

A Light in the Darkness: U.S. Mine Lamps, the Early Years— Candlesticks, Oil Lamps, and Safety Lamps

By Paul J. Bartos

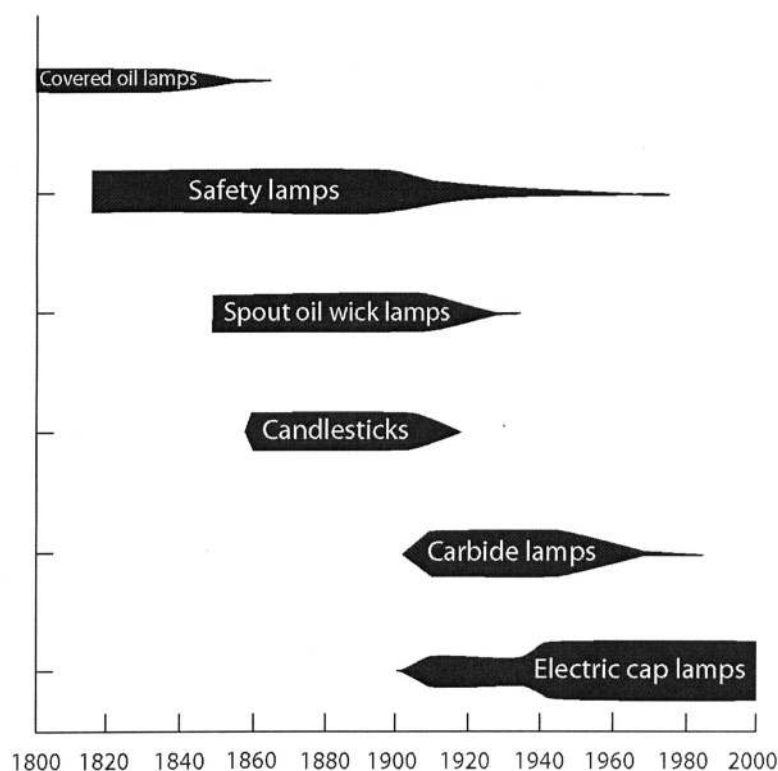
Six major lamp types have been used in the two hundred years of U.S. underground mining. These are, in approximate temporal sequence, covered oil lamps, safety lamps, spout oil wick lamps, candles and their holders, carbide lamps, and electric hand and cap lamps. What is surprising is amount of temporal overlap between the various lamp types, in many cases from thirty to as much as seventy years. This is in spite of the fact that many new lamp types represented superior technologies that should have made prior types obsolete. How then did these more primitive lamp types last as long as they did?

In part, the overlap between lamp types encompassed different types of mines, and thus slightly different uses. Generally, metal mines in the United States had a lighting progression of covered oil lamps, candles, carbide lamps, and electric battery lamps. Non-gassy U.S. coal mines had a lighting sequence of covered oil lamps, spout wick oil lamps, carbide lamps, and electric battery lamps. Gassy U.S. coal mines had a sequence of covered oil lamps, safety lamps, and electric battery lamps. However, even allowing for different usages, there was considerable overlap and delay in the adoption of new lighting technologies.¹

This article is a detailed history of how early mine lights evolved and developed, with the idea of shedding light, as it were, on innovation in the mining industry: how it occurred, and from where it derived. The literature on mine lighting is rather sparse, with several small review articles in rather obscure journals.²

In recent years, several excellent publications dealing with mine lighting from a collecting aspect have appeared.³ Mine lamps and candle holders, called candlesticks, are now prized collectables. However, electric battery lamps are not as prized, and information on them is far more scattered and incomplete. The Colorado School of Mines Geol-

U.S. Mine Lamp Time Sequence



A sequence timeline for U.S. mine lamps. The shapes are approximately proportional to the amount of a given mine lamp type in use at that particular time. Note the considerable overlap in time among the various types, despite the fact that many of the lamps represented superior new technologies that superseded earlier ones.

ogy Museum, where the author served as director and curator, has an excellent mine lighting collection that remains a continuing resource.

The Earliest Mine Lights

Mine lamps (and artificial lighting in general) appear to have remained in stasis for millennia; it is only in the last two hundred and fifty years or so that significant advances have been made. Since ancient times, simple open oil lamps—consisting of a uncovered hollow receptacle to hold the oil, a gutter or groove in which rested a wick, and perhaps a handle opposite the wick-groove for carrying—have been used in mining.

An extremely simple oil lamp dating to about 10,000 BC, consisting of an oil cup with a wick, has been found in an English chalk mine. Oil mine lamps are mentioned by various Greek and Roman writers, the fuel for these lamps being

plant or fish oil or animal fat. Pure olive oil is mentioned as a lamp fuel in the Bible.⁴

The style of these earliest open-saucer oil lamps did not vary much. A fifteenth-century Scottish saucer lamp, for example, is extremely similar in appearance to a two-thousand-year old Armenian oil lamp.⁵

Other early mine lighting implements included torches of wood or of bundles of reeds or rushes soaked in tallow or palm, olive, or fish oil. Typically the fat-saturated reeds were braided together and coiled, and burned quite quickly. Examples of this type of mine lighting date from Neolithic times to the near present, and from locations as various as Mammoth Cave, Kentucky, and Krzemionki Opatowski, Poland.⁶

Europeans used lights such as these extensively for domestic purposes up to the seventeenth century. The Pilgrims of New England used rush lamps to a limited degree in the 1600s. Early co-



*A sixteenth-century German woodcut showing miners using covered oil lamps. Lamps such as these were common in Roman times and appear to have been little modified since. (Agricola, *De Re Metallica*, book VI.)*

lonial rush holders are simple iron tongs or clips, with a tongue or hook that could be inserted into a crack in a wall or beam.⁷

Pitch pine, known as “candlewood,” was another common early illuminant. Pieces of resinous pine were cut into lengths of one to two feet and placed in improvised holders. Given that the only expense was cutting and drying the wood, this was an extremely cheap illuminant and used for many

years. A Pilgrim writing in 1642 mentioned the use of pitch pine candlewood, particularly among “poorer folks.”⁸ Records are insufficient to determine which lighting type predominated in underground mines of that era.

