NEVADA HISTORICAL
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DEVELOPMENT OF WASHOE AND REESE RIVER SILVER PROCESSES

ERNEST OBERBILLIG

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NEVADA HISTORICAL SOCIETY

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The Society believes that it can best serve the State by arousing in the people an historical consciousness which it hopes will be carried to succeeding generations. Thus, through its director, the Society sponsors an educational program which carries the history of Nevada to the schools and organizations throughout the State.

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Development of Washoe and Reese River Silver Processes

ERNEST OBERBILLIG

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INTRODUCTION

The importance of the silver ore processes described here can be shown by the statistics of world silver and gold production from 1493 to 1875, a span of 382 years. These figures show that even despite the huge gold output from California and Australia in the quarter century 1850–1875, world silver production was still $1.5 billion more than the total gold to that date. World silver to 1875 totaled $8,137,000,000.00.

We may have the everyday common belief that Inca gold was the treasure sought by the Spanish Conquistadores; this is true, but the mines worked by the Spanish in the Inca lands of Peru and Bolivia yielded silver valued at ten times the gold produced for the same period.

Mexico produced twice the silver of the Inca Empire and only half the gold, so the silver-gold ratio for Mexico was 40 to 1 for that same period.

The above ratios show the extremely high relative value of silver from the new world's precious metal production in its first four centuries' occupation by colonists and conquerors.

Because of this extremely great importance of silver, the following article will describe the early long-forgotten, now antique Spanish methods for recovering the silver from the ore. These seemingly crude methods of the Spaniards, the Patio and Barba Kettle, produced more silver in the world to 1875, than the total silver output to date for the United States.

These methods of the Spaniards will be described and it will be shown how the Nevada silver recovery methods used from 1860 to 1900 developed from the early Spanish inventions and methods. However, the slow, crude, laborious methods of the Spaniards had to be mechanized and speeded up for the Nevada silver mines. The Spaniards used enslaved Indian labor, but the Nevada mines used "free" men for labor and their methods had to be developed to pay these men a living wage and still leave a profit. This article also describes the important silver ore milling processes developed in Nevada from the early Spanish methods. These Nevada methods were termed WASHOE and REESE RIVER Processes, which were named for the Nevada mining regions where they were born. From Nevada these perfected metallurgical innovations spread throughout mining camps and districts, not only in this nation but all over the world.

DEVELOPMENT OF WASHOE SILVER PROCESS—1860

The Washoe silver process was developed in Nevada on the famous Comstock Lode,—a fabulously rich silver-gold region at Gold Hill and Virginia City. These silver ores of the Comstock were new to the American miners and the metallurgical process to unlock the silver and gold from them became a problem of tremendous importance. This account will trace the development of the Washoe process from its earliest principles and machines dating from the 16th century. The name Washoe signified the Comstock area and was given to this region which was near the home of the Washoe Indians.

Presently, the Washoe process has almost completely been replaced by more modern silver milling methods such as flotation and smelting; however, since this process marked the first American triumph in the metallurgy of gold and silver ores and was the answer to silver ore milling problems at so many other Western camps, it seems fitting that it now be accorded the credit it deserves. Without the Washoe process and its modifications, we may not have had the boom mining camps of the Comstock, Reese River (Austin), Humboldt, White Pine, and Pioche, all in Nevada; Silver City, Banner, and Atlanta in Idaho; Silver Clip, Tombstone, Silver King, and Prescott in Arizona with important operations at Silver Reef, Utah, (near St. George).

After its successful development in the Western United States the process was accepted and adapted in Mexico, Peru and Bolivia where its principles originated.

Since most of the features of this process depended upon principles and methods used in the early 16th century in Spanish America and evolved from these methods, they will be described first.

These ancient methods and processes are called: Patio, Barrel, and Kettle with stamp mills and arrastras pulverizing the ore for the three above mentioned processes. The treatment of the ore for any of the silver recovery processes started with crushing and grinding. The crushing apparatus used from the 16th century days of Agricola shown in Fig. 1 was the 16th century stamp mill. Phillips[1] gives a good one-sentence description of the stamp mill:

> "The stamping mill essentially consists of a series of heavy pestles, working in a rectangular mortar, each of which is alternately lifted by means of a cam, and subsequently let fall with its full weight upon the ore to be operated on, and of which, after being previously reduced to fragments of proper dimensions, a constant supply is introduced into the mortar, or battery box."

After the placers tapered off in California in the mid-1850's, attention was directed to the gold quartz veins, and to work these the ancient stamp mill was modernized and made from steel and cast iron. These modifications resulted in a new-type stamp mill shown in the complete Washoe type mill illustrated by Fig. 12. Quite properly this newly perfected machine was labeled "California Type stamp mill".

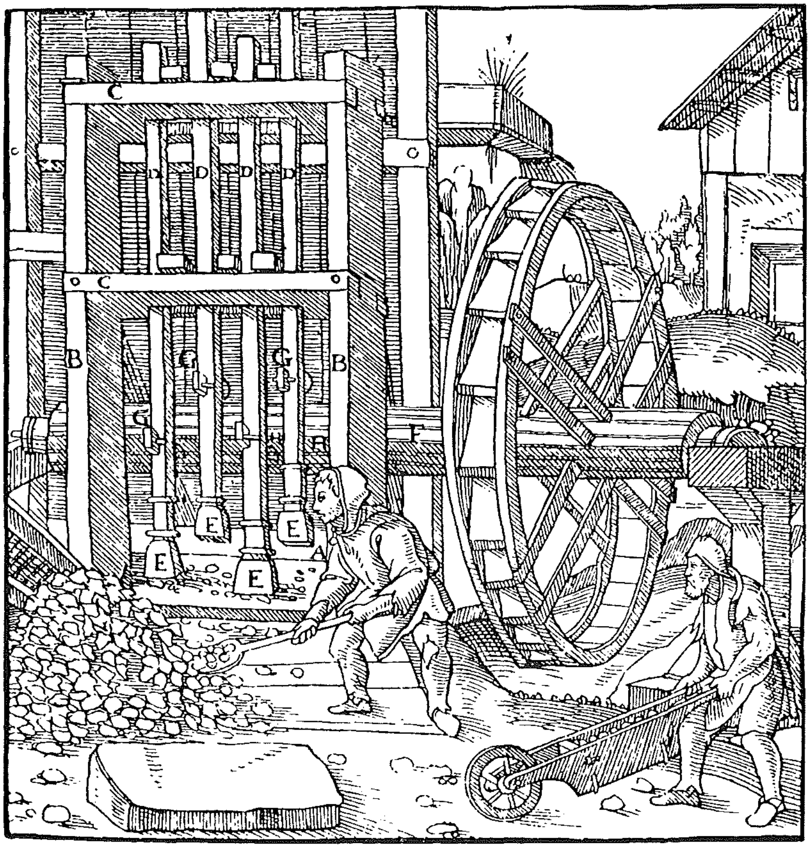

Fig. 1. A stamp mill in the sixteenth century. Woodcut from Agricola's original book. Careful examination of the above figure shows letters which refer to the following legend: A—Mortar. B—Upright posts. C—Crossbeams. D—Stamps. E—Their heads. F—axle (camshaft). G—Tooth of the stamp (tappet). H—Teeth of axle (cams).

After reduction of the ore to a coarse sand in the stamp mill, further grinding was done in the arrastra. While the arrastra could crush and grind pieces of ore as large as walnuts, its capacity was sharply reduced when fed anything other than the sand discharge from the stamp mill. Phillips[2] gives a good description of the arrastra, and abstracting this the following explanation is offered.

A Mexican arrastra is a twelve-foot diameter circular pavement of stone. The ore is ground by two or four large muller stones dragged around a circular path by either one or two mules. A rough curbing of wood or flat stones around the circular pavement forms a two feet deep tub. In the tub's center, firmly bedded in the ground, is a stout wooden post about level with the exterior curbing. Working on an iron pivot in this central post is another strong vertical wooden shaft, secured at its upper end to a horizontal beam with another iron pivot and bearing. This horizontal beam is supported at its ends on strong vertical posts about six feet high (not shown in sketch). This vertical wooden shaft is crossed at right angles by four strong wooden arms, one of which is extended where the mules are hitched for motive power.

The muller or dragstones are attached to the arms with chains or raw-hide in such a way that their leading edges are raised nearly an inch above their trailing edge. These hard stones, weighing three to four hundred pounds each, catch ore particles under the leading edge and by a grinding and mulling action pulverize the ore.

This grinding is done in a thin mud or slurry and a small trickle of water fed into the tub carries the ground ore out over a V-cut discharge and ditch into rock tubs for settling. Fig. 2 is a woodcut drawing of the arrastra. It will be shown further along that the one important machine of the Washoe process, the Washoe pan, is nothing more than a small size mechanized arrastra made of iron instead of stone.

After the ore was ground to a fine powder in the arrastra it was then ready for treatment by any one of the early silver processes: Mexican Patio, Barba's Kettle method, or Freiburg Barrel.

OPERATION OF THE PATIO PROCESS

The Patio process, as its name indicates, was performed on a level tamped earth area of ground as large as 300 feet square. This plot of ground was partitioned into circular enclosures about 50 feet in diameter, the perimeter of each circle fenced by a low stone border. The bottom of this circular enclosure was generally paved with flagstones to minimize the loss of mercury and silver amalgam.

Ore, which had been pulverized in the arrastra was dumped into these circular "patios" to a depth of about one foot, and this ore was mixed with water to the consistency of thin mud,—neither runny nor plastic as putty, but similar to plasterer's mortar. Next from three to five percent common salt is added, and this mixture is then trod and mixed by the hooves of horses, mules, or burros to effect the combination or mix the salt with the ore. After this, a crude copper sulphate (common name, blue vitriol), called "magistral" by the Mexicans, to the extent of one percent of the ore in the patio was added. After this latter chemical has been trod into the ore by the animal's hooves for about an hour, mercury was squeezed through a canvas bag onto the ore and by this means the entire mass of ore was sprinkled with a shower of mercury.

The mercury was then mixed and trod into the ore; this mass of ore being a pancake-shaped pile of mud was termed "torta" by the Mexicans.[3] Fig. 3 shows a "patio".

After being subjected to mixing by the hooves of the animals every other day, with additions of mercury and water as needed, the chemical reaction was observed and controlled by continuous testing for a time varying between 15 and 40 days, depending on the season (warm weather speeds the process).

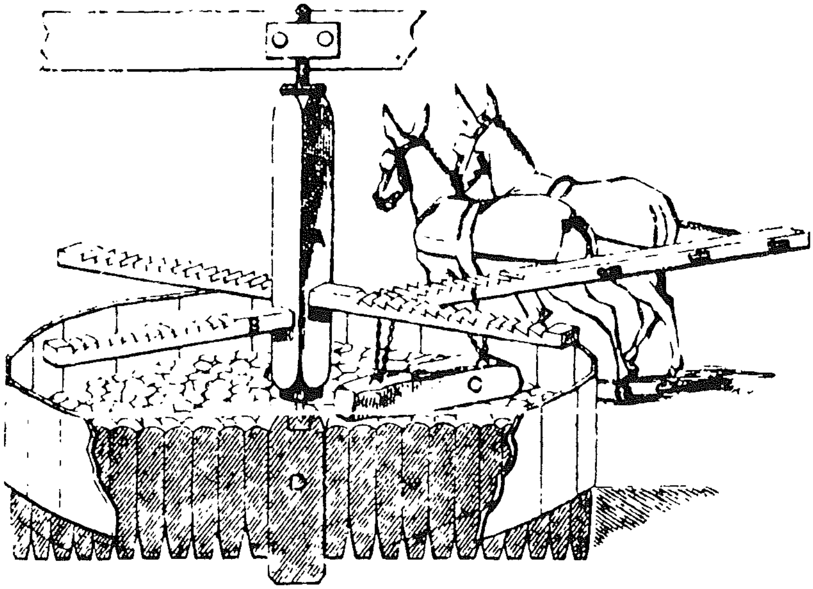

Fig. 2. Mexican type arrastra. From: Phillips, Arthur J., "Mining and Metallurgy of Gold and Silver," E & FN SPON, London, 1867, p. 169.

