Franz Pieler's Spirit Lamp

by David Gresko

The second half of the 19th century brought significant changes in the coal mining industry. This period was the start of the Industrial Revolution, and the world was hungry for energy and coal was the main source. Coal mines expanded their production by deepening and opening up additional sections. Unfortunately, expanded production brought disastrous explosions on both the Continent and British Isles caused by firedamp. The occurrence of firedamp, or methane, increased as productivity grew.

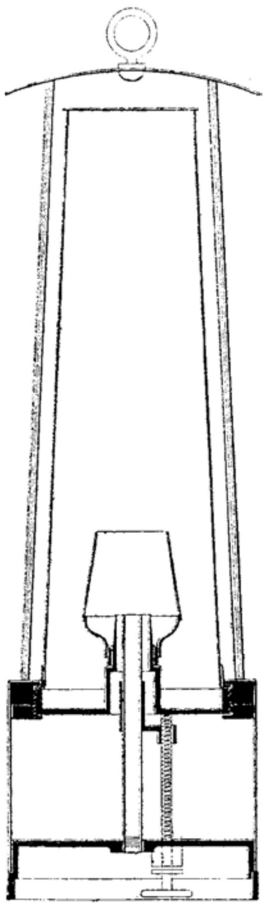

Figure 1:Pieler's Spirit Lamp-Original design from Pieler's 1883 paper. Note the air intake from the bottom through the center of the wick tube.

The fiery atmospheres caused by increased production requirements drove the technology and art of mine ventilation engineering. Large fans, such as the Struve, were installed to drive huge volumes of air through the workings to dilute methane and coal dust below explosion limits. Velocity and total volume increased substantially in underground workings.

Franz Pieler, a Bergmeister (Mine Manager) in Westphalia, was a practical mining man who had experience in day to day production challenges in the Bergbau (Mining Industry). He realized that the same technology that provided increases in air volume to dilute firedamp also masked great dangers. Detection and measuring devices of that time were not accurate below 2.5% methane, and were not useful in well-ventilated workings. It was a classic case of a technology that was developed to solve one problem, creating another. In 1883, Pieler wrote a paper[1] addressing ventilation problems in this new era of coal mining, and discussed practical ways of measuring methane and carbon dioxide in underground coal mines. Pieler indicated that while a typical Davy lamp might indicate a "gas free" atmosphere, great dangers could exist under certain circumstances. Pieler wrote:

"The occurrence of explosive atmospheres in underground workings is mostly observed with the safety lamp, which has been proven to only be accurate down to 2.5 methane to 100 gas mixtures. However, in most cases, the return air in gassy mines can not be observed for changes in methane, which occur in small proportions due to dilution by ventilation. In addition, in the individual sections of a pit that are explosive-free by dilution by ventilation, are not by any means safe. If in such a section, that regularly receives through ventilation 100 cubic meter of fresh air per minute while 2 cubic meters of methane developments, the mixture of 2:100 is not detectable, but it is detectable in less ventilated parts. If a local disturbance decreases the ventilation to 20 cubic meters, then the atmosphere in the section for a short period becomes 2/20=10% of firedamp, thus a explosive atmosphere has already formed and the danger be all the more greater as the entry was thought to be firedamp free."

[1] ÜBER EINFACHE METHODEN zur UNTERSUCHUNG DER GRUBENWETTER (Easy Methods for Examining the Air in Underground Mines) , Fr. Pieler, Aachen, 1883. Pieler describes, practical ways of measuring methane and carbon dioxide. He describes and illustrates an air sampler, carbon dioxide detector, a hydrogen burner and spirit lamp for measuring firedamp.

The “local disturbance” that Pieler mentions is disruptions in the ventilation system encountered everyday in an underground mining. These disruptions can be caused by shot firing, opening a ventilation door, fan failure due to power outage, pillar failure, or simply a train passing through a fresh air entry and blocking air flow.

Pieler advocated in his paper that mine managers not only have to know the percent fire-damp in each section of the mine, but the actual volume of methane released. In addition, the industry was beginning to realize that low percentages of methane mixed with coal dust can cause violent explosions. Pieler wrote:

“For production management, it is in the interest of safety to be able to observe the immediate dangers of firedamp in diluted air where it is not indicated in a safety lamp”.

To accomplish this, many samples, over many days, must be taken in all of the return-air entries and sections and analyzed for methane and carbon dioxide. This was problematic, because up to then only well-equipped labs with experienced chemists were able to accurately measure low concentrations of methane in air samples. It wasn’t practical to collect dozens of air samples in containers from underground workings, take them to the surface and send them out to a lab for testing. Portable and accurate testing devices were needed.

Figure 2: (above and right): This is Pieler’s original design, but with scales added. The gauze is steel with a copper cap similar to a Saarbrücken lamp. The font is complex because of having to facilitate the hallow tube that runs from the bottom of the lamp through the center of the burner. Circa 1887.