Some underground mines used open-pan, hanging iron lamps as late as the 1700s. However, at some point prior to that date, the industry developed covered mine lamps. *De Re Metallica*,

published in 1556, contains a plate showing miners descending underground holding lamps of a style similar to early Roman covered oil lamps.⁹

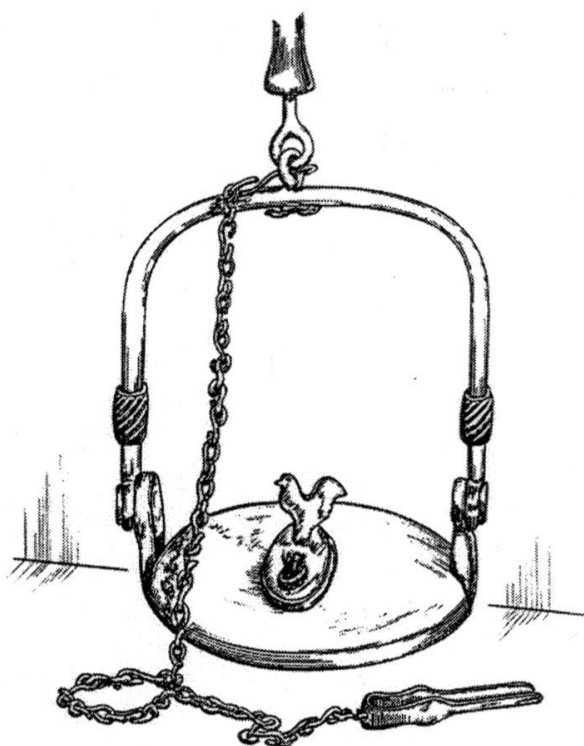
Spanish miners in the American Southwest circa 1800 utilized a cast-iron or bronze-covered oil lamp hung from an arched or swiveled bail, with a series of linked wire rods typically allowing height adjustment. Tweezers were often chained to the lamp to allow adjustment of the wick. Colorado School of Mines has one such lamp in its collection (left), commonly called a “tunnel” or “lenticular” lamp. This particular lamp features a “good luck rooster” as the fuel-opening plug, and has been attributed to Greek origin. Lamps of highly similar appearance come from northern France, as well as Germany, Austria, Spain, and Portugal, and were popular in Peru and Chile.¹⁰

A variant of the covered oil lamp, known as

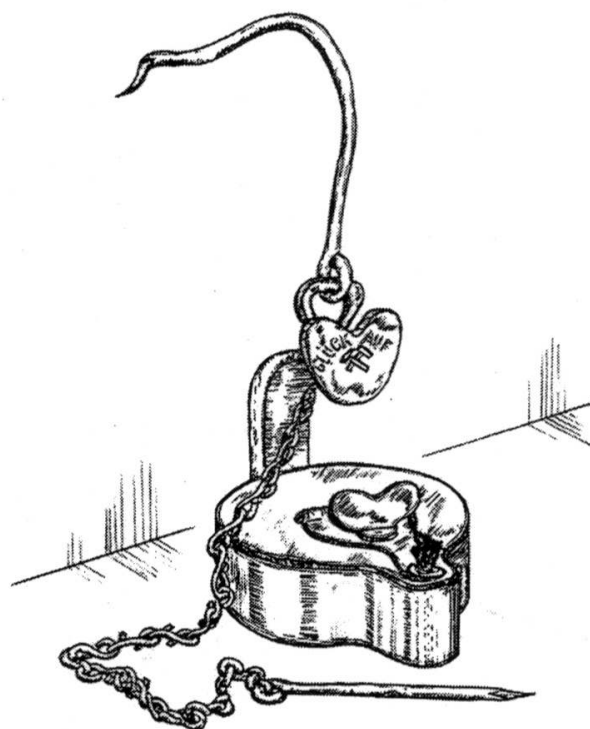
a “frog” lamp, appears to have been commonly used in mining from the seventeenth century to the end of the nineteenth century. An example of this type from the Colorado School of Mines’ collection dates to circa 1850 (right).¹¹

This lamp has a hinged covered top, with a defined spout at one end. Rather than a swiveled bail, the lamp is on a rigid arm attached to a large hook. This particular lamp contains a shield with crossed sledge and pick, the “Schlagel und Eisen” or “mallet and gad.” This shield includes the words *Glück auf*—literally “luck up” or may you have good luck in returning from underground—a tradition greeting and mining symbol from Ertzgeberge, an early European mining center in Saxony.¹²

Lamps of this general sort were extremely common in domestic use by 1600, where they

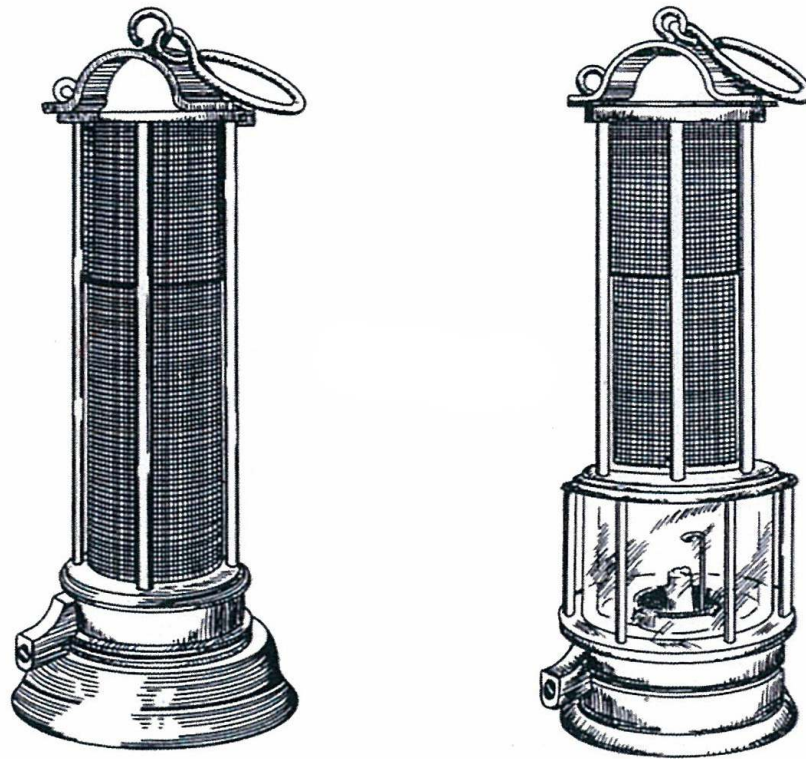


*European hanging oil-wick lamp,
fashioned with a good-luck rooster*



*“frog type” lamp with
a German good-luck symbol*

Pen and ink drawing of two early covered oil lamps currently on display at the Colorado School of Mines Geology Museum. (Pohs, Underground Mine Lamps. Courtesy of the Arizona Historical Society.)



Pen and ink drawings of Davy (left) and Clanny (right) lamps. Note the screw locks, the small projection at lower left part of the base of each lamp; these characterize models after about 1835. Other than the lock, the designs are little changed from their introduction in 1815. The Colorado School of Mines Geology Museum displays an identical Clanny lamp used in English coalfields around 1900, and a similar Davy lamp used in Colorado, circa 1874. (Pohs, Underground Mine Lamps. Courtesy of the Arizona Historical Society.)

were known as “Betty” lamps. Colonial manufacture of Betty lamps commenced as early as the 1640s, twenty years after Mayflower’s landing, with the discovery of a bog iron deposit close to Boston.¹³

Hanging oil lamps appear to have been quite common in Europe to nearly the end of the nineteenth century, but were much less common in the United States. Lamp use seems to have been essentially the same in mining as for domestic purposes, with no evident differentiation or specialization for mining purposes prior to approximately 1800.

Safety Lamps

A significant problem in underground coal mining is the generation of methane gas, known as fire damp. This phenomenon is part of the geologic processes that created the coal, and coal-bed methane is now a major target of exploration in the natural gas industry. Amounts of methane in a coal mine can be quite variable, some portions of a mine can be relatively gas free while others can have a concentration of methane that the slightest spark can ignite.