"Some of the arrastres used by Mexican gold miners, and for the purpose of testing the value of quartz veins, are very rudely put together, the bottom being made of unhewn flat stones laid down in clay; but in a well-constructed arrastre, intended to be permanently employed, the stones are carefully dressed and closely jointed, and, after being placed in their respective positions, are grouted in with hydraulic cement."

The salt, mercury, and copper chemicals were quite corrosive to the animal's legs and caused the poor creature's early demise. Mercury poisoning was a health hazard equally destructive to animals as to men.[4]

After the chemical process had effected the recovery of the silver as an amalgam (a mercury-silver "alloy"), this mercury-silver amalgam must be separated from the large bulk of mud. This separation was accomplished by washing and diluting the mud in tubs by stirring water and decanting off the thin mud slurry. This dilution and slow-stirring allowed the heavy particles of silver-white amalgam to settle to the bottom of the tub. After repeating the dilution-stirring cycle several times, the amalgam becomes fairly well concentrated on the bottom of the tub where it could be scraped and shoveled into buckets. This amalgam was next heated or roasted in iron retorts to separate the silver from the mercury. Retorting the amalgam is a process whereby the mercury is driven off as a vapor which flows into condensers where it is saved and the silver is left behind in the bottom of the retort as a "sponge" metal. This sponge bullion was then melted and cast into the silver "bricks" ready for market or sold to the mint.

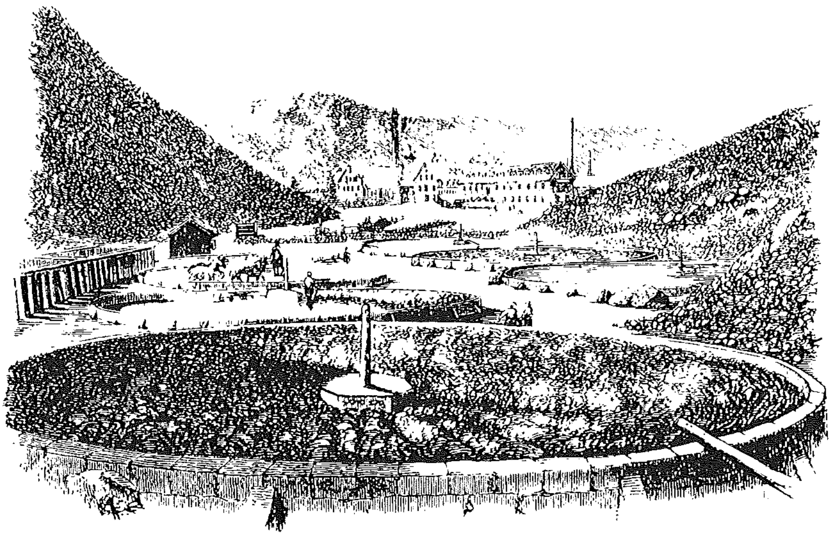

Fig. 3. Patio used at Gould and Curry Mine, Virginia City, Nevada. From: Phillips, A. J., "Mining and Metallurgy of Gold and Silver," 1867, p. 335.

The washing apparatus used to mix, dilute, and decant the waste mud is shown here as Fig. 4. (Note the similarity of this device to the later developed agitator for the Washoe process.)

The Patio Amalgamation Process was employed effectively in Mexico during the Spanish occupation but was used less efficiently in the colder silver regions of Peru and Bolivia. In spite of this, it was tried and used for a time on the Comstock Lode with the cost results shown in the following table:[5]

Ore From Ophir Mine, Comstock, Worked at Ophir Works, Washoe. Average Cost Per Ton of Working During Eighteen Months, Ending June 1864.

PATIO
From December 1st, 1862, to June 1st, 1864.*

	Labour	Wood	Salt	Sulp. Copper	Mercury	Castings	Material	Horses	Total
Crushing	$2.68	$1.85	....	....	....	$0.85	$0.22	....	$5.60
Beneficiating	3.82	0.19	$5.95	$0.55	$2.85	....	0.07	$1.56	14.99
Washing up	1.48	0.09	0.17	0.10	0.80	....	0.02	....	2.66
Total Cost	$7.98	$2.13	$6.12	$0.65	$3.65	$0.85	$0.31	$1.56	$23.25

*Furnished by Mr. W. W. Palmer.

The Patio process was never successful in the United States because of its high-cost, low silver recovery, and excessive time needed for treating each batch of ore. It was most successful in Mexico where the warm climate, low-cost labor, and "mañana" attitude all prevailed.

DISCOVERY OF THE PATIO PROCESS

This process was discovered by Bartolome Medina, a native of Pachuca, Mexico in 1557. Phillips[6] adds interest to this account of the discovery by analyzing how it developed and this explanation will be given in the footnote below.

CHEMISTRY OF PROCESS

The intricate chemical reactions in this process can be summarized as follows:[7]

1. The salt and copper sulphate react together to form copper chloride.

"It is difficult to understand by what course of reasoning a man totally unacquainted with chemical science could have been led to the discovery of a process, of which the *modus operandi* is, even now, to a certain extent, a disputed question, and of which the efficiency does not admit of being at once tested by means of a simple experiment; but which, on the contrary, requires weeks, and, under certain circumstances, even months, for its completion. Although, however, this process requires a considerable period for the full development of its results, the operation of reduction commences almost immediately, and we can therefore only suppose that Medina, being aware of the affinity of mercury for silver, and having mixed this substance with silver ore, sulphate of copper, and common salt, found that a certain portion of the silver had entered into combination with mercury. By keeping this mixture for some time, and occasionally testing the amount of silver taken up by the mercury, which could be readily ascertained by taking a weighed portion of the amalgam and driving off the quicksilver by heat, it would be found, that, for a certain period, the proportion of silver gradually increased, but subsequently remained without change. It is therefore probable that some simple series of experiments of this kind may have conducted him to the discovery of a process which has been of such vast importance, not only to Mexico, but to the world at large, and has so materially affected the total production of silver."

2. The copper chloride combines with the silver minerals (both sulphide and metallic) to form silver chloride.

3. The silver chloride then combines with the mercury to form the silver-mercury amalgam.

BARBA'S COPPER KETTLE PROCESS

Alonzo Barba, a Basque priest from Andalusia, Spain was in Peru and Bolivia from 1600 to 1630 and in 1640 published his "Arte de los Metales"[8] at Madrid. His process was summarized by Liddell.[9]

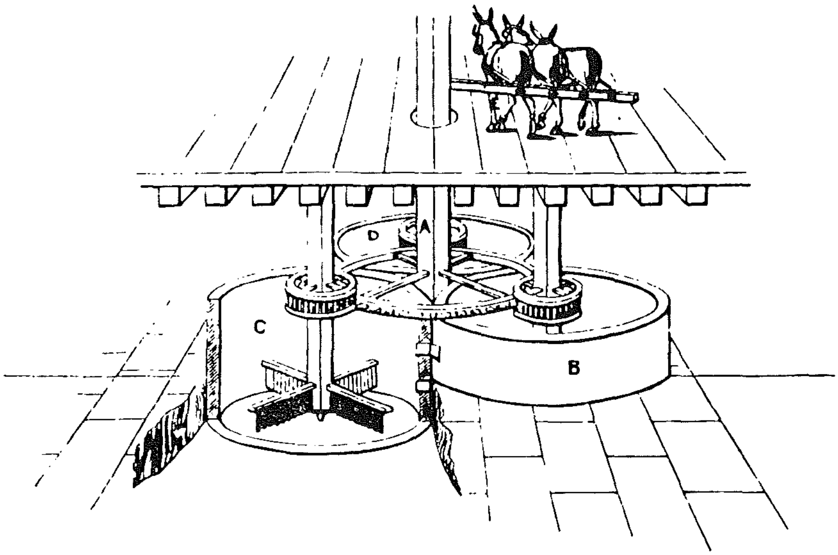

Fig. 4. Washing apparatus employed at Guanaxuato [Mexico] for separating silver amalgam from the waste mud after the ore was treated by the Patio process. From: Phillips, p. 342.

> "The 'Cazo' or caldron ["Kettle"] process was invented in 1590 by a priest, Alvaro Alonzo Barba, at Tarabuco, 24 miles from La Plata, Peru (now Bolivia). This process was the ancestor of the pan-amalgamation [Washoe] process. It was particularly adapted to the rich surface ores of that district containing chloride of silver, and it was also applied to silver sulphide ores to some extent. The process was conducted in a vessel made wholly of copper,* or having a copper bottom. This vessel or caldron was provided with a vertical shaft, to which radial arms were attached for agitating the ore. Finely ground ore, water, and common salt were mixed together to the consistency of a thin pulp and placed in the caldron.
>
> "The caldrons, usually four in number, were placed on top of an adobe furnace built like a cook stove, and heated so as to keep the

*Author's Note: Plates of native copper metal were found in the copper ores of Chacarilla, Bolivia and elsewhere in Peru and Bolivia. These chunks of nearly pure copper could be pounded and shaped into kettles.

ore pulp at the boiling point. Mercury was added, and the boiling pulp was stirred continuously for several hours, after which time the amalgamation was completed. The caldron was removed from the furnace, the tailings washed away with water, the amalgam recovered, and the process repeated with a new charge of ore. The active chemical reagents were the copper of the caldron and the boiling solution of common salt. The silver chloride in the ore was dissolved in the hot brine and reduced to the metallic state by the copper of the caldron, and then amalgamated by the mercury. The cuprous chloride formed was also dissolved by the salt solution and became active in converting the silver sulphide minerals into the chloride, although if a large amount of sulphide minerals were present preliminary roasting was recommended on account of the consequent loss of mercury. In later years, iron was added to the caldrons to reduce and recover mercury that had become soluble or floured."

This Kettle process of A. Barba was much faster than the Patio process because the reaction takes place in a boiling slurry of ore and water. The application of this process, however, requires abundant labor and consequently would have been too costly in the United States. It can be seen from the description that it was essentially the same chemical process as the Patio, but speeded up.

FREIBURG BARREL PROCESS[10]

The Freiburg district of Germany from 1790 to 1856 employed an amalgamation process for their silver ores which came to be called the Freiburg Barrel Process because the amalgamation was effected in revolving wooden barrels developed and used there. First, the pulverized ore was roasted with salt which converted the silver to silver chloride. The cooled ore was then introduced into the barrels with pieces of iron, mercury, and copper sulphate. After the amalgamation is complete, the barrels are dumped and the amalgam separated from the waste rock by washing as in the Patio process. Fig. 5 shows the Freiburg barrels.

