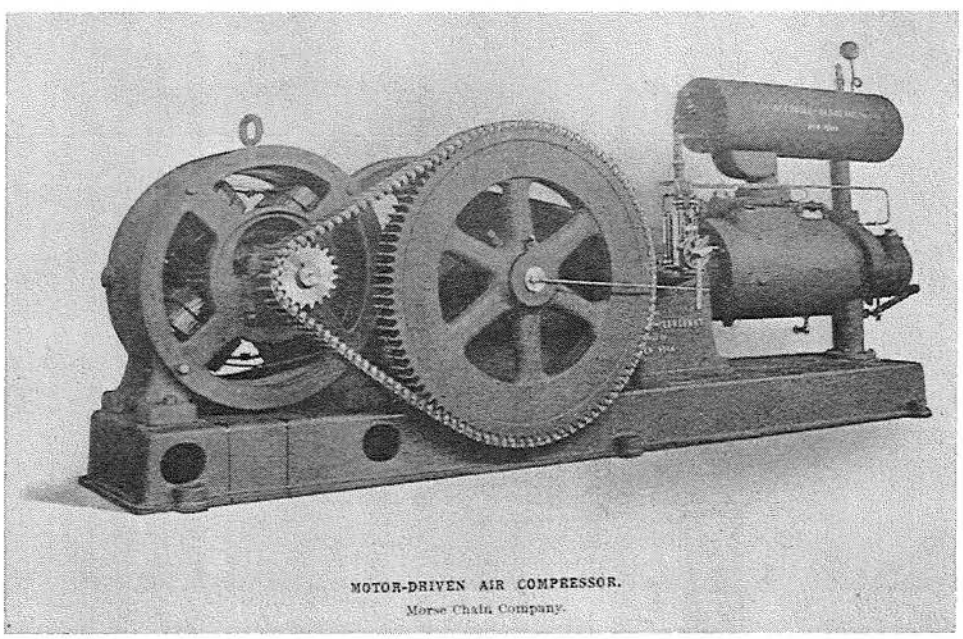
By 1910 many of the profitable mining companies were expanding their plants, as well as replacing worn machinery, translating to a demand for new



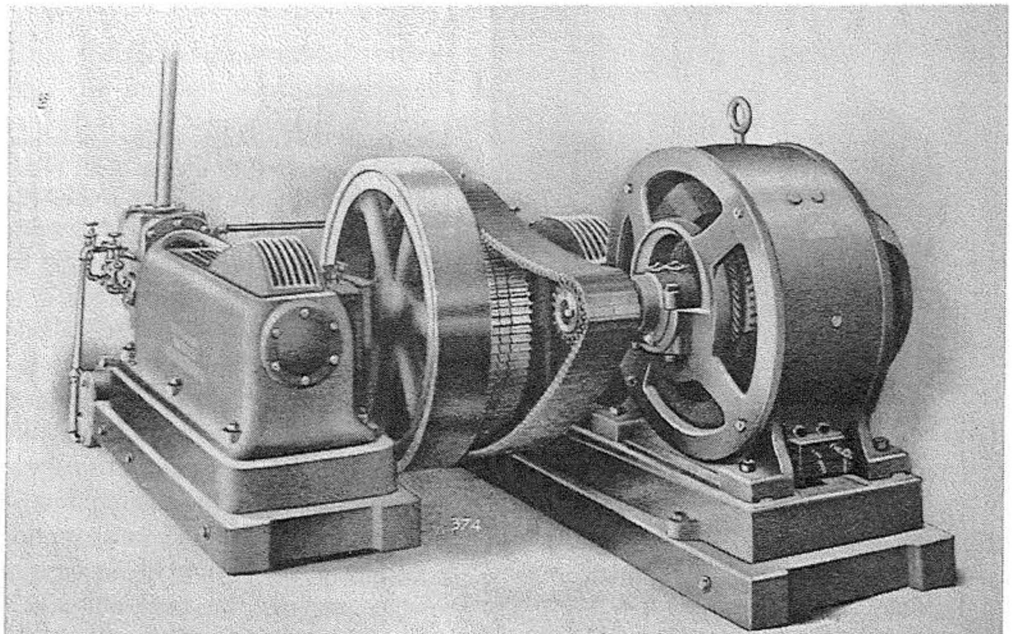
View inside the Los Angeles Mine's hoist house, Cripple Creek. The hoist operator (left) is at the ready behind an electric hoist , and the standing figure (center) is probably the mine superinte n-dent. The time period is 1901 or slightly earlier. Source: *Engineering & Mining Journal* March 1, 1902 p307.