Methane could build-up literally overnight. Up to the early twentieth century, it was com-

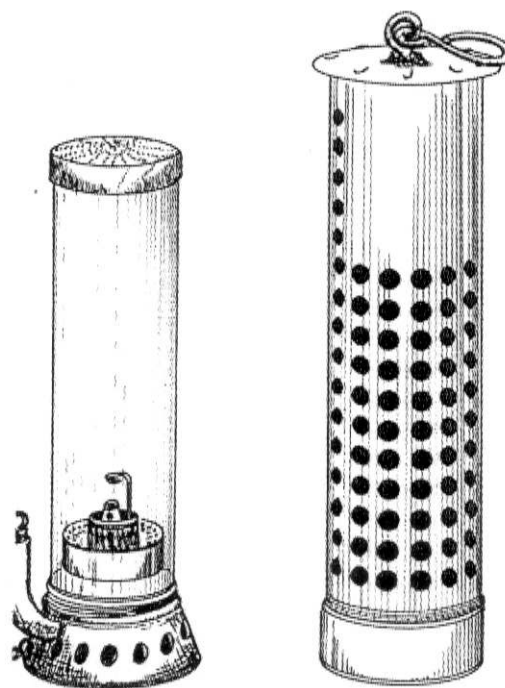
mon practice after each blast to send in an individual equipped with a candle at the end of a long pole to attempt to burn off small pockets of the gas. If these accumulations proved too large he would “brush” them by waving a large cloth in an attempt to redistribute the air. Such individuals were known as “firemen,” which could not have been a particularly popular occupation.¹⁴

Deaths in coal mines from methane gas explosions have been known since 1621. An explosion in 1812 at Newcastle-on-Tyne, England, killed ninety-two men and boys and led directly to the invention of the safety lamp. This particular mine disaster drew great publicity, and led to the formation of the Society for the Prevention of Colliery Accidents. In the summer of 1815, the society contacted noted scientist Sir Humphrey Davy, who agreed to attempt to solve the problem.¹⁵

In less than a month, Davy discovered, through a series of experiments, that a flame would not pass through a metal mesh screen with a fineness greater than 784 holes per square inch. The gauze breaks up the burning gas flame into a series of tiny streamlets that are individually cooled below the ignition point of methane by conductive contact with the wire mesh. Thus, the methane inside of the mesh can burn, but the flame cannot ignite gas on the outside of the gauze as long as the wire mesh remains unheated and unbroken. Otherwise the flame passes through, igniting the external gases.

Davy’s discovery of these principals led directly to his developing the Davy safety lamp used in coal mines for more than sixty years.¹⁶ Interestingly, Davy did not apply for a patent for his lamp, as he considered his discovery a purely *pro bono publico* act. Nonetheless, he jealously defended his primacy in inventing the lamp, and ended up being made a baronet for it.¹⁷

At approximately the same time that Davy was working on the lamp, George Stephenson independently discovered the same principles as Davy and designed the Stephenson safety lamp, also known as the “Geordie.” The two lamps were



Pen and ink drawing of a Stephenson “Geordie” lamp and cover. (Pohs, Underground Mine lamps. Courtesy of the Arizona Historical Society.)

quite similar. Davy surrounded the flame with a long cylinder of wire screen gauze. Stephenson fitted an open-topped glass cylinder inside the wire mesh and covered the glass with a copper top perforated by many air holes. This created a blanket of “burnt” air above the flame that tended to inhibit flame propagation.

The Stephenson system also protected the flame from drafts. The Davy lamp could only operate in still air conditions, otherwise the gauze opposite the draft would heat up and generate explosions. Neither lamp provided much illumination, approximately a quarter candlepower, but protection from explosions was the foremost consideration.¹⁸

Just before this, in 1810, a doctor named William Clanny, of Sunderland, England, began ex-

perimenting with coal miners' lamps. He developed an airtight lantern with water cisterns and bellows, which he presented to the Royal Society in 1813. This proved to be impractical, however, and was never developed beyond a laboratory model.

Clanny's second lamp type, of 1839–40, now known as the Clanny lamp, featured a stout glass cylinder about the flame and safety gauze above the cylinder. This design significantly improved illumination to about 0.3 to 0.5 candles, two or three times that of the Davy lamp. The Davy lamp was not displaced technologically by the Clanny, since the Davy's flame could be used more easily to determine the methane content of mine air and whether it was approaching a dangerous level.

Ironically, the development of the safety lamp did not increase safety. Records suggest that more coal mine explosions occurred than before the lamps were invented.¹⁹ Buoyed by a false sense of confidence, miners entered areas previously known to contain dangerous concentrations of methane and found other ways to create the sparks that triggered explosions. Miners also sometimes opened the lamp mesh to clean wick tips or relight an extinguished lamp, not realizing that it was methane that caused the lamp to sputter or go out in the first place. Eventually, specially designed locks were installed on the lamps to prevent such occurrences.

The Davy, Clanny, and, to a lesser degree, Stephenson lamps were used in coalfields wherever methane was a problem. They were imported to the United States and continental Europe, and used extensively until approximately 1915. The dominant fuels for these lamps were kerosene or other heavy oils.²⁰

In 1840, J. Mueseler of Belgium developed a Clanny-type lamp with a conical bell-mouthed metal chimney designed to aid combustion, particularly in areas with strong air currents. In the 1860s, the Belgian and French governments both commissioned studies to determine the optimal type of safety lamp. Both decided the best lamp

was the one safest in a methane gas mixture with strong air currents, and chose a Mueseler model. In 1864 the Belgian government went further, issuing a decree making use of Mueseler lamps mandatory in Belgian coal mines. Ironically, in 1883 a French engineer named Marsuat demonstrated that Mueseler lamps were quite dangerous when burned in still air with methane present.²¹

Carl Wolf of Zwickau, Germany, developed his safety lamp in 1883. The Wolf lamp was the first to use naphtha as a fuel. Prior to this, lamps had to be lit with an open flame, which necessitated returning the lamp to the surface or to a specially ventilated lamp room if the flame went out. Wolf lamps could be relit at the job site using an internal lighter. This style of safety lamp saw use, with minor modifications, into the 1950s.

During their last few decades of use, safety lamps were not used as a direct source of light, being replaced by electric cap lamps for that function. The safety lamp continued to be used as an oxygen and methane detector, however. The flame would decrease with insufficient oxygen and a blue crown would form above it if methane were present. Trained observers could actually determine the percentage of oxygen or methane in the mine air based on the action, color, and height of the flame. Electronic gas detectors started to usurp the Wolf safety lamp's function as early as 1940, but the early 1980s still saw safety lamps used, albeit infrequently.²²

All told, more than 350 models of safety lamps are known, the vast majority coming from Europe, particularly England, Germany, France, and Belgium. At least fifteen known U.S. manufacturers existed, of which only five—Hughes Brothers, Everhart, American Safety Lamp and Mine Supply Company, Wolf, and Koehler—could be considered serious producers. Approximately half of these safety-lamp manufacturers were located in Pennsylvania, and the remainder on the eastern seaboard in New York and Baltimore, or in the Midwest in St. Louis and Evansville, Indiana.²³

Candlepower Comparison of Mine Lights	
Light Type	Candlepower
Safety Lamps:	
Davy	0.1 - 0.3
Geordie	0.1 - 0.2
Clanny	0.3 - 0.4
Mueseler	0.4 - 0.5
Wolf	0.6 - 1.0
Spout Oil Wick Lamps:	
Regular	~0.7 - 1
Sunshine	1.5
Candles	
Tallow	~0.7
Stearic Candle	1.0
Carbide Lamps:	
1905-1910	2-6
1914	10-17
Electric Cap Lamps:	
1915	1-3
1931	70
1949	240
Data from: Chance, 1917; Bayles, 1956, 1957; Trotter, 1982; and Pohs, 1995.	