The Barrel Process as adapted to treatment of the Ophir ores cost $20.14 per ton of ore treated (without amortization of plant) according to the following table.[11]

COST OF REDUCTION OF ORES BY BARREL AMALGAMATION AT THE OPHIR WORKS, 1865

Labour, of every description, per ton	$9.50
Wood, at $5 per cord	6.00
Salt, 4 per cent. at 3 cents. per lb.	2.40
Quicksilver, 1 lb. at 64 cents	0.64
Shoes, Screens, Shovels, Belts, Tools, &c.	0.75
Castings, Scrap Iron, Timber, &c.	0.65
Charcoal, Assay office expenses &c.	0.20
Total	$20.14

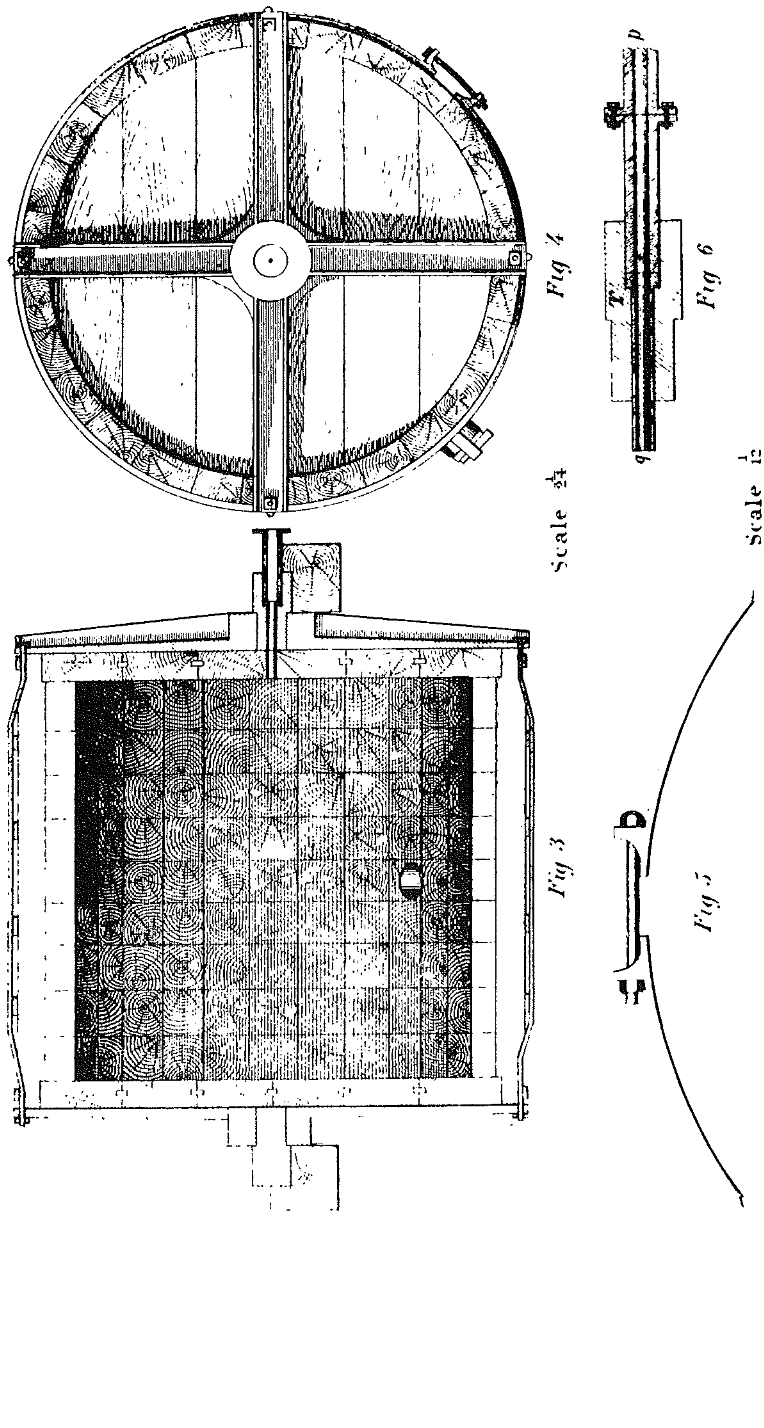

Fig. 5. Freiburg barrels. See Eissler, "Metallurgy of Silver," p. 150, and the above figure is from: "U.S.G.S. Exploration of 40th Parallel," James D. Hague, after p. 266.

DESCRIPTION OF WASHOE PROCESS

These processes and machines described, to this point, all had a part in the development of the Washoe Pan-amalgamation process; the stamp mill, arrastra, patio process, kettle process, and Freiburg barrels all contributed some feature to be combined into the new silver recovery method known as the Washoe process. This traces the metallurgy knowledge known and used up to 1860 when the Comstock Lode took the center of the stage. The first silver ore of any quantity from the Ophir mine and the Comstock Lode in 1859 was a shipment of 38 tons packed over the mountains to San Francisco and treated by Mosheimer and Kustel by the Freiburg Barrel Process. This 38 tons yielded $112,000 gross or a net of $91,424 after deducting treatment charges.[12] This was a net of $2,400 per ton. This rich ore, however, did not persist and the astute miners with foresight knew a milling process was needed so the abundant but lower grade ore could be treated in the near vicinity of the Comstock Lode to minimize the freight charges.

Almarin B. Paul, a California mill operator experimented with the newly discovered Washoe silver ores during the winter of 1859–60 using a then recently introduced amalgamating device called the Knox Iron Pan.[13] This machine was a cast iron type of Spanish arrastra as shown in Fig. 6. But the Knox Pan was not expected to grind as well as the arrastra.

Two mills were being built in the summer of 1860 at Gold Hill (Nevada) to treat the Comstock silver ores. Paul was installing a 24 stamp (24 tons per day capacity) mill and Coover and Harris were erecting a 12 stamp mill; both of these mills were equipped with Knox Pan amalgamators.

Washoe Pan Amalgamation started in those two small mills in 1860. During this time the Freiburg Barrel process had been used with the Ophir ores so these two processes became the basis of the Comstock ore milling controversy, "Pans vs. Barrels".

The "Washoe" pan process centered around the use of the iron amalgamation "pan" rather than a "barrel", the essential feature of the Freiburg process. This controversy over the proper method of milling was carried on by Almarin B. Paul,* advocate of the "Pan" method and Guido Kustel, chief proponent of the "Barrels".

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*Almarin B. Paul was a well-informed California gold mill operator with a far better than average education, (and, fortunately for the present-day historical researcher, had a flair for writing.) While Paul was, at times, over-optimistic regarding future production estimates, his newspaper letters and articles provide some excellent descriptions and accounts of Gold Hill and Comstock mines and mills. Particularly good is a series of 12 articles over the period September 12, Kustel's acquaintance with silver ore treatment started in Freiburg, Germany, continued in Arizona, and finally, as a partner with Joseph Mosheimer in a San Francisco assay and chemical laboratory,[16] worked the first ore from the Ophir mine delivered by Judge Walsh and H. T. P. Comstock.[17]

Kustel was listed with Joseph D. Winters, John D. Winters, and Joseph Mosheimer as the co-owners of "Aurora Mills" at Dayton in the 1863 NEVADA DIRECTORY.[18]

On March 30, 1860,[19] Kustel proposed his pet method—the Barrel Process, for the Washoe silver ores. In continuing his crusade for the Freiburg Barrel method, Kustel wrote on October 24, 1861:[20]

> "There is, however, a very great and important difference between these two methods (Barrel vs. Roasting), and that is the pans cannot work poor silver ores with the same advantage as the barrels can, nor rich ore either. If one has patience enough to wait, he will get here pans for the price of old iron in abundance."

The above statement by Kustel was absolutely wrong and the referee finally raised Almarin Paul's hand to declare him the winner of the "Pans vs. Barrel" bout when the Gould and Curry Company replaced barrels with pans in their Comstock mill in 1863 at a cost of more than one-half million dollars.[21]

Inaccurately, at a later date, Eissler[22] credits Kustel with the development of the Washoe Process:

> "Thanks to the efforts of some metallurgists with European training and experience (amongst whom special notice is deserved by the Hungarian engineer Guido Kustel), the treatment of the ores gradually improved, and it eventually developed into the now perfect Washoe Process, named after the district in which the Comstock Lode is located."

With due respect to Guido Kustel for his splendid book on Washoe metallurgy, it was Almarin Paul and not Kustel who had more to do with fathering and developing the Washoe "Pan" Process.

The stamp mill selected as the first machine in the Washoe Process by Paul was the Howland Rotary Stamp shown by Fig. 7. This stamp mill differed from the already described "California" type by having its stamps arranged around the cam in a circle and the single rotating cam

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1862 to September 28, 1863 published by the SAN FRANCISCO EVENING BULLETIN.[11]

Guido Kustel labels himself "Mining Engineer and Metallurgist" on the title page of his book, NEVADA AND CALIFORNIA PROCESSES OF SILVER AND GOLD EXTRACTION.[15] The preface of this book ends with the notation: "Dayton, N. T., May 1863".

This book, aside from being probably the first book written in Nevada Territory, practically enfolds between its two covers the entire silver and gold ore milling knowledge available in the early 1860 era.

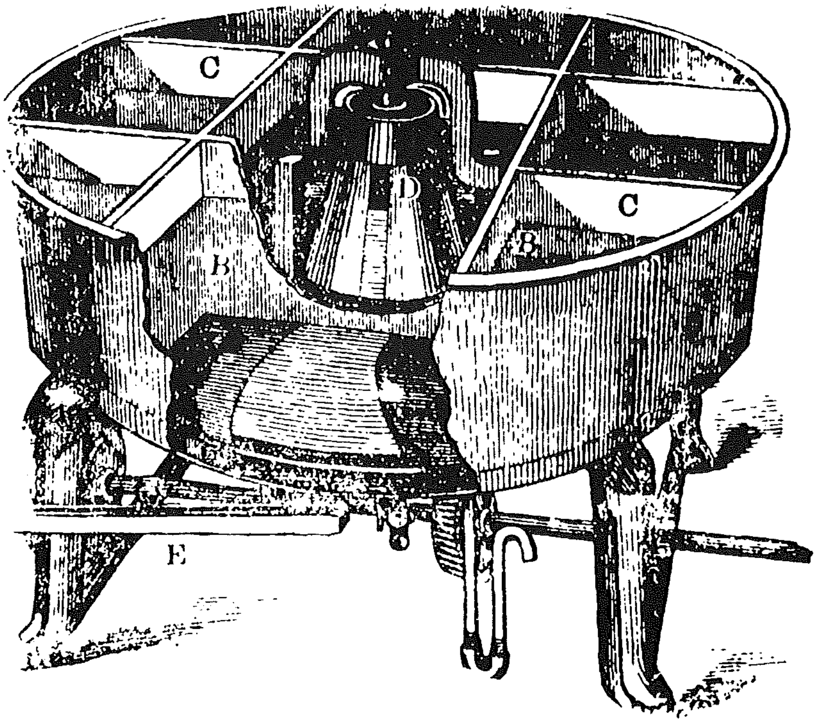

Fig. 6. Knox amalgamator. From: Raymond, R. W., 1870, (2nd Annual Report), "Statistics of Mines & Mining in the States and Territories West of the Rocky Mountains," Washington, Government Printing Office, p. 685.

"This pan is usually made about four feet in diameter for working gold ores, and fourteen inches deep. The pan used for working silver ores is five feet in diameter. The construction may be seen by reference to the figure. The bottom is flat, but rises in the centre in the form of a truncated cone, as high as the rim of the pan. This cone is hollow, and gives room for the bearings of a vertical shaft, geared by bevel spur-wheels to a horizontal shaft under the pan, and intended to give motion to the mullers. These mullers are four in number, thin and flat, and are bolted to an annular collar or centre-piece, surrounding the bottom of the cone, and upon which two upright bars or standards are cast, which lock into the ends of the yoke on the top of the vertical shaft. C C is a board frame, fitting the inside of the pan, and reaching downward to within half an inch of the mullers. B B are amalgamated copper plates, fastened to the board frame for the purpose of catching the lighter particles of gold as they float through the pulp when stirred by the rotation of the mullers. The discharge of this pan is central, through an opening in the cone near the top, D, and controlled by a gate, at the pleasure of the operator. The pulp and waste discharged are received in a sluice, E, below."

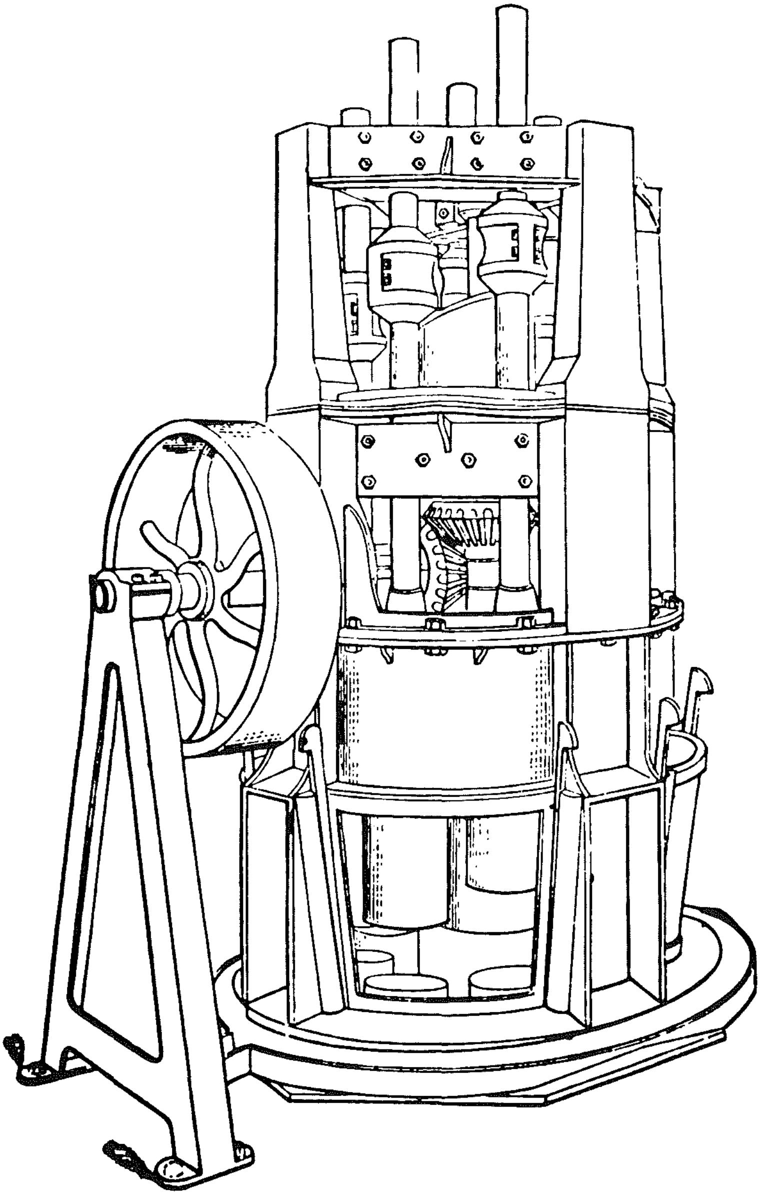

Fig. 7. Howland's rotary stamp battery, from: R. W. Raymond, "Mining Statistics West of the Rocky Mountains," 1870, p. 666.

raised each of the stems as it revolved, rather than a cam for each stamp like the California type.