compressors, hoists, and dewatering pumps. Greater numbers of mining companies began turning to electrical machines, which at last were capable of withstanding the abuses of mining. Still, at this time large mining companies continued to install steam-powered machines. Between 1898 and 1910, the *E&MJ* and the *M&SP* recorded the installation of 101 hoists - 59 steam-powered, 20 electric and rated between 45 and 15 horsepower, four gasoline, two horse whims, and 16 small, light-duty electric units set up by lessees underground over winzes. All but one of the mines which installed electric hoists were either small producers or exploratory operations with sinking-class surface plants. Only one sizable producer, the Granite Gold Mine, installed a production-class 300-horsepower electric hoist, but in 1900, after less than two years of operating the machine, Granite declared the contraption a failure and replaced it with tried-and-true steam technology.[19]

The 1907 edition of *Sanborn's Insurance Maps,* which may be the most objective record of active mines in the district, documented the nature of mine plants and their power sources. Of the 187 mines depicted by Sanborn, 161 relied on steam power for hoisting, 16 had electric hoists, one had a gasoline hoist, and one hoist was manual. Concurrent with the conclusions drawn from the *E&MJ* and the *M&SP*, no large mining companies used electric hoists, only small producers and exploratory operations used them.

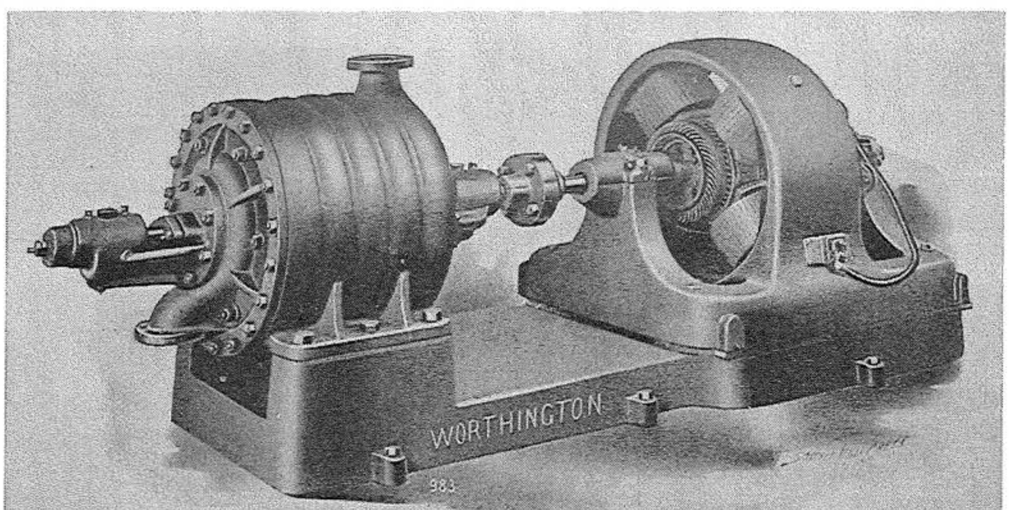


The electric compressor depicted in the illustration is similar to some of those used at Cripple Creek mines between 1900 and 19 20. This model, a straight line unit, is geared to an electric motor located on the left. Traditionally, the compression cylinde r on the right was linked to a steam piston. The compressor's constant and easy rotation lent itself well to being motor -driven. Source: *The Practical Management of Dynamos and Motors*.



RAND, "IMPERIAL," TYPE 10-2, CHAIN-DRIVEN, COMPOUND AIR COMPRESSOR.