Spout Oil Wick Lamps

Spout lamps, consisting of a small teapot-shaped oil lamp that could be hung on a hat, appear to have originated in Scotland in about 1850 and were later used in the Welsh coal mines. Miners immigrating to the United States are believed to have brought these lamps with them. The first U.S. patent for a spout lamp occurred in 1858, with a steady stream of patents, 110 in total, up to 1917.²⁴

The lamps were similar in appearance, with a reservoir 2 to 2.5 inches high, a hinged snap cap, an upraised spout filled with cotton wicking, and a hook on the opposite side for hanging the lamp from one's hat. These lamps were quite lightweight, between two and eight ounces. Haul drivers in the main passageways of mines used a larger variety, typically 2.5 to 3.5 inches high and

with a wider spout. The swifter air currents in haulage ways necessitated a larger lamp to prevent the flame from being extinguished.

Spout lamps, though widely popular in U.S. coalfields, appeared in only a few metal-mining districts, such as the Tri-State lead district near Joplin, Missouri, the Northern Michigan copper mines, and the Minnesota–Michigan iron fields.²⁵ It is noteworthy that only those metal districts operating prior to the introduction of mass-produced candles appear to have experienced significant spout lamp use.

Approximately 110 patents exist for this very simple type of oil lamp, with at least 73 brands of these lamps known, not counting varieties manufactured in Scotland and distributed in the United States. Thirty-nine known U.S. manufactures of these lamps existed, the vast majority located in Pennsylvania, principally in greater Pittsburgh



Bluefield oil-wick cap lamp

Pen and ink drawing of a typical spout oil wick cap lamp. (Pohs, Underground Mine Lamps. Courtesy of the Arizona Historical Society.)

and the Scranton–Wilkes-Barre areas. The dominance of the manufacturers proximal to the Appalachian coalfields emphasizes the location of the market.²⁶

Various animal and vegetable oils served as early fuels, with grease mixed with kerosene providing another common, if smoky, fuel. Rape-seed oil seems to have predominated in continental European mines, while bacon grease and lard oil—a mixture of rendered animal fat and kerosene—were apparently the fuels of choice in Britain and the United States. All of these fuels generated large amounts of smoke and soot and smelled quite bad, making air quality a significant issue in many mines using oil lamps.²⁷

States, particularly Pennsylvania, passed various laws that attempted to regulate the fuel used in these lamps. An 1899 Pennsylvania Department of Mines regulation specified only pure, “summer yellow” cottonseed or animal oils were to be used for illumination, with no explosive or impure oils, i.e. kerosene, added. This instruction was codified

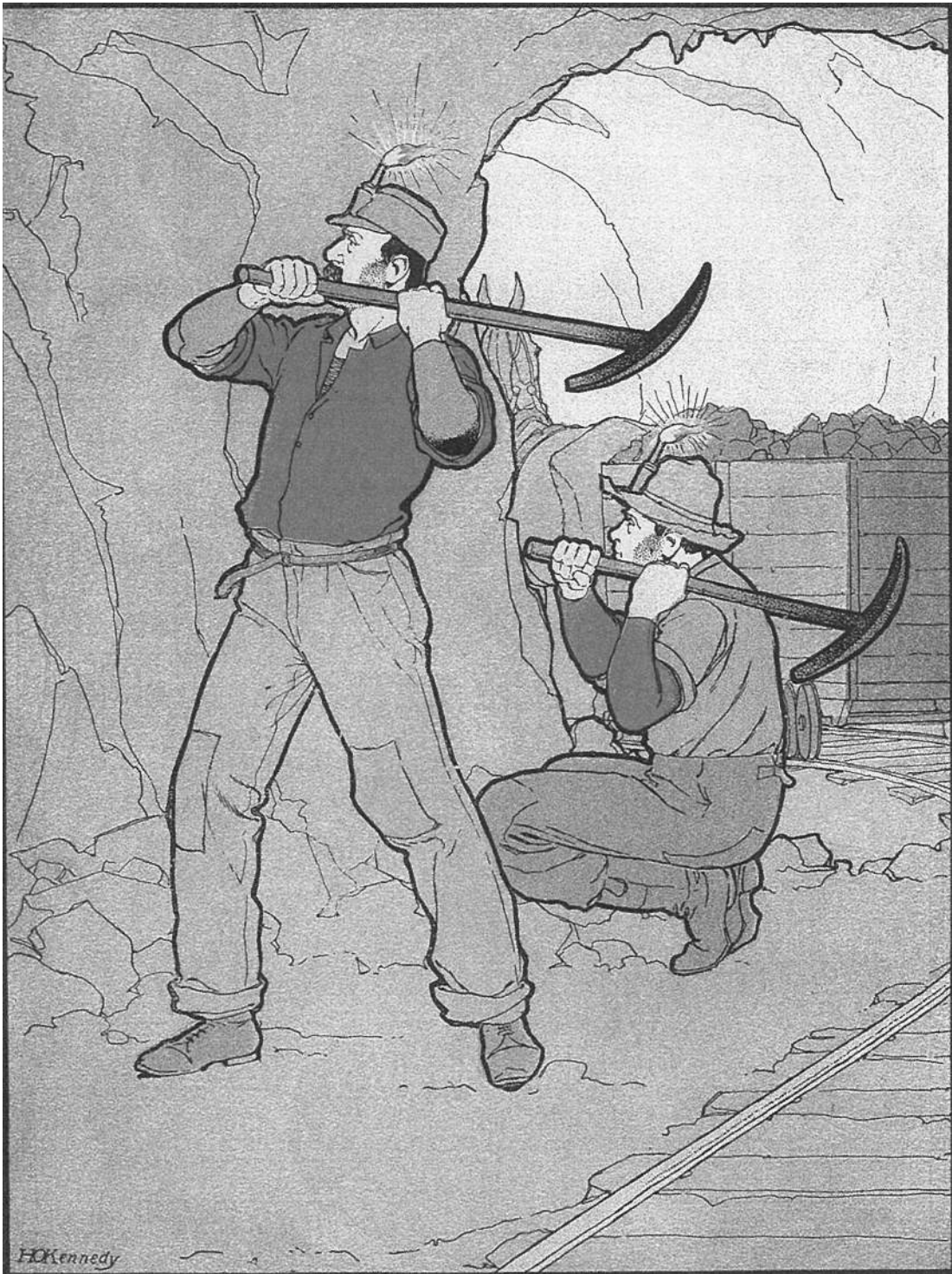
in the Pennsylvania Bituminous Mining Law of 1911, which also specified specific soot contents for lamp mine fuels when burned in general operating conditions. These soot contents could only be achieved by using high-grade fuel oils.²⁸

These laws did not prove to be particularly effective. The specified fuels were expensive and miners themselves bore the costs of the lamps and fuel individually, so they evaded these regulations whenever possible.²⁹ This also helps explain why coal miners did not convert to using stearic candles (see below) after those came into widespread use in metal mines. Simply put, the candles cost two to three times more per day to use than oil lamps.