In the beginning of silver ore milling, most mill operators of 1860 were of the opinion that dry crushing in the stamp mill was the proper procedure for pulverizing the ore for amalgamation. The interchange from dry to wet crushing was described by Paul in the following account:[23]

> "It soon became quite evident to me—so I fancied—that the only mode to fall back on, and the only one likely to exhibit fully the value of Washoe, was the dry process; and consequently I embarked into it, stood for some time in the clouds of dust peculiar to this system of working, in what might be considered a 'brown study'—how to get out of it. I saw nothing but death to men and destruction to machinery, unless some other system was invented or discovered. To go back to the California mode of working, I had now learned was but making a positive failure. The very simple question: What is the use of crushing quartz dry and then wetting it for amalgamation? came up in my mind."

Paul did not immediately stop the mill to make tests of wet crushing because he was required to induce the people for whom he was custom milling to give their permission for a trial. To continue in Paul's own words:

> "Well, my pioneer friends, Coover and Harris, got the same idea into their heads about the folly of crushing dry and amalgamating wet, and at the thought commenced tearing away for the change, and to them I will accord the credit of having introduced first the Washoe Process (of wet crushing). Their embarking into it allowed the opportunity of the more readily determining as to the merits or demerits of the mode. It took but a few 'runs' to satisfy me. Preferring my own tests, and desiring them to be as practical as possible, I tore away in part for it and run 16 stamps 'wet' and 16 'dry'—the same rock side by side, one half dry and the other half wet. I meant to test the matter fairly. I made several crushings of various kinds of rock, and every time the wet process produced the most metal. After this I did not hesitate to tear the two mills to pieces and embark fully in the 'Washoe Process' and am now ready to pronounce dry crushing a humbug. I will go as far as to declare even that for silver ores—and to those who doubt it I will say that that fact, in due time, will be established—dry crushing is awful work and would kill the devil himself, notwithstanding his adamantine lungs, while as to machinery it is terribly destructive. Founders ought to advocate dry crushing, for it makes a vast deal of old iron and creates a great demand for new."

The transition from dry to wet crushing in the stamp mill was the first step in development of the Washoe Process and was soon effected in both mills with Paul changing over sometime in early 1861 or late 1860.[24] This simple discovery of a new mode of stamp mill operation was very important for the following reasons:

1. It yielded more gold and silver recovery in subsequent amalgamation operations.
2. Wet crushing gave larger capacity with the same stamp mill—as much as double the tonnage of ore milled.
3. It was less injurious to the machinery.
4. Wet crushing eliminated the dust health hazard.

The next step in the Washoe Process was the amalgamating pan and before describing it and its development, first a word about how it was selected for this duty. Paul, a Nevada City, California mill operator, was given 80 pounds of Comstock silver-gold ore by his partner, George Hearst. During the winter of 1859–1860 Paul experimented with the ore using a newly introduced Knox iron pan amalgamator.[25, 26]

Paul found in these experiments, using this Knox iron pan with salt, blue vitriol and mercury, he could "in six hours accomplish the same silver recovery that took 30 days with the Spanish Patio Process."[27]

Both of these pioneer Washoe steam-driven mills operating on Gold Hill ores used the Knox pan for amalgamation. The Knox pan was more an amalgamating device not designed to accomplish much grinding. The development of an improved pan capable of both operations—amalgamation and grinding—was carefully traced and described by Eliot Lord.[28] Finally by January 1, 1863 the Wheeler pan had been perfected with a steam chamber under the grinder to heat the pulp during processing and included heavy, trajectory grinding shoes. Fig. 8 pictures this improved pan. This Wheeler pan was nothing more than a cast iron refinement of the old arrastra but more improved than the Knox pan.

The efficient adaption of the amalgamating pan into the Washoe Process (exactly like the wet vs. dry crushing in the stamp mill) required the discovery of a practical innovation. This came about as follows: After adopting wet crushing in his stamps, Paul ran the pulverized slurry of ore and water direct to his amalgamating pans which were arranged in series on "steps" to permit gravity flow from one to the next in line.

Because of surges and overloading of the first pans in the line, the above so called "direct flow" procedure, Paul soon changed by running the stamp mill discharge into settling and dewatering tanks made of lumber. This change required "batch" feeding by shoveling the ground ore from the settling tanks into the pans; even though more laborious and costly, this permitted closer control over the all-important amalgamation operation. The closer control of the pan operation soon paid more in higher recoveries than the extra labor cost.

The pan operation, being a combined physical (grinding) and chemical (amalgamation) process, required careful control and observation by skilled and artful "amalgamators" as this step is the heart of the Washoe Process.

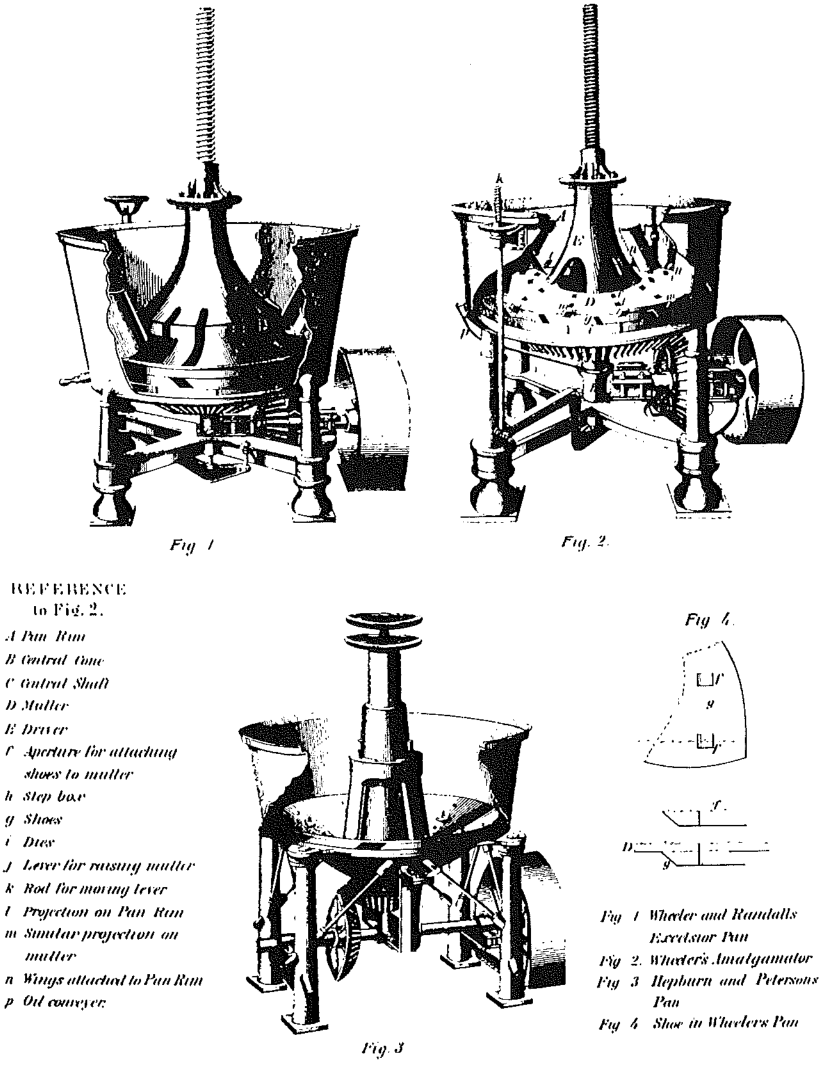

Fig. 8. Wheeler pan. From: "U.S.G.S. Exploration of 40th Parallel," Clarence D. King, Vol. III, Mining Industry by James D. Hague, after p. 219.

After completion of the pan operation, the pulp (ore-water-chemical mixture) was discharged from the pan into the separator or settler leaving the amalgam in the bottom of the pan. Fig. 9 shows one of these machines and Eissler[29] gives a good description but it will be paraphrased.

By reference to Fig. 9, it will be seen immediately that the settler is designed very similar to the arrastra or Knox pan. When operating this machine slower than the Knox pan and with no grinding done by its wooden shoes, it became a decanting classifier. The ore slurry will overflow into the agitator (described below) leaving heavy particles of ore and amalgam which escaped the pan in the bottom of the tank. This amalgam and ore can be scraped into buckets to be cleaned with the amalgam going to the retort and the heavy ore particles returned to the amalgamating pan.

Following the separators in the Washoe flowsheet the pulp then flowed to the agitators. These functioned as a further type of settler to wash the tailings and scavenge all the finely-divided mercury, amalgam and unrecovered valuable minerals possible before discharging the tailings from the mill. Hague[30] described the agitator but Fig. 10 shows it to be essentially only a slightly modified settler. This machine operates slowly and the rakes stir the slurry to overflow and decant off the waste.

Beyond the agitators are usually a number of contrivances, usually blanket frames to further glean any escaping valuable material in the tailings or waste material. Even with all this treatment, usually 30 to 40 percent of the silver was lost in the early mills.

Fig. 11 is a schematic drawing of the flowsheet for the Washoe Process and Fig. 12 is a drawing of a complete Washoe Process mill. A rock crusher is shown in this mill ahead of the stamps and sometimes a heavy "breaker" stamp served in place of this crusher but in either case the Comstock ores, being soft, did not require much primary crushing.

Smith[31] gives a brief but complete comparison between the "barrel" or Freiburg process and the Washoe Process:

> "The Freiburg process, which involved dry crushing with stamps, chloridizing—roasting in ovens and amalgamating in revolving barrels or in tubs, was a slow intricate, and costly process. It was very successful in saving the silver (averaging 80 percent), but lost part of the gold. The Washoe Process, on the other hand, saved the gold but lost part of the silver."