The photo depicts a duplex compressor chain-driven by an electric motor. The compression cylinders flank the central flywheel. Because energy was lost through the chain, and because chains were expensive, most mines used canvas belting which passed around the compressor's flywheel to the motor. Duplex compressors could deliver more air than straight line models, but they cost more to buy. Source: Rand Drill Company *Catalog 10* Rand Drill Company, New York, NY 1904.



FIVE-STAGE MOTOR-DRIVEN TURBINE PUMP.
Adapted to Heads up to 750 Feet.

Conventional steam-powered mine dewatering pumps were expensive to operate because steam had to be plumbed down into the mine where miners had installed the machine. Over distance steam lost considerable temperature and pressure, causing it to condense. Electric pumps did not suffer the same inefficiencies and significantly decreased pumping costs. In addition, the high-speed rotation of electric motors permitted the production of better pump designs, such as this turbine model. Source: *The Practical Management of Dynamos and Motors*

Between 1898 and 1910 the *E&MJ* and the *M&SP* recorded 48 air compressors installed - 22 steam powered, 25 electric-powered, and one powered with a gasoline engine. The 1907 edition of Sanborn's map depicts 58 steam compressors and eight electric compressors.

From 1910 to 1920 mining companies installed electric surface plant components at an accelerated rate as the technology improved and old machines wore out. During this time, in fact, the *E&MJ* and the *M &SP* reported 12 hoists installed - three run by steam and nine powered by electric motors. In the context of the district, while Cripple Creek was in decline during the 1910s and fewer mining and exploration operations were active than during the previous decade, many dozens of claims were still being worked, making the overall number of electric hoists installed during this time seem relatively small. The Last Dollar Gold Mine, one of the district's top 19 producers, installed the district's first successful production-class electric hoist during the 1910s.[20] However, the remainder of mines which had electric hoists continued to be minor producers; the larger mines were still powered with steam technology. The seven compressor installations reported in the *E&MJ* and the *M &SP* were all electric-powered. However, the district's largest and best-producing mines, including the Elkton, the Independence, the Portland, the Golden Cycle, the Hull City, the Vindicator, the American Eagle, and the Ajax each relied on massive, fast, and energy-efficient production-capacity steam hoists into the 1920s. These mines may be viewed as technological bellwethers among Cripple Creek's mines. Owners of these large mines had a strong incentive, and the economic resources, to equip their works with the most effective technology to maximize production and to minimize costs.

The Arkansas Valley Railway, Light, & Power Company printed a map about 1911 charting the principle power lines and electric customers in the district. According to the map, 14 of the 40 mines significant enough to be included had electric surface plant components. The fact that the 1911 map illustrates only 14 major electrical customers also suggests the switch to electric mining machinery was gradual, if not retarded. However, many mines in the district were wired for electric lighting as indicated by the Arkansas Valley Railway, Light, & Power Company and Sanborn maps.

Archaeological evidence remaining in the district today also indicates that the majority of mines in Cripple Creek did not use electric power during the boom. Between 1995 and 1997 I conducted an archaeological inventory of mines associated with public lands and proposed mining in the district for Paragon Archaeological Consultants, Inc.[21] Of the 50 relatively large boom-era mines and prospect shafts studied, 25 exhibited evidence of employing steam hoists, eight used electric hoists, 13 had gasoline hoists, and four had either gasoline or electric hoists. The archaeological evidence indicative of steam power included boiler foundations, steam pipes associated with compressor and hoist foundations, and deposits of fuel residue consisting of boiler clinker, burned slate fragments, and pieces of low-grade bituminous coal. Electric powered hoists were signified by substantial hoist foundations coupled with a lack of boiler evidence, and the presence of electrical artifacts. The archaeological record of all large and many medium-sized mines included in the study exhibited evidence of steam power. All of the mines under study that used electric hoists were small but productive, and all of the mines that once used gasoline hoists were merely prospect operations abandoned after a short life.