Standard Oil Company produced a later fuel used in spout lamps called Sunshine. The company developed this product, a patented mixture of paraffin and approximately 3 percent mineral oil, about 1900. It produced a clean, bright flame with minimal soot. Other petroleum companies created similar products, known collectively as “miner’s wax.” However, Sunshine was the dominant product and most oil lamp specialists use the term Sunshine to refer to the whole category of miner’s wax.³⁰

Sunshine was sold either in blocks about four by ten inches in size, for approximately five cents a block, or in tin pails similar to one-gallon paint cans. A block lasted about two shifts. To use Sunshine, the wax had to be broken into small chunks or shaved with a knife. Lamps that used Sunshine required a special double-tube feed system. This liquefied the paraffin by transmitting the heat of flame down to the fuel, so that it could flow up the wick. A similar effect could be achieved by inserting a copper wire within the wick.³¹

Spout lamps lasted in non-gassy coal mines into the 1920s, when they were finally replaced completely by electric lamps. Before then they lost a good share of their customers to carbide lamps, which produced a brighter flame at significantly less cost. As early as 1917, one authority stated that the spout oil lamp had outlived its gen-



"Uncle Sam's Workers," 1901. A chromo-lithograph showing two coal miners with spout oil wick lamps. Note the horse-drawn ore cart and the absence of hard hats.

Fuel Costs of Mine Lights	
Light Type	Cost per Ten-Hour Shift (cents)
Safety Lamps	variable
Spout Oil Wick Lamp (Sunshine)	2.4 - 2.7
Stearic Candles	4 - 8
Carbide Lamps	1.5 - 2
Electric Cap Lamp	not comparable
(Data from: Rice, 1911; Chance, 1917; Pohs, 1995.)	

Individual Lamp Costs	
Light Type	Lamp Cost (dollars)
Safety Lamps (Wolf)	2.10 - 2.90
Spout Oil Wick Lamp (face)	0.07 - 0.14
Spout Oil Wick Lamp (driver)	0.11 - 0.25
Candlestick Holder (iron forged)	0.40 - 0.75
Candlestick Holder (wire)	0.25
Carbide Lamp (brass)	0.85 - 1.50
Carbide Lamp (nickel plated)	1.25 - 2.00
Data from: Pohs, 1974; Leahy, 1978; Wilson and Bobrink, 1984; Clemmer, 1987. All costs from 1907-1918.	

eral usefulness; nevertheless it remained in service for another five years or more.³²

Candles

Candles, although existing since at least the first century AD, found limited use in mining until approximately 1850, when their mass production commenced. Prior to that, candles were hand dipped, then made in molds after 1800. A skilled worker could produce, at best, two hundred dipped candles per day. Thus, candles were considered a luxury good in the early seventeenth century. Colonial practice used oil lamps for day-to-day needs, saving candles only for special occasions. Tallow candles also had other disadvantages: they smoked and smelled disagreeably, dripped badly, gave off inconsistent light, burned rapidly, and guttered in slight breezes.³³

In 1834, Joseph Morgan invented the first continuous-wicking, piston-ejecting candle molding machine.³⁴ Candle factories soon appeared and produced large quantities of candles. At approximately the same time, researchers began examining the chemical nature of candles. They determined that only part of the tallow—derived from animal fat, usually cattle—was useful for burning.

Tallow is principally composed of stearic acid, oleic acid, and glycerin, the stearic acid being the desired component. Tallow was melted via steam washing, then mixed with alkali and steam under pressure. This separated the glycerin; the oleic and stearic acids were separated through high-pressure filter pressing. The process required multiple pressings to produce the stearic acid, which in its purest form was a hard, snow-white wax. Mining candles were advertised on the basis of the number of pressings, as with the Triple-Pressed Mining Candles from the Emory Candle Company.³⁵

The best stearic candles had distinct properties: they emitted little smoke or odor; withstood temperatures up to 140 degrees F. without bending or melting; resisted guttering in a draft;

burned without much dripping; provided a consistent, bright light; and extinguish quickly without smoldering. Stearic mining candles were thus a high-end product of significantly better quality than domestic candles—and advertised as such.³⁶

Twenty known U.S. manufacturers produced stearic candles, the principals including the M. Werk Company of Cincinnati, the Goodwin Manufacturing Company of St. Louis, the F. Schneider Company of Chicago, and Proctor and Gamble of Cincinnati. All of these companies were located in major meatpacking communities to provide a ready source of large quantities of animal fat and tallow. San Francisco's five known manufacturers also produced significant quantities of stearic candles.³⁷

Starting around 1850, large quantities of paraffin wax also became commercially available for use in candles. Paraffin, a valuable component for regulating the burning characteristics of stearic candles, was principally derived as a byproduct from oil refining and produced by America's new and growing oil companies. Some of these, such as the Standard Oil Company, became significant manufacturers of mine candles.³⁸

Thanks to these three trends, an entire industry dedicated to mining candles evolved. Although a wide variety of brands and types developed, based on the quality of the stearic acid and amount of paraffin wax, the industry standardized candle size at a diameter of .75 inches. This produced candles weighing twelve to fourteen ounces per set of six, in lengths ranging from 7.75 to 9.5 inches, 9 inches being average.³⁹

These candles typically came in boxes of 120 and 240, wrapped in sets of six, and priced at three to five dollars per 240-unit box, thus one to two cents per candle. In the remotest districts during the rush period, such as Treasure Hill, Nevada, during the winter of 1868–69, prices could go as high as thirty-five cents per candle. Miners typically burned between three and four-and-a-half candles per day, depending on the type of candle and operating conditions.⁴⁰

Candlesticks

Accompanying the mass production of candles was the development of candle holders specific to the mining industry. The first known mining candlestick patent was issued in 1872 and the last in 1917. All told, eighty-seven patents have been issued for miner's candlesticks, and thirty-three of these are known to exist as working models.⁴¹

The traditional miners' candlestick consisted of an iron spike, of one-quarter- or three-eighths-inch diameter, with a wire loop handle at the end opposite the point. The length ranged between six and eighteen inches, ten to twelve being the most common. Toward the center of the spike a spring-clip thimble held the candle upright, perpendicular to the spike. Opposite the thimble, offsetting its weight, a perpendicular hook attached the candlestick to natural crannies or protrusions where beams or cracks for the spike were unavailable.⁴²

The earliest underground candleholders were nothing more than wetted clay used to paste the candle onto the rock face. This practice apparently originated in England and followed Cornish miners over to the Michigan copper fields in the 1850s.⁴³

The earliest known evidence for a metal mining candlestick, based on engraved illustrations, is from 1860 on the California Mother Lode and 1861 on the Comstock Lode. These candlesticks consisted of a thin spike with a metal thimble, but no handle or hook. The first candlestick handle appeared in 1865 on the Comstock, and the first hook in 1878.⁴⁴

Given the simplicity of its design, a candlestick could be fashioned by virtually any blacksmith, and numerous examples of these exist. However, many candlesticks appear to have been mass-produced in small foundries or machine shops and were readily available from mining supply stores or catalogs. Both Montgomery Wards and Sears Roebuck sold miners' candlesticks.