The relative cost of the two processes was compared by Paul in early April 1863 wherein he condemned the barrel process as follows:[32]

> "The barrel process, as applied to Washoe, is one that will never be held in high favor. Neither is it advisable, according to my imperfect views, that it should be for the following reasons:

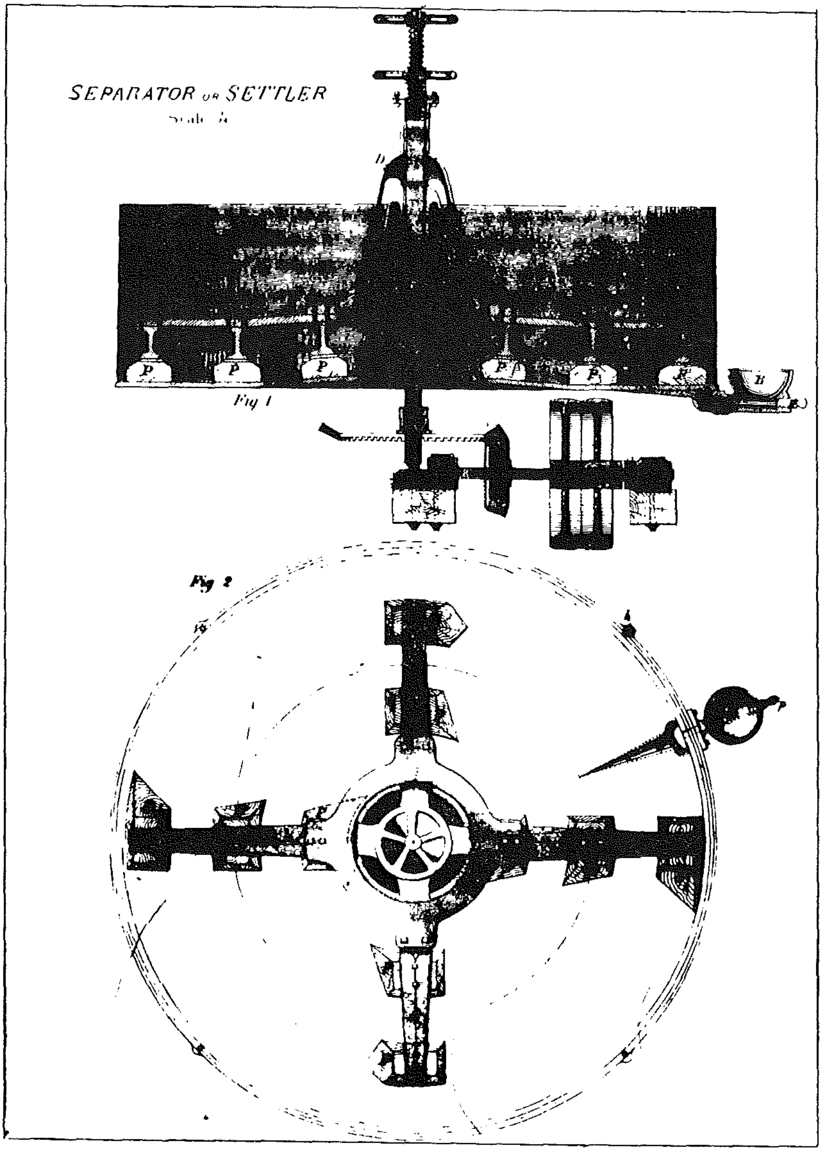

Fig. 9. Settler or separator. From: "U.S.G.S. Exploration of the 40th Parallel," Clarence D. King, Vol. III, Mining Industry by James D. Hague, after p. 222.

"1st to work properly the ore should be roasted. This creates an enormous expense for wood and men to handle and attend to the ores and which may be set at from $13 to $16 per ton unless the works are situated as are the Ophir, along the whole mountainside of timber; while in being thus situated there is an enormous tax of not less than $8 per ton for simply transporting the ores to that wood. To say nothing of chemicals this roasting or hauling cannot be set at less than $28.00 per ton for poorer ores, while richer ores will cost from 50 to 100 percent more."

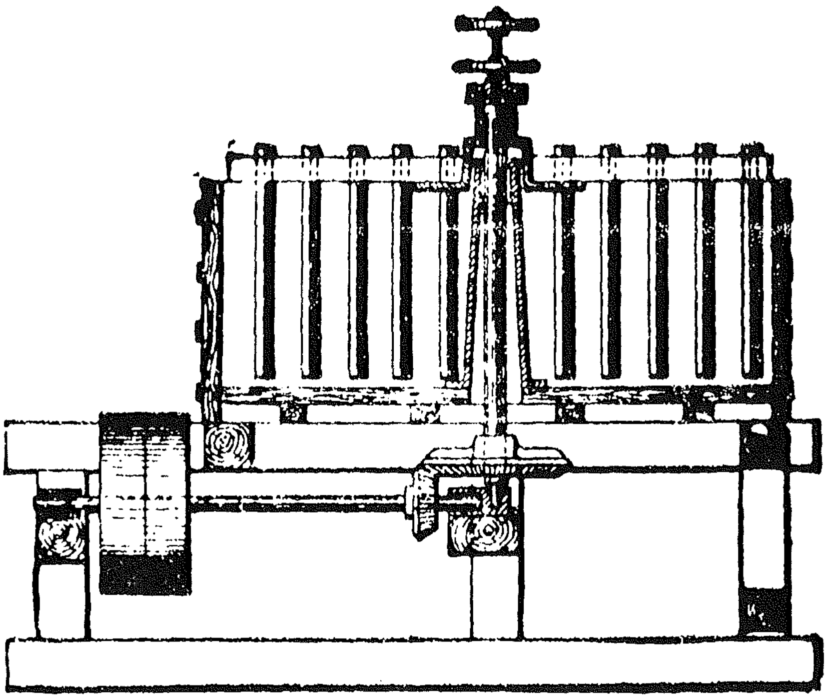

Fig. 10. Agitator taken from Eissler's "Metallurgy of Silver," p. 80. Attached to the top rotating horizontal arms are shown vertical stakes or "rakes" dipping down into the ore slurry. Slow rotation of this stirring device further gleans a small amount of amalgam before discarding the waste product into dams or dumps.

This would put the total cost of treatment by the Freiburg barrel process in early 1863 at close to $50 per ton and Paul gives the Washoe Process cost at that time as $12 to $15 per ton.[33, 34]

After reducing the gold and silver values in the ore (from either the pan or barrel process) all that remains is to separate the mercury from the bullion in the amalgam. Hague[35] describes this procedure and gives pictures of the retort and tools needed. Briefly the steps are as follows:

1. First the amalgam is washed and cleaned of dirt and minerals with water; then the washed amalgam is strained through a canvas filter or conical bag. The amalgam is then reduced further by a press to remove all the possible mercury.

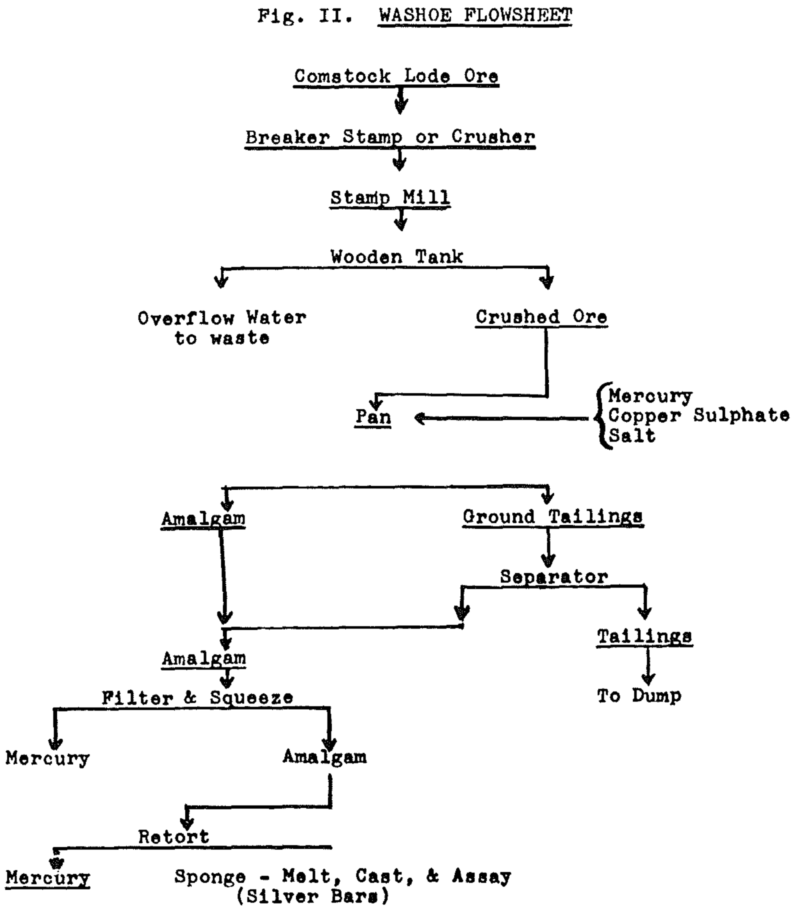

Fig. 11. Washoe flowsheet.

2. The "dry" amalgam is then charged into cast iron retorts, the charging lids are sealed and the retorts are heated to expel the mercury.

3. The "sponge" bullion is then melted and cast into bars of bullion. These ingots of bullion were chipped or drilled for a sample and this sample was assayed to determine the silver and gold content of the bar.

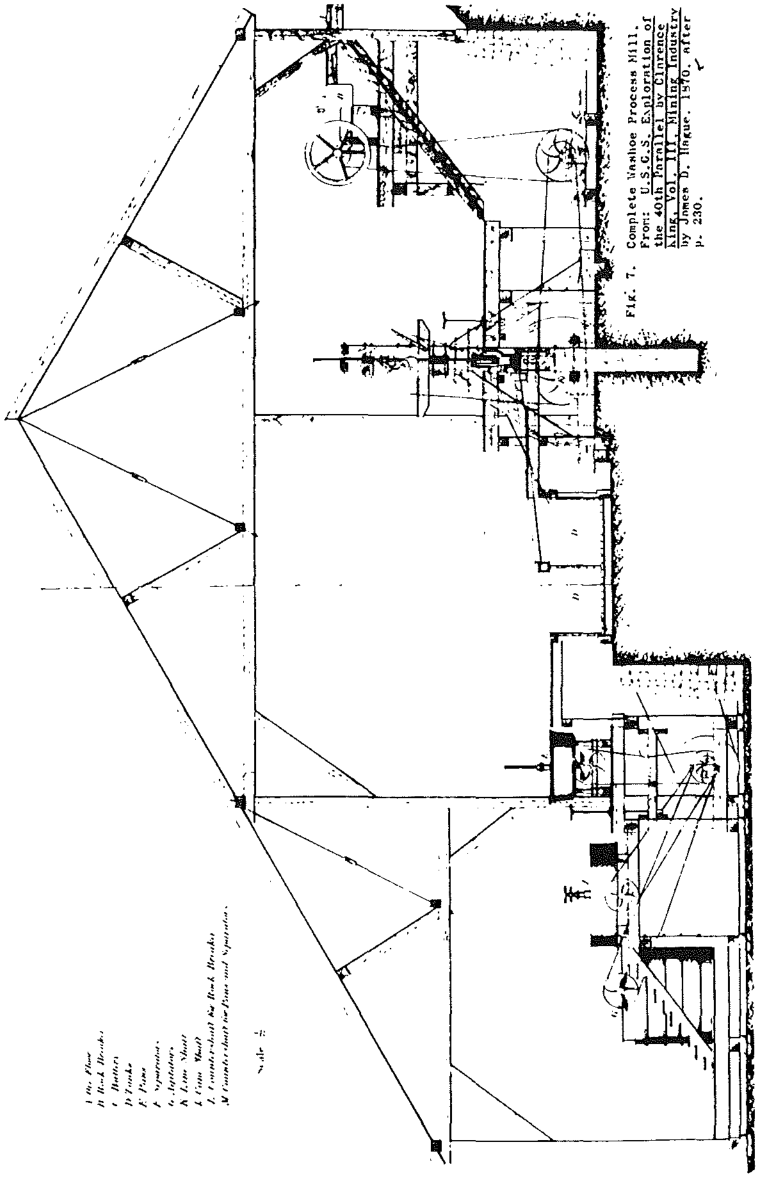

Fig. 12. Complete Washoe process mill. From: "U.S.G.S. Exploration of the 40th Parallel," by Clarence King, Vol. III, Mining Industry, by James D. Hague, 1870, after p. 230. (This was copied from photo 15 center of book by Paul, "Mining Frontiers," which was reduced in size.)

HISTORY OF WASHOE PROCESS CHEMISTRY

Almost the earliest known wet process for treating gold and silver ores was amalgamation. This process uses the affinity mercury has for gold, silver and silver chloride. Gold amalgamation was known to the Romans and was recorded by Pliny, but in this no reference was made to silver. The first recorded use of mercury in the metallurgy of silver, and in this connection with it the first recorded use of chlorine in any metallurgical process, occurs in a treatise entitled "De La Pirotechnia" by Vanoccio Biringuccio, published in Venice in 1540.[36, 37] Liddell[36] gives a brief description of this pioneer process:

> "In this treatise it is stated that the ore (previously roasted, if refractory) was finely ground in a stone mortar, screened wet, and dried. The dry ore was moistened with vinegar or water, in which had been dissolved mercuric chloride, copper sulphate, common salt and sometimes ferrous sulphate. The ore pulp was then covered with mercury and ground, or stirred, in the mortar for an hour or two. The tailings were washed away with water, and the silver was recovered by retorting the amalgam."