Conclusion

Contemporary and historic descriptions of the Cripple Creek Mining District belie the degree to which the district's mines used electricity for power during the boom, and the importance of the district's electrification relative to western mining. In 1898 one of the *E&MJ* editors stated: "Probably no other mining district is so thoroughly supplied with electricity, for the home of the miner is lighted by incandescent lamps, he goes to work in an electric street car, by an electric hoist he descends the mine, electric lamps furnish illumination for his work; electrically driven pumps keep the mine dry; electric air compressors run drills; electric hoists raise the ore; and by electricity blasts are fired from switchboards remote from the point of explosion." Mining engineer George Gibson authored an article for a 1902 edition of the *E&MJ* in which he states: "In July, 1888 electric machinery was first introduced in the [Cripple Creek] district." Robert Guiliford Taylor states in

Cripple Creek Mining District: "with this [electrical] solution the mines and urban areas rapidly completed the conversion to an electrical power base." In *Ghost Towns of the West,* Lambert Florin claims that "all mines were electrified." The noted historian Brian Levine claims the district was electrified in 1892 in his book *Cripple Creek: City of Influence*. In *Colorado: A History of the Centennial State*, Carl Abbott states that Cripple Creek was electrified in "its first years."[22]

Those mining engineers and historians have been mistaken; a close look at historic data and the archaeological record of the district reveals that most mines did not use electricity for power during the boom, and that in the context of western mining, electrification in Cripple Creek was part of a technological ground swell rising throughout the mining industry.

The transition from steam to electric power amid Cripple Creek's mines was gradual and lasted more than 20 years. Because of the economics of start-up capital, some lessees quickly embraced electric power while large mines generally installed electric machinery when replacing worn-out appliances, or when expanding their facilities.

Even at the retarded pace of electrification among Cripple Creek mines, certain types of machines lent themselves better than others to be driven by motors, and they were electrified faster. For example, hoists were among the last surface plant components to be electrified; their constant starting and stopping, varying speeds, and being subjected to different loads made them physically difficult to adapt to electricity. In addition, miners considered steam hoists to be almost sacred and they resisted unconventional versions of the machines their lives depended upon. Other types of machines, especially those with low drag coefficients and those that operated through constant rotation, such as air compressors, blowers, pumps, and shop tools, lent themselves well to being run by electric motors.

Cripple Creek's mines did not become heavily electrified until the 1920s when the problematic technological problems were solved, and much of the steam equipment in the district had become worn and in need of replacement. True to T.A. Rickard's prediction, not until the 1920s did electric hoists, compressors, and other machines integral to mining prove more economical in terms of power consumption, performance, and durability. By the middle of the decade large and small mining companies had fully embraced electric power and abandoned their hissing steam boilers. Ironically, companies rehabilitating mines in Cripple Creek during the 1920s and 1930s salvaged the old steam hoists for reuse, but stripped them of their steam equipment and retrofitted them with electrical motors. In terms of electric power, the Cripple Creek Mining District was clearly not a technological spearhead among western mining districts. Out of practical and economic interests, the district's mines relied on traditional and conventional Industrial Revolution technology well into the 1910s.

NOTES

1. Cross, Whitman & Penrose, R.A.F. Jr. *Geology & Mining Industries of the Cripple Creek District, Colorado* p115. Rickard, T.A. *The Cripple Creek Goldfield* Abstract of Proceedings, Industry of Mining & Metallurgy, London, 1899 p4. Sprague, Marshall *Money Mountain the Story of Cripple Creek Gold* University of Nebraska Press, Lincoln, NE 1979 p44. Taylor, Robert Guilford *Cripple Creek Mining District* Filter Press, Palmer Lake, CO 1973 p23.
2. Grimstead, Bill & Drake, Raymond *The Last Gold Rush* Pollux Press, Victor Co. 1983 p130. Sprague, Marshall *Money Mountain the Story of Cripple Creek Gold* University of Nebraska Press, Lincoln, NE 1979 p231, 297. Taylor, Robert Guilford *Cripple Creek Mining District* Filter Press, Palmer Lake, CO 1973 p164, 167.
3. Colliery Engineering Co. *A Treatise on Metal Mining* Burr Printing House, New York, NY 1899 A42 p2. Colliery Engineering Co. *Coal Miners' Pocketbook* McGraw-Hill Book Co., Inc., New York, NY 1916 p580. Peele, Robert *Mining Engineers' Handbook* John Wiley & Sons, New York, NY 1918 p252.
4. Saunders, William [Untitled] *Engineering & Mining Journal* Jan. 2, 1892.
5. Wyman, Mark *Hard Rock Epic: Western Miners and the Industrial Revolution 1860-1910* University of California Press, Berkeley, CA 1979, p103.
6. Holt, M.B. (Untitled) *Engineering & Mining Journal* Jan.