Over eighty brands and at least thirty-two

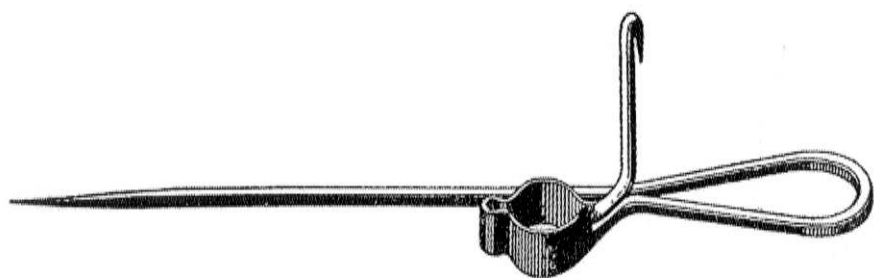
manufacturers existed, the two largest being Nathan Varney of Denver, with eighteen models in multiple sizes, and the Ludlow-Saylor Wire Company of St. Louis, with thirteen models. This repeats the pattern seen in candlemaking of a central manufacturing center removed from the actual mining locations.⁴⁵

Ultimately, Nathan Varney dominated the candlestick market, outselling all other brands combined. A 1911 catalog price lists a one-piece Varney candlestick at six dollars per dozen, while a similar model sold for nine dollars a dozen in 1918. Cheaper varieties of candlesticks were made by continuously coiling a piece of number six steel wire to form the thimble, spike, and hook. These retailed for three dollars a dozen in 1911, half the price of the Varney model.⁴⁶

Individual miners bore the cost of the candlestick; mining companies only supplied the candles. Possibly because of this, the candlestick holder became a symbol of metal mining. Numerous examples exist of fancy candlesticks made as presentation pieces, complete with nickel-chrome plating; shields or additional pieces such as miniature mining tools, lodge emblems, or a woman's leg about the thimble; inlaid silver, or engraving. Some of these approach true works of art.

It may be difficult to believe that about ninety patents could be issued for something as simple as an iron-spike candleholder, but its components could be arranged in a nearly limitless variety of ways. Many of the patent designs had detachable pieces or folded in a manner similar to a modern pocket knife. Others added accessories such as fuse cutters, knife blades, matchstick holders, snuffers, and cap crimpers.⁴⁷

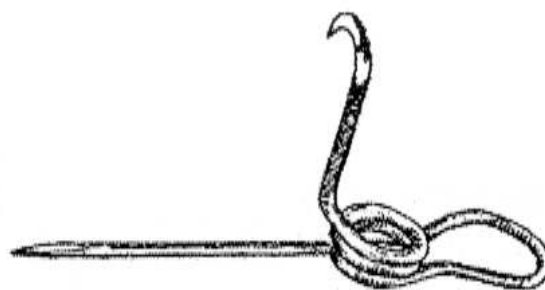
The last known patent for a candlestick model actually marketed was issued in 1914. Catalogs continued to carry candlestick holders until at least 1918, and one authority documented some catalogs listing mining candles into the late 1930s, although these may have been discontinued, distressed stock. All told, miners used iron candlesticks for something like seventy-five years,



Pen and ink drawing of a Varney candlestick holder. This illustration comes from a 1911 advertisement in Mining Science magazine. Identical candlesticks advertised in Mining Science in 1914 cost \$1.50 apiece. By that time, carbide lamps had been established for over a decade and electrical cap lamps for three years.

STEEL COIL

Wire coil candlestick holder from a circa 1900 catalog of the Pacific Hardware and Steel Company of San Francisco.



No. 5.

including during the early days of California gold mining and the Comstock Lode, when patents for candlesticks are unknown.⁴⁸

Patent applicants for candlesticks hailed from throughout the mining West. Seventy-seven of the eighty-seven candlestick patents recorded in W. E. Wilson's *Miners' Candlestick Patents* went to applicants in ten western mining states, and from many of the famous mining camps. (Eight of the remaining ten came from the Great Lakes copper and iron country.) This suggests miners, mining engineers, and associated mill workers modifying and refining a working tool with which they were intimately familiar. This inventing was an individual rather than a corporate endeavor.

Candlesticks appear to be mostly a western mining phenomenon. They were known in other

countries, including Germany, Australia, Mexico, England, and Korea,⁴⁹ but were not in common use compared to the American West. In those countries mines were principally illuminated by oil lamps of varying types. Likewise, few candlesticks appeared east of the Mississippi, save in the northern Michigan copper and iron mines. Mine lighting in most of the region was provided by spout oil wick lamps.

The relatively high cost of candles was probably the dominant factor in their distribution. Only in the western United States did use of stearic candles dominate, and only the United States had as centralized and industrialized a meatpacking industry.⁵⁰

Centralized meatpacking was necessary to supply the copious quantities of animal fat needed

by stearic candle factories. European nations still relied on local butchers or slaughterhouses that did not generate the amount of animal fat needed, so the cost of stearic candles in those countries would have been higher.

But the European situation does not explain the difference in the United States between oil wick lamps in the East and candles in the West. Almost universally, metal miners used candles and coal miners used oil lamps except where high-gas environments required safety lamps. This demarcation even occurred in places like Colorado, which had both coal and metal mining industries.

Candles gave off less smoke and thus were better suited to the comparatively poor ventilation characteristic of most metal mines. Since noxious gases were typically not an issue in metal mines, their ventilation was generally not especially powerful. The smoke generated by oil wick lamps would have constituted a significant hazard in most metal mines, though lamps that used Sunshine burned much cleaner.

Candles were also perceived to be significantly less of a fire hazard than oil lamps. In most cases, an overturned candle extinguished without igniting mine timbers.⁵¹ This was less true of oil lamps, which had a bigger flame and resisted extinguishing in this manner. The oil lamp fuel itself constituted a significant fire hazard, was messy to work with, and inconvenient to transport. As a dry good, candles would have been much easier to deal with, particularly in remote locales.

Sunshine fuel for oil lamps should have constituted a significant competitive threat to stearic candles after 1900. Cost tests suggest that lamps that burned Sunshine were significantly less expensive to use than candles. Nonetheless, there is no evidence that metal miners converted to oil lamps. Instead, metal miners converted directly to the new carbide lamps, which were significantly brighter and cheaper to operate.

A Performance Matrix

A performance matrix table (page 60) permits comparison of two or more competing technologies. Behavioral anthropologists use this method to compare all factors, quantitative and qualitative, of competing technologies to determine why particular items were adopted.⁵²

The performance matrix will help address several key questions associated with the U.S. adoption of mine lamps: Why were the candle and the spout lamp able to operate simultaneously, albeit in different mining spheres, rather than one technology supplanting the other? Why did the clearly superior carbide lamp not displace the spout oil wick lamp, which instead lasted into the 1920s and was finally replaced by the electric lamp? Why did the carbide lamp last as long as it did against another superior technology, the Edison electric cap lamp?