The Spanish version of discovery of the chloride silver amalgamation method as applied to the patio is accorded to Medina, a native miner of Pachuca, Mexico in 1557. It was intimated by a report in 1643 that Medina derived his idea from Spain and it appears reasonable the original information came from the same source which was recorded by Biringuccio in 1540.

Kustel[38] describes the "Washoe Process" under the name of "Amalgamation in Pans". Essentially the process is the working of already crushed ore in the grinding pan with mercury, salt and blue vitriol, at a temperature of about 160–180° F. for about three hours. The reaction of the chemicals produces amalgamation of the silver and gold in the ore much the same as accomplished by the Kettle process of the Basque priest, Barba.

Kustel recognized the importance of the iron pan and muller shoes by the following statement:[39]

> "It is known that friction and iron decompose tough silver sulphurets, without chemicals. Friction and iron are powerful chemicals in themselves. Silver ore, treated with chemicals in a stone arrastra for 12 hours will not yield half so much silver as one Wheelers' pan in 3 hours without any chemicals."

Either metallic silver or chloride of silver can be amalgamated or collected with mercury but not the sulphide silver minerals of the Comstock ores. Essentially the "Washoe Process" is to convert the silver sulphide minerals in the ore to either a chloride or metallic silver which could be amalgamated or saved with mercury. Gold, in the Comstock ore was more readily and easily amalgamated than the silver.[40] This fact accounted for Paul's early success with Gold Hill ores which contained a higher percentage of gold than the Comstock ores further to the north—close to Virginia City.

While later processes have largely replaced the Washoe Process, it still is being used in remote parts of Mexico and South America. Bangle[41] describes one such application in 1907, and this writer saw the method still in use in Bolivia in 1942.

Recovery of Silver and Costs of Washoe Process

Since recovery of the precious metals was the ultimate goal, various tests for recovery will be quoted.

Tests with 15 to 20 lbs. of pulverized ore in a small (18 inch diam.) Wheeler pan were conducted on two ores from the Comstock Lode by Hague.[42]

	Recovery Percent	
Class Ore	Gold	Silver
Kentuck (Comstock)	81.5	81.1
Savage "	70.6	32.5

The Savage ore had galena and other sulphides occluding the gold and silver sulphides making these values hard to "free" and save. The Savage ore could better be treated by the Reese River Process to be described here later.

Kustel[43] when discussing recovery states:

> "Almost everything, between blue vitriol and tobacco or tea decoction, which reasonably or unreasonably permitted a supposition that it might effect the decomposition of the sulphurets, has been experimented on, and yet, there are no chemicals known by means of which more than fifty or sixty per cent of the silver can be extracted. If a higher percentage is obtained, it is on account of the gold, or the prevalence of silver glance.
>
> "But the decomposition of silver sulphurets does not depend on chemicals alone, as is demonstrated by Wheeler's pans, by which the silver can be extracted from 10 to 15 percent closer than in common pans . . ."

Not all silver ore combinations were suitable for the Washoe process. It seems that the difficulty of decomposition grows with the amount of sulphur in the ore, and especially with that of antimony, arsenic, and lead. This is the class of ores treated by the Reese River Process, a description of which will follow.

Eissler,[44] writing at a much later time (and naturally at a higher perfection of the pan process) writes:

> "The ordinary working result obtained by treating the ore as above described, in pans and settlers, varies between 65 and 75

percent of the assay value, which by subsequent treatment, as indicated in the foregoing paragraph, is increased sometimes to 85 or 90 percent, or possibly a little more."

On December 2, 1864, Professor Benjamin Silliman[45] in a report of one of the Gold Hill operations computes 66 percent recovery for the Empire Mill and Mining Co. for a standard Washoe process mill.

Cost of the Washoe Process

Almarin Paul gave a table in which he gives costs of mill and costs per ton as follows:[46]

No. Stamps	Cost	Crush Tons Daily	Cost/Ton
10	$25,000	10	$16
15	37,500	15	15
20	50,000	20	14
25	62,500	25	13
30	75,000	30	12
40	100,000	40	10
50	125,000	50	8

This table appears to show a building cost of $2,500 per stamp or per ton of daily mill capacity and an operation cost between $16 and $8 per ton depending on the size of the mill.

This account has traced the Washoe silver process from the discovery of its basic principles through its adaption to the Comstock Lode ores and the development of the machinery to efficiently do the job. This ore treatment method proved effective in saving both the gold and silver from the "Bonanza" ore at a lower cost than the "barrel" process. This was the first triumph of American mechanical and scientific genius in metallurgy and was the result of many men of ability, each contributing a part to eventually develop the successful end product—the Washoe Process.

REESE RIVER SILVER PROCESS—1872

Reese River is in Lander County which was created and formed by a Nevada Territorial Legislature Act on December 10, 1862. In the summer preceding this,—on May 2, 1862, William H. Talcott, a former Pony Express Rider, discovered a rich silver quartz vein in Pony Canyon. This canyon is the present site of Austin, the Lander County Seat. The prospectors who rushed to Pony Canyon formed the Reese River Mining District on May 10, 1862 and bestowed the honor of District Recorder on the discoverer, Talcott. During the first season of 1862 shallow surface cuts were excavated to trace the silver veins but the big rush did not develop until 1863.

John Frost, accompanied by Felix O'Neil, J. Q. C. Vandenbosh and

George Buffett arrived in Pony Canyon on December 18, 1862. They found Messrs. Marshall and Cole running a tunnel on the south side of Pony Canyon near the middle of present day Austin.

Mr. Frost and his partners staked the North Star, Oregon, and Southern Light claims and then returned to their ranch on the Truckee River to spend the winter.[47] They returned the following spring and their claims became the nucleus of the Manhattan Silver Mining Company and were the best claims on Lander Hill.

The company erected a 20-stamp mill and helped develop the so-called Reese River Process.[48]

The silver ores of Nevada fell into two classes depending on their ease of treatment. The first class was called docile or free-milling treated by the Washoe Process and the second was called refractory or rebellious and needed the more costly Reese River Process. Essentially the Reese River Process was dry crushing, roasting with salt, and amalgamation in Freiburg barrels or modified Wheeler pans.

The more costly, dusty, dry stamp crushing was used because roasting was needed, and this saved drying the wet crushed ore; and wet crushing caused oxidation of some of the silver minerals making the roasting and amalgamation steps less efficient.

The proper use of the dry-crushing stamp mill was developed only after considerable experimentation. A solid foundation for the stamps came to be essential to keep the machine in place and exactly vertical. The pounding of the stamps on a poor foundation would soon work the machine out of line.

The speed, weight, and amount of drop for each stamp was also determined after lengthy experimentation; and the placement and mesh of the stamp screens also had to be determined for each ore for the most efficient operation. Rossiter Raymond explains this in great detail in 1870.[49]

Until 1870 the Reese River mills used reverberatory furnaces where the ore was heated on hearths and roasted with the flame passing across the top of the bed of ore. These furnaces took seven hours to roast each charge, consumed salt amounting to 8 or 10 percent of the charge, burned a cord of wood per ton capacity, and required labor averaging two men for each ton of ore treated. The labor was used for loading and unloading the furnaces, hand rabbling, mixing or hoeing the charge during roasting, and also firing the furnace.

There was a question over which was best here,—Freiburg barrels or Washoe pans but apparently the later installed mills preferred a special Wheeler pan with wooden sides.

Rossiter Raymond[50] described the Mettacom mill at Yankee Blade near Austin, Nevada as a typical Reese River Process mill and was similar to the Manhattan Co. mill. Raymond gives a table of costs for the Mettacom mill and this itemization will be copied below:

METTACOM MILL COSTS

Actual Cost of Power

2 engineers, $6 and $5.50 per day	$11.50
4¾ cords of wood, at $10	47.50
Repairs and oil	5.00
Cost of power, per day	$64.00

Cost of Crushing

Power, (batteries require about half the power)	$32.00
2 men to break rock and feed, $4.50 and $4	8.50
1 man to clean battery and help them	4.00
Average daily repairs	3.00
Total daily expense of batteries	$47.50
Average daily crushing, 13 tons; cost per ton	$3.65

Cost of Roasting

11 men, at $4	$44.00
1 foreman, at $5.50	5.50
4 cords of wood, at $10	40.00
Salt, 10 per cent. on 6½ tons, 0.65 tons, at $45	29.25
1 cooler, (also employed at the barrels, charge half-time,) at $4	2.00
Repairs and incidentals	8.00
Total daily expense of furnaces	$128.75
Average roasting per day, 6½ tons; cost per ton	$19.80

(The cost at the Manhattan is said to be only $15.)

Cost of Amalgamation

Power, (half the power of engine)	$32.00
Old wrought iron, 100 pounds daily at $2.50	2.50
3½ men, at $4	14.00
Loss of quicksilver, 2 pounds per ton	13.20
Repairs	2.00
Light and oil	2.00
Total daily expense of barrels	$65.70
Average daily amalgamated, 10 tons; cost per ton	$6.57

RECAPITULATION

	Per ton
Cost of crushing	$3.65
Cost of roasting	19.80
Cost of amalgamating	6.57
Retorting and melting	1.00
Total cost of treatment	$31.02

The cost of treatment of chloride ore, unroasted, would be:

	Per ton
Crushing, about	$3.50
Amalgamating	6.57
Retorting and melting	.75
Total	$10.82

Raymond further remarked that if Mettacom had been using Manhattan type reverberatories the total costs would have been $26.22 instead of $31.02, and if the new Stetefeldt furnace had been used Mettacom costs should have been reduced further to $21.22.

Meanwhile, merely for comparison, Mr. Raymond included in that table the costs for a Washoe mill and estimated that it would treat the same tonnage of ore as the Mettacom for only $10.82 per ton—about one-third the cost of the Reese River Process in the Mettacom mill. This comparison is facetious inasmuch as Reese River ore could not be treated in a Washoe Process mill.

It can be seen in the above table that nearly two-thirds of the Mettacom costs were the roasting step for each ton of ore. This focused attention on this costly step in the process and Mr. C. A. Stetefeldt was the man who did something about it. His revolutionary new furnace will be covered shortly.

STETEFELDT FURNACE

Before launching into the description of this furnace, two comments on its importance can be cited:

1. Raymond in 1870[51] said:

   "This invention is one of the most important steps of progress yet achieved in our American silver metallurgy; and its direct effects in stimulating the production of bullion, by reducing its cost, will be felt immediately."

2. Eissler in 1889[52] stated:

   "It [Stetefeldt Furnace] may be considered, in truth, as one of the best inventions in silver metallurgy, for without its introduction it is doubtful if so many mines in Nevada and elsewhere on the Pacific Coast carrying base metal ores would have been successful . . ."

The inventor, C. A. Stetefeldt, himself said that he conceived it at Austin in 1867 but it was not built until October 1869 at Reno. Immediately after its success was proven at Reno the Manhattan Company had one built at Austin.[53]

Essentially, the principle of the furnace is that finely ground silver ore and salt are completely chloridized when they fall against a current of hot air in a shaft with no obstructions to hinder the fall of the ore. Tests made with the Reno furnace showed the ore to be 88 to 92½ percent chlorized or in condition to be amalgamated.[54]

Using the principle as described above, a sketch of a cross section of a furnace may serve to illustrate its basic construction and operation. Fig. 13 is included here for this purpose.