23, 1890 p134; "Concentrates" *Mining & Scientific Press* Sept. 22, 1900.

7. Clark, W.N. "Fifty Years Service" *Colorado Mining Association Yearbook*, 1947. Taylor, Robert Guilford *Cripple Creek Mining District* Filter Press, Palmer Lake, CO 1973 [Indiana University 1966], p63.
8. "Cripple Creek Mines in 1898" *Engineering & Mining Journal* Jan. 14, 1899 p47-48; Clark, W.N. "Fifty Years Service" *Colorado Mining Association Yearbook*, 1947.
9. Clark, W.N. "Fifty Years Service" *Colorado Mining Association Yearbook*, 1947; "Applications of Electricity in Cripple Creek, Colorado" *Engineering & Mining Journal* Oct. 28, 1900 p520-521; Cripple Creek, Colorado Mines in 1899" *Engineering & Mining Journal* Jan. 12, 1900 p50.
10. Hazelhurst, Dr. S.R. "The Cripple Creek District, Col orado, VI-The Power Plants" *Engineering & Mining Journal* Dec. 8, 1900 p669.
11. Clark, W.N. "Fifty Years Service" *Colorado Mining Association Yearbook*, 1947; Clark, Winfred *Skaguay* Century One Press, Colorado Springs, CO. 1989, p18; "Mining Su mmary: Colorado, Teller County" *Mining & Scientific Press* Nov. 24, 1900 p550.
12. Raber, W.F. *The Arkansas Valley Railway, Light, & Power Company* State Bureau of Mines, Denver, CO. 1911.
13. Clark, W.N. "Fifty Years Service" *Colorado Mining Association Yearbook*, 1947.
14. Rickard, T.A. "Electric or Steam For Hoisting" *Engineering & Mining Journal* May 2, 1904 p881.
15. Seager, James "Electrical Mine Machinery Troubles" *Engineering & Mining Journal* Feb.4, 1911 p274-276.
16. Crocker, Francis & Schuyler, Wheeler *The Practical Management of Dynamos and Motors* D.Van Nostrand Co., New York, NY 1896 p27; Colliery Engineering Co. *The Coal & Metal Miners' Pocket Book* International Textbook Co., Scranton, PA 1905 p225; Colliery Engineering Co. *Treatise on Metal Mining* Colliery Engineering Co., Scra nton, PA 1899 A23 p5.
17. "The Cripple Creek Mining District in Colorado" *Engineering & Mining Journal* Jan.11, 1896 p37.
18. Ibid.
19. *Mining & Scientific Press* August 18, 1900 p192; *Mining & Scientific Press* Dec. 1, 1900 p563.
20. *Mining & Scientific Press* August 14, 1917 p177.
21. Sara, Tim; Twitty, Eric et al *Mitigative Treatment of Historic Properties Involved in a Land Exchange Between Cripple Creek & Victor Gold Mining Company and USDI-Bureau of Land Management Near Victor, Colorado* Paragon Archaeological Consultants, Inc. Denver, CO 1997.
22. "Applications of Electricity at Cripple Creek" *Engineering & Mining Journal* Oct. 28, 1899 p 520. Gibson, George II "Electricity in Mining" *Engineering & Mining Journal* March 1, 1902 p308. Taylor, Robert Guilford *Cripple Creek Mining District* Filter Press, Palmer Lake, CO 1973 [Indiana University 1966]. Florin, Lambert *Ghost Towns of the West* Promontory Press (no city or state listed) 1970. Levine, Brian *Cripple Creek: City of Influence* Historic Preservation Department, City of Cripple Creek, Cripple Creek, CO 1994. Abbott, Carl et al *Colorado: A History of the Centennial State* University Press of Colorado Niwot, CO 1994.