The matrix compares spout oil wick lamps and candlesticks. The seven main variables to consider include: cost, both to purchase and operate; quality of light in candlepower generated and consistency; ease of operation; ease of transport of the fuel; safety; ventilation; and intangibles.

Cost clearly favored oil wick lamps, which were significantly cheaper to operate and to purchase, although the miners themselves bore the latter cost. The quantity of light generated was approximately the same, but candles tended to produce a more constant light. Candlesticks and oil lamps rated about the same in terms of ease of operation. Candles were considered safer, although that is a debatable point. But candles were clearly superior in fuel transport and handling and also generated less smoke, making them the illuminant of choice in poorly ventilated areas.⁵³

Thus the competitive issue could be more accurately framed as: Did the candle's advantages in perceived safety, improved ventilation, ease of fuel transport, and in the relative constancy of its light offset its decided disadvantage in cost? In the case of continental Europe, the answer is

Performance Matrix Comparing Candlesticks to Spout Oil Wick Lamps		
	Candlesticks	Oil Wick Lamps
Cost		
Initial Purchase	-	+
Operating Cost	-	+
Light		
Quantity (candlepower)	~	~
Quality (constancy of flame)	+	-
Ease of Operation	~	~
Ease of Fuel Transport	+	-
Safety	+?	-?
Ventilation (smoke generated)	+	-
Intangibles (tradition)	~	~
(+ decidedly better; - decidedly worse; ~ approximately the same; ? uncertain)		

clearly no. Oil lamps continued to be employed until replaced by carbide and electric lamps, while candles saw minimal use.

In the United States the answer is much less definitive. Here is where the last category, the intangibles, principally tradition, comes into play. As a rule, metal and coal miners did not mix, and each employed their own tools and traditions. It seems likely that these traditions overruled the relatively minor perceived differences in lighting technologies.

Significant resistance to technological change, which appears to characterize the industry in those years, also slowed the introduction of new light sources in both U.S. coal and metal mining. Candle users converted to the carbide lamp only after its superiority was well established, and even then the switch took approximately ten years. Miners took even longer to abandon spout oil lamps—approximately fifteen years. They lasted underground until finally replaced by electric lamps in the 1920s.⁵⁴ ■

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He has also served as director and curator of the Colorado School of Mines Geology Museum, responsible for the design and layout of its current building and care of its extensive mine lamp collection. This study represents his attempt to come to grips with this collection and its significance. He wishes to thank the Arizona Historical Society, especially Dr. Bruce Dinges, its director of publications, for allowing reproduction of Henry Pohn's mine lamp line drawings from his excellent 1974 study.

Notes:

1. Paul J. Bartos, "Innovation in the Mining Industry through Time" (Ph.D. diss., Colorado School of Mines, 2006).
2. T. Allen, "Coal Mine Illumination," *Mining Congress Journal* 26 (Apr. 1940): 59-61, 76; (May 1940): 44-7. L. B. English, "Mine Illumination," *Canadian Mining and Metallurgical Bulletin* 48 (1955): 27-30. G. E. Bayles, "The History of Mine Lighting," parts 1 and 2, *Mechanization* 20, no. 12 (1956): 77-81; and 21, no. 1 (1957): 73-6. J. Leahy, "Early American Mine Lighting," *Mines Magazine* 68, no. 8 (1978): 22-5. N. S. Wagner, "Miners' Candlesticks: A Glimpse of Yesterday's Mining Industry," *Oregon Geology* 44, no. 12 (1982): 142-5.
3. H. A. Pohs, "Early Underground Mine Lamps: Mine Lighting from Antiquity to Arizona," Museum Monograph no. 6, Arizona Historical Society, Tucson, Arizona, 1974. W. E. Wilson, *Frog Lamps: A Survey of Examples from 1529 to 1979* (Talcottville, CT: The Rushlight Club, 1981). W. E. Wilson, *Miners' Candlestick Patents* (Tucson, AZ: Mineralogical Record, Inc., 1983). W. E. Wilson and T. Brobrink, *A Collector's Guide to Antique Miners' Candlesticks* (Tucson, AZ: Mineralogical Record, Inc., 1984). G. S. Clemmer, *American Miners' Carbide lamps: A Collector's Guide to American Carbide Mine Lighting* (Westernlore Press, Tucson, Arizona, 1987). H. A. Pohs, *The Miner's Flame Light Book* (Denver: Flame Publishing Company, 1995).
4. L. Thwing, *Flickering Flames* (Rutland, VT: Charles E. Tuttle Co., 1958). English, "Mine Illumination." A. H. Hayward, *Colonial Lighting*, 3rd ed. (New York: Dover Publications, 1962). Exodus 27:20.
5. Hayward, *Colonial Lighting*, plate 2.
6. D. A. Trotter, *The Lighting of Underground Mines* (Clausthal-Zellerfeld, Germany: Trans Tech Publications, 1982), 1. Haywood, *Colonial Lighting*, 8.
7. Hayward, *Colonial Lighting*, plate 3.
8. Haywood, *Colonial Lighting*, 12.
9. Pohs, "Early Underground Mine Lamps," 4. G. Agricola, *De Re Metallica*, 1556 (H. C. Hoover, L. H. Hoover, trans., Dover Publications, New York, 1950).
10. Pohs, "Early Underground Mine Lamps," 4-5; 100, note 12. Wagner, "Miners' Candlesticks," 142. The rooster, symbolizing dawn, is a common motif on mine lamps, conveying the notion of the miners returning from the darkness of underground toward the light of the surface.
11. Wilson, *Frog Lamps*.
12. *De Re Metallica* describes mining practices in Ertzgerberge, the area of the first mining schools.
13. E. N. Hartley, *Ironworks on the Saugus: The Lynn and Braintree Ventures of the Company of Undertakers of the Ironworks in New England* (Norman: University of Oklahoma Press, 1957). Hayward, *Colonial Lighting*, 13. The first governor of Plymouth Colony purchased an iron Betty lamp in Holland just prior to embarkation to the New World. This lamp (reproduced in *Colonial Lighting* as the unnumbered figure on page 11) appears extremely similar to the Colorado School of Mines' "frog" lamp.
14. Allen, "Coal Mine Illumination," 61.
15. Allen, "Coal Mine Illumination," 61. Prior to the Newcastle disaster, newspapers typically did not publish information about coal mine disasters for fear of offending mine owners. N. E. Zern, "The History of Mine Lighting," *College of Engineering Bulletin* (University of West Virginia, Morgantown, WV) ser. 2, no. 1 (1916): 14.
16. Zern, "History of Mine Lighting," 16-7. Colorado School of Mines has a Davy lamp used in the Fremont County, Colorado, coalfields in the mid-1870s. Davy lamps were used in the U.S. as late as 1915.
17. Trotter, *Lighting of Underground Mines*, 6. J. Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (New York: Oxford University Press, 1990), 111, note 20.
18. Allen, "Coal Mine Illumination," 61.
19. Pohs, *Miner's Flame Light Book*, 328-30.
20. Trotter, *Lighting of Underground Mines*, 7.
21. Trotter, *Lighting of Underground Mines*, 7. Bayles, "History of Mine Lighting," part 2.
22. Allen, "Coal Mine Illumination." T. Allen, "[Colorado School of Mines] Collection of Safety Lamps, Special Lamps, Open Lights," Morse Bros. Machinery Co., Denver, Colorado, 1952, 46 (an unpaginated catalog, sponsored by Morse Bros., describing lamps in the School of Mines' collection). Trotter, *Lighting of Underground Mines*, 8-9.
23. Pohs, *Miner's Flame Light Book*, 731. Anthony Moon, written communication, summer 2009.
24. Allen, "Collection of Safety Lamps," 46. Pohs, *Miner's Flame Light Book*, 695-9. In this paper I have used the term "spout oil wick lamp" to distinguish these teapot-shaped oil lamps from early safety lamps, covered oil lamps, and frog lamps, all of which used oil and wicks. The distinguishing feature of the teapot-shaped lamp is its large spout containing the wick, thus "spout oil wick lamp."
25. Leahy, "Early American Mine Lighting," 23. Another