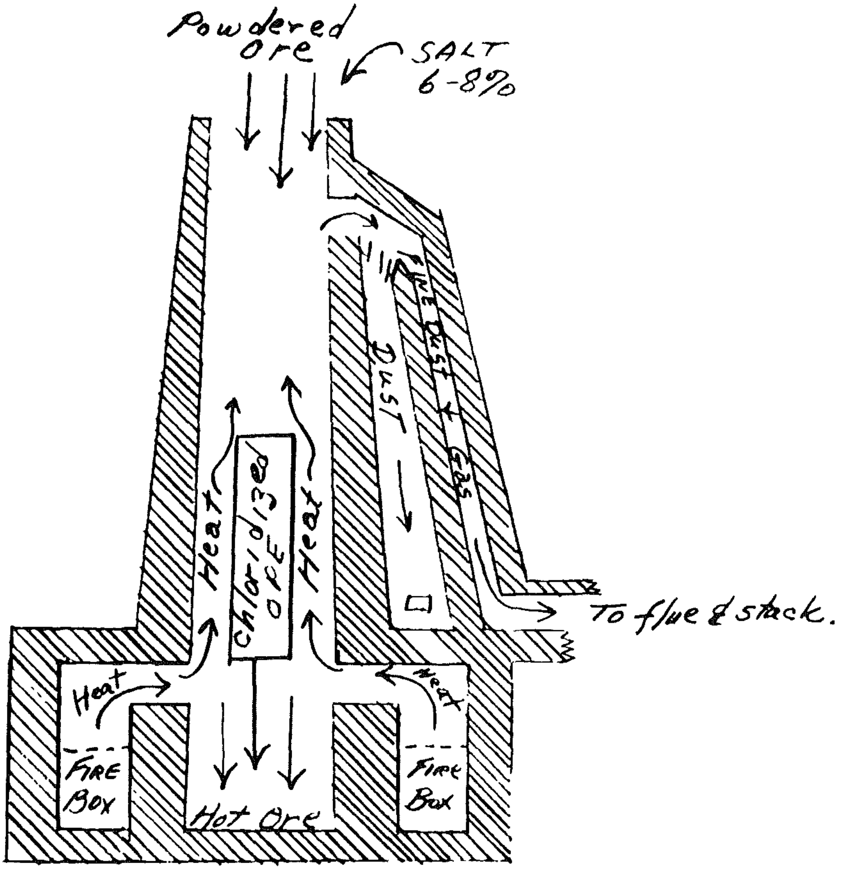

Fig. 13. Sketch showing Stetefeldt furnace principle wherein dry ore and salt drop down a furnace shaft through an ascending current of flame and heat at 300° C. Ore is 90 percent chloridized in the few seconds' time it takes to fall 25 to 40 feet to the calcine pit of the shaft bottom. The furnace shaft is sealed off by the water-cooled ore feeder and hopper at the top of the furnace.

Eissler operated a Stetefeldt furnace at Mineral Hill, Nevada and his description and sketches of the furnace and its feeder are the best that could be found and will be reproduced here from his book[55, 56] and in Eissler's own words:

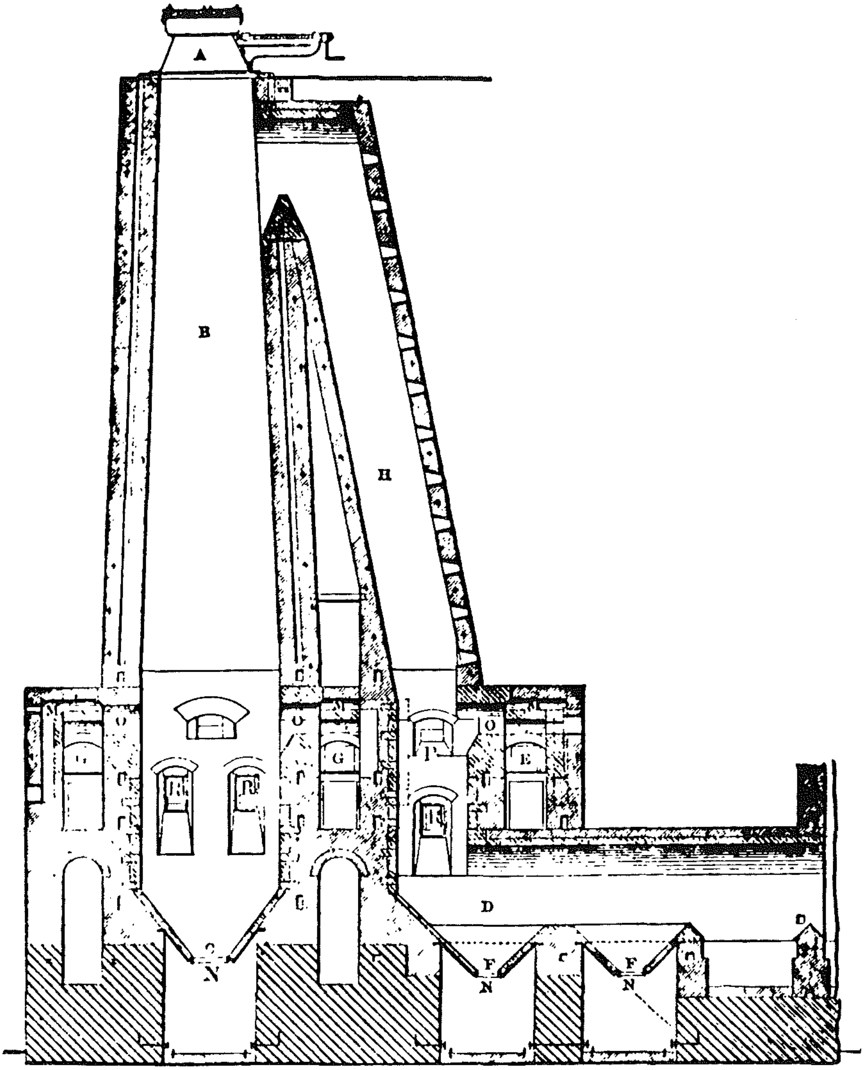

Fig. 14. Illustration of Stetefeldt furnace from Eissler, M., "The Metallurgy of Silver," 5th Ed., 1901, Crosby Lockwood & Son, London, p. 179.

"The furnace (which is shown in Fig. 59) consists of a perpendicular roasting shaft, B, from 26 to 36 ft. in height, heated by the fireplaces, G. The flue, H, is also heated by a fireplace, E, and carries off the waste gases and the dust. When the ore arrives at the hopper placed above the furnace, it is mechanically discharged into the automatic charging apparatus. Fig. 60, which consists of an iron hopper, A, placed on the top of the furnace, provided with a draw valve, B, which is always open when the furnace is in operation. Above this is another cone, on the top of which is a cast-iron grate, C, and on the top of this is a screen made of steel plate punched with holes. Above the screen is a wrought-iron frame, E, on the bottom of which a coarse screen, F, of heavy wire is placed. This frame with its screen rests on friction rollers, G, rotating on brackets, H, which can be raised or lowered by means of set screws so as to have any desired distance between the punched screen, D, and the wire one, F. The bracket, K, carries an eccentric shaft which is connected with the shaft."

"The furnace consists of a perpendicular roasting shaft, B, from 26 to 36 ft. in height, heated by the fireplaces, G. The flue, H, is also heated by a fireplace, E, and carries off the waste gases and the dust. When the ore arrives at the hopper placed above the furnace, it is mechanically discharged into the automatic charging apparatus, Fig. 60 [See Fig. 15 of this article], which consists of an iron hopper, A, placed on the top of the furnace, provided with a draw valve, B, which is always open when the furnace is in operation. Above this is another cone, on the top of which is a cast-iron grate, C, and on the top of this is a screen made of steel plate punched with holes. Above the screen is a wrought-iron frame, E, on the bottom of which a coarse screen, F, of heavy wire is placed. This frame with its screen rests on friction rollers, G, rotating on brackets, H, which can be raised or lowered by means of set screws so as to have any desired distance between the punched screen, D, and the wire one, F. The bracket, K, carries an eccentric shaft which is connected with the shaft, M, which moves the frame, E; but as the oscillating motion would not always be sufficient to force the ore through the two screens, stationary blades, O, are fastened to the brackets, N, which can be raised or lowered by the nuts, P, so as to bring them into more or less close contact with the screen, F. The blades distribute the pulp over the screens evenly. The frame, E, is kept in motion by a cone pulley, and is so arranged that it can be made to take any motion that it is desirable to give it. The usual velocity is between twenty and sixty strokes per minute. By changing the distance between the screens, and also the velocity of the movement, any desired amount of ore can be delivered in the furnace with the greatest regularity."*

Eissler[57] gave costs ranging from $5.00 to $9.00 per ton for the roasting operation in a Stetefeldt furnace; the higher cost cited was where labor, fuel, and salt were costly, and the low figure refers to places these items cost less.

Kustel[58] gives the costs for 25–30 tons per day at $5.00 to $6.00 per ton.

A letter in the October 28, 1871 SCIENTIFIC PRESS[59] describes the new Stetefeldt furnace operation at Austin and gave the recovery as follows: less than $300 ore, 80 percent recovery; $300–$500 ore, 83 percent recovery; more than $500 ore, 85 percent recovery.

This letter further stated that treatment charges were reduced from $60 to $20 per ton of ore. This, however, does not match the figures given by Raymond,[60] but Raymond's figures may have referred to 1870 and not 1871. Raymond gave $30–35 per ton custom mill charge and the Stetefeldt royalty fixed at $2.00 per ton.

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*This ore feeder at the top of the Stetefeldt furnace was quite similar to a mechanical home kitchen flour sifter with its oscillating rotary blade feeder just above the sieve wire cloth. A lever and squeeze handle mechanism and the return spring give the rotary blade its back and forth motion.

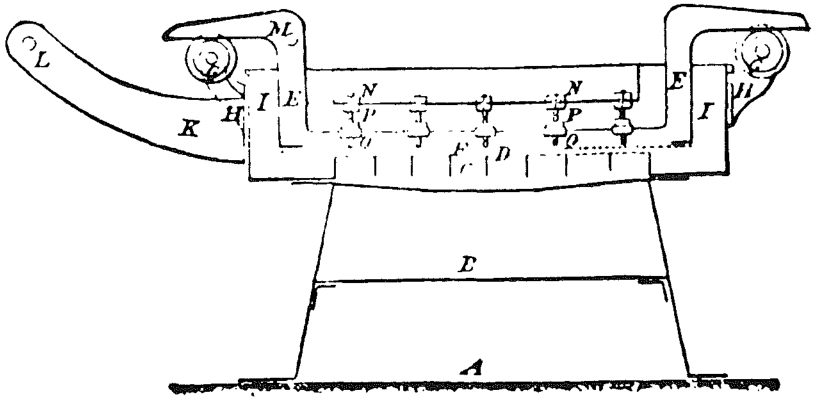

Fig. 15. Stetefeldt furnace feeder, from Eissler, op. cit., p. 181.

"The main shaft, B, was 26 ft. high at Mineral Hill, and was heated by the ascending gases from two gas-generating furnaces, G. Where ordinary furnaces are employed, as shown in Fig. 59, the gases and flame enter the shaft by means of the opening, O, which communicates with the outside air by means of channels having openings, M, one on a level with O, the other below, and they are closed by an iron sliding door, so as to regulate the quantity of air to be admitted to furnish the required oxygen for the perfect combustion of the gases. The fireplaces are provided with doors at the ash-pits. On a level with the opening, O, in the face of the furnace where the discharge is located, is a door, P, and also one in the return flue, H, also marked P, which are for the purpose of observing the flame and heat in the furnace shaft and return flue, and there are also the doors, R, which serve for the introduction of the tools for scraping the walls when any ore sticks to it.

"The main shaft is built slightly tapering, and if ores are very rebellious it may be increased in height to even 46 ft. The horizontal section is from 4 to 6 ft. square, giving a surface of 16 to 36 square ft.; and, as is shown in the drawing, the walls of the main stack are double, having an air space between, which keeps the heat regular. Our furnaces being heated by gas generators, all the portions of the furnace exposed to the direct action of the flame and the generators were constructed of the best firebricks. The fuel employed was wood and charcoal mixed, at the beginning of the firing, and then charcoal alone."

PAN AMALGAMATION

While the roasted product from Stetefeldt furnaces could be treated by Freiburg barrels, the pan seemed to be favored in the Reese River Process. However, the pans were modified with wooden sides.

The Wheeler pan used here is shown by Fig. 16 and the sketch and description are from Raymond.[61]

The settlers and agitators from the Washoe process are used here but without modification.

COMPLETE REESE RIVER PROCESS MILL

Eissler[62] gave a sketch of a complete mill for this process including a dry crushing stamp battery, Stetefeldt furnace, pans, agitators and settlers as shown in Fig. 17.

A summary of the above descriptions would give Stetefeldt furnace used in the Reese River Process the following advantages over reverberatory roasting:

1. Plus 90 percent chloridization of silver.
2. Less than ½ hour in furnace.
3. Save half the salt.
4. Operates on less than one-third the fuel.
5. Costs less to build.
6. Saves 60 percent of labor force.

This traces the Reese River Process from Austin, Nevada where the process originated using reverberatory furnaces for chloridizing roasting and where Mr. Stetefeldt developed his ideas. The Stetefeldt Furnace was successful at Reno, then it was returned in an improved form back to its birthplace, Austin. This is reminiscent of returning the Washoe Process to Mexico and Bolivia where its principles were first used for silver recovery in crude forms.

In 1872 Nevada had two proven processes to treat everything from docile to rebellious silver ores; these processes were first the Washoe and second Reese River with the improved Stetefeldt Furnace. The Reese River Process used many slightly modified machines of the Washoe method: such as stamp mills, amalgamating pans, agitators, separators, and the retort, and bullion handling equipment.

Nevada's past century of mining could be likened to a huge threatrical stage. The Comstock was the first act of the drama followed by Reese River, White Pine, Eureka, then a return engagement for Comstock back in the spotlight in 1870. After this several smaller camps kept the footlights burning. These were Pioche, Bristol, Delemar, Tuscarora, Cortez, Reese River again, Candelaria, Belmont, Lodi, Union, Unionville and

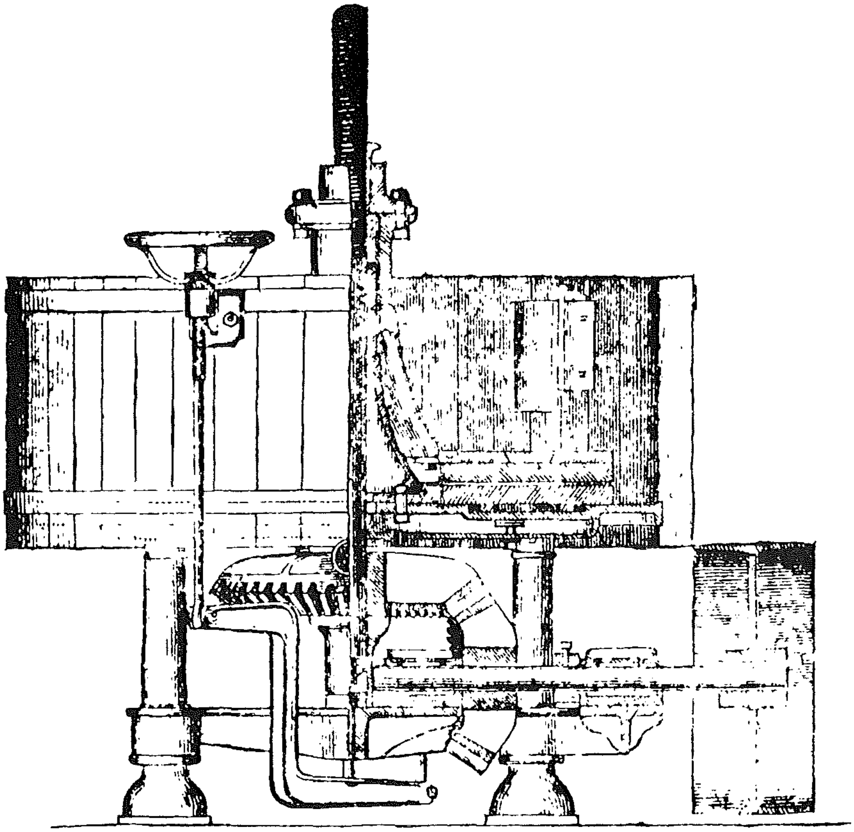

Fig. 16. Wheeler's pan. From Raymond.[61]

It is five feet in diameter, but not quite so deep as Patton's, and the attachment of the staves to the bottom plate is different. There is also a wide annular space between the dies and muller and the sides. The distance between the muller and the dies is regulated by a screw with a hand-wheel upon the outside of the pan, which, by means of a bent lever at the bottom, raises the vertical shaft and so lifts the muller. This arrangement is the same as used in the older forms of Wheeler's apparatus.

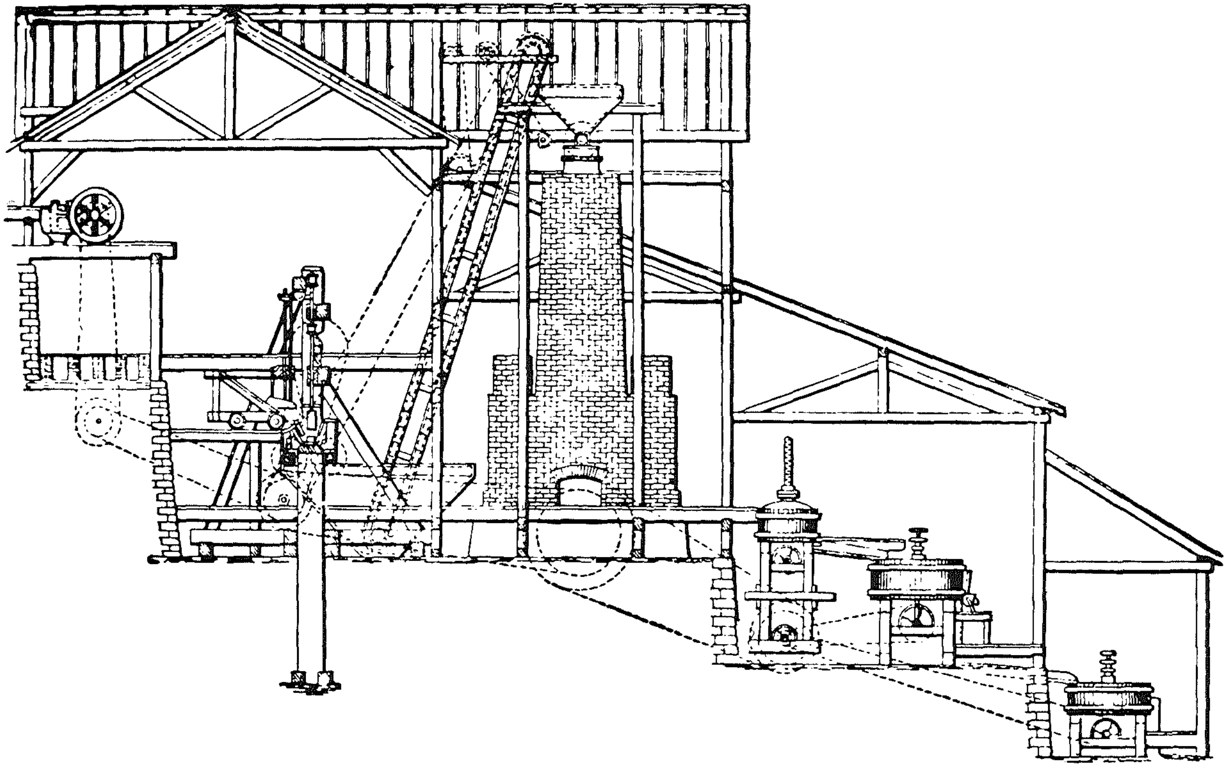

Fig. 17. Stetefeldt furnace—Reese River process mill. This shows an inclined bucket elevator used to lift the crushed ore to the furnace feed hopper at the top of the furnace, and conventional arrangement of the pans, settlers, and agitators.

Cherry Creek. Even in the face of falling silver prices these smaller camps, made possible by the Washoe and Reese River metallurgy methods, maintained lights in the theater and paid the rent for the 1870 to 1900 decades so that the curtain could raise on the fabulous Tonopah and Goldfield extravaganza at the turn of the century. The show does go on.

These metallurgical methods for silver served their purpose, in the 1860–1900 decades, and just like a piece of stage scenery or props are discarded to pass into history and have been replaced by modern developments such as cyanide and flotation, nevertheless Washoe and Reese River Processes did do the job of recovering silver and sustain Nevada's mining industry through a difficult, slow period, until Tonopah and Goldfield were ready to occupy the center of the stage, and after that they too fade away for a new performer.

NOTES

Footnote No.

1 Phillips, J. Arthur, *Mining and Metallurgy of Gold and Silver,* E. & F. N., SPON, London, 1867, pp. 171–172.

2 Ibid, pp. 168–169.

3 Ibid, pp. 334–338.

4 Phillips, Ibid, p. 341, relates a further interesting sequel to the animal's physiological condition in this unusual service:

"The animals employed for the repasos [patios] are kept exclusively for that purpose, and when they have finished treading, are at once taken to a large cistern, prepared for that purpose, and carefully washed. They, however, often lick themselves, on leaving the torta, probably for the sake of the salt contained in the mixture adhering to them, and consequently, when they die, a ball of amalgam is frequently found in their stomachs. These pieces of amalgam sometimes weigh many ounces, and are always exceedingly hard, and contain but a comparatively small proportion of mercury." [Mercury would be dissolved by the stomach acids.]

5 Ibid, p. 358.

6 Ibid, p. 322.

7 Eissler, M., *The Metallurgy of Silver,* Crosby Lockwood & Son, London, 1889, 1st Ed., 1901, 5th Ed. pp. 26–27.

8 Barba, Alvaro Alonzo, *El Arte de Los Metales,* 3rd Book, Madrid, Spain, 1640, Douglas and Mathewson, English Translation, New York and London, 1923, pp. 149–194.

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10 Phillips, J. Arthur, pp. 364–389.

11 Ibid, p. 389.

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13 Paul Almarin B., *Scrapbook,* pp. 293–294.

14 Paul preserved clippings of nearly all his writings from early California days down to as late as 1908—a span of 60 years—in a scrapbook which survived the San Francisco earthquake and fire and now reposes in the Huntington Library of San Marino, California.

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21 *Mining and Scientific Press,* Feb. 24, 1877, p. 120.

22 Eissler, M., *The Metallurgy of Silver,* 1889, pp. 2–3.

23 Paul, Almarin B., "Washoe: Its Mines, Mills and Machinery," *San Francisco Evening Bulletin,* Nov. 1, 1861, p. 1, c. 1.

24 *Daily Alta California,* San Francisco, Mar. 23, 1861, p. 1, c. 1.

25 *San Francisco Evening Bulletin,* April 10, 1863, p. 1, c. 1.

26 "Knox Patented Amalgamator" described in *Mining and Scientific Press,* June 23, 1860, p. 40.

27 Almarin Paul's *Scrapbook,* pp. 293–294.

Footnote No.

28 Lord, Eliot, *Comstock Mining and Miners,* 1883, pp. 82–84, and pp. 117–120.

29 Eissler, M., work cited, pp. 77–80.

30 Hague, James D., *U.S.G.S. Exploration of 40th Parallel,* Vol. III, Mining Industry, p. 229.

31 Smith, Grant H., *History of the Comstock Lode,* 1850–1920, Univ. of Nevada Bul. No. 37, July 1, 1943, No. 3, p. 18.

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38 Kustel, Guido, work cited, pp. 67–90.

39 Ibid, p. 68.

40 Hague, James D., work cited, p. 293.

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42 Hague, James D., work cited, pp. 273–293.

43 Kustel, Guido, work cited, pp. 68–69.

44 Eissler, M., work cited, p. 40.

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50 Ibid., pp. 733–740.

51 Ibid., pp. 749–750. (1870)

52 Eissler, M., work cited, 1889, pp. 179–180.

53 Raymond, Rossiter W., work cited, p. 750; Hague, James D., work cited, 1870, pp. 270–272. Earlier the Twin River Co. at Ophir Canyon, erected the first Stetefeldt furnace but it was not operated continuously; then, the second furnace was installed at Reno, and the third,—more improved than its predecessors, was installed at Austin by the Manhattan Co.

54 Raymond, R. W., work cited, 1870, p. 754.

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62 Eissler, M., work cited, p. 164 shows the Taylor Mill, but this same sketch appeared in Raymond, 1873, p. 471 and he credits his source as the Catalogue of H. J. Booth & Co. of San Francisco.

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