place where candles and spout lamps apparently co-existed, at least on a limited basis, is at the Stanley Mine in the Idaho Springs district of Colorado, where an 1891 photograph shows miners with both sets of lamps.

26. Pohs, *Miner's Flame Light Book*, 251-4. Bartos, "Innovation in the Mining Industry."
27. Pohs, *Miner's Flame Light Book*, 223. Trotter, *Lighting of Underground Mines*, 4.
28. Pohs, *Miner's Flame Light Book*, 230. E. M. Chance, "Portable Mine Lamps," *Bulletin American Institute of Mining Engineers*, no. 122 (1917): 236-7.
29. The question of who paid for lamp fuel, owners or miners, is not without controversy. However, most evidence suggests that coal miners bought their own lamps and fuel, while metal miners bought their own candlesticks, but were provided candles by the company. The difference may be that stearic candles and carbide were specialty items, used almost exclusively in mines, whereas lamp oil was also used for domestic lighting. So in the former case it probably made sense for the owners to supply the item and in the latter case for the miners to bring it from home.
30. Pohs, *Miner's Flame Light Book*, 231.
31. Pohs, *Early Underground Mine Lamps*, 26. Trotter, *Lighting of Underground Mines*, 5.
32. Pohs, *Miner's Flame Light Book*, 228. Leahy, "Early American Mine Lighting," 23. Trotter, *Lighting of Underground Mines*, 5. Chance, "Portable Mine Lamps," 242.
33. Trotter, *Lighting of Underground Mines*, 2. Hayward, *Colonial Lighting*, 75, 77.
34. Wagner, "Miners' Candlesticks," 142.
35. Anon., "Stearic Wax Miners' Candles," *Engineering and Mining Journal* (5 Apr. 1902): 487. Anon., "The Manufacture of Miners' Candles," *Engineering and Mining Journal* (17 May 1902): 700. The end of the box for Triple Pressed Mining Candles from the Emory Candle Company is on display at the Colorado School of Mines' Geology Museum.
36. Anon., "Stearic Wax Miners' Candles."
37. Wilson and Brobrink, *Collector's Guide*, 11. Pohs, *Miner's Flame Light Book*, 676-8. Tallow and hides were the principal products from San Francisco, then known as Yerba Buena, prior to the gold rush. This business expanded significantly with the arrival of the gold miners. D. J. St. Clair, *The Gold Rush and the Beginnings of California Industry in a Golden State: Mining and Economic Development in Gold Rush California* (J. J. Rawls and R. J. Orsi, eds.), (Berkeley: University of California Press, 1999), 185-208.
38. Wilson and Brobrink, *Collector's Guide*, 11.
39. Pohs, *Miner's Flame Light Book*, 128-9.
40. C. T. Rice, "Candle Tests," *Engineering and Mining Journal* (29 Apr. 1911): 848. W. T. Jackson, *Treasure Hill: Portrait of a Silver Mining Camp* (Tucson: University of Arizona Press, 1963). This rate of consumption made candles a significant commodity in mining camps, and the location of their principal manufacturers in the Midwest required the nation's emerging distribution network to supply them to the mountain mining districts.
41. J. D. Ramsdell and N. S. Wagner, *Patents, Miners' Candlesticks* (Carson City, NV: privately published, 1982). Wilson and Brobrink, *Collector's Guide*, 16. Wilson, *Miners' Candlestick Patents*, summary page. Collectors are continually scouring the more than six million U.S. patent records for additional candlestick and spout oil lamp patents. The current counts for candlestick and spout oil wick lamps are 91 and 131, respectively. Anthony Moon, written communication, summer 2009.
42. Wagner, "Miners' Candlesticks," 144.
43. Wilson and Brobrink, *Collector's Guide*, 12-3. Clay lumps continued to act as candleholders in English coal mines into the twentieth century. They were banned by a law passed in 1911 which stipulated that mine candles be placed in a metal holder for fire safety. Allen, "Coal Mine Illumination."
44. Wilson and Brobrink, *Collector's Guide*. Although there were hooks patented as early as 1874, these did not immediately appear in general use.
45. Wilson and Brobrink, *Collector's Guide*, 23-4.
46. Wilson and Brobrink, *Collector's Guide*, 24. Pohs, "Early Underground Mine Lamps," 12-3.
47. Wilson, *Miners' Candlestick Patents*.
48. Pohs, *Early Underground Mine Lamps*, 12. Wagner, "Miners' Candlesticks," 142. Wilson and Brobrink, *Collector's Guide*, 17.
49. Wilson and Brobrink, *Collector's Guide*.
50. H. C. Hill, "The Development of Chicago as a Center of the Meat-Packing Industry," *Mississippi Valley Historical Review* 10, no. 3 (1923): 253-73. R. J. Arnold, "Changing Patterns of Concentration in American Meat Packing 1880-1963," *Business History Review* 45, no. 1 (1971): 18-34. J. A. James, "Structural Change in American Manufacturing, 1850-1890," *Journal of Economic History* 43, no. 2 (1983): 433-59.
51. Although not always. An overturned candle caused the infamous Yellow Jacket mine fire that claimed thirty-seven lives on the Comstock Lode in 1869. D. McDonald, *Virginia City and the Silver Regions of the Comstock Lode* (Las Vegas: Nevada Publications, 1982).

52. A recent example of performance matrix analysis can be found in M. B. Schiffer, "The Electric Lighthouse in the Nineteenth Century: Aid to Navigation and Political Technology," *Technology and Culture* 46, no. 2 (2005): 275-305. Schiffer and A. R. Miller offer an extended discussion of the technique in *The Material Life of Human Beings: Artifacts, Behavior, and Communication* (London: Routledge, 1999). In essence, a performance matrix is a type of pro-and-con checklist that weighs various factors.
53. Bartos, "Innovation in the Mining Industry," 79-81.
54. Anon., "Portable Electric Mine Lamps," *Mines and Minerals* 22 (Dec. 1901): 195. On the subject of resistance to technological change, see P. J. Bartos, "Is Mining a High-Tech Industry? Investigations into Innovation and Productivity Advance," *Resources Policy* 32 (2007): 149-58, esp. 156.