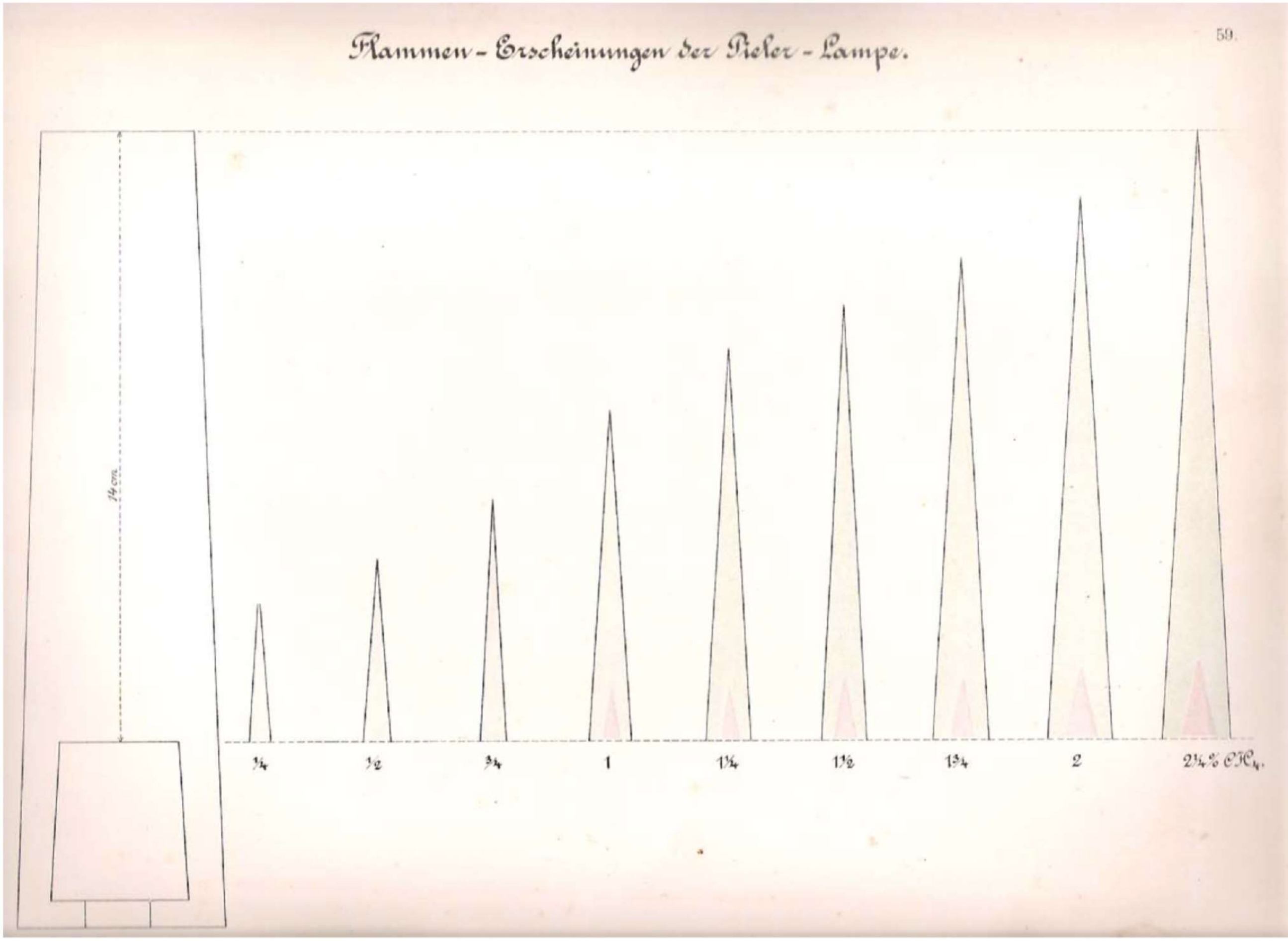

Figure 3: Flame observations using the Pieler lamp. Notice how the height of the flame exaggerates with small changes in methane. From the Prussian Firedamp Commission's 1886 report.

Pieler evaluated apparatuses available at the time for accuracy and portability. He determined Coquillon's apparatus, which was based on the contraction of volume caused by the combustion of methane in an air sample, was not practical because it was complicated to use and could not be used underground at all [2] Liveing's apparatus was based on the well known comparative measurement of the light of two glowing platinum wires, of which one is exposed to the gas mixture being examined, while the other one is surrounded by pure air. No special skill was needed to operate the apparatus, and it could be used underground. Unfortunately, since the platinum wires deteriorated quickly and required frequent replacement, regular use of the apparatus was difficult because the manufacturer was in England.[3]

Figure 4: Early Friemann & Wolf Pieler. Serial #46710; circa 1888. No fixed scale. Notice that the lamp has a pointing device that slides up and down one of the standards for marking the height for the flame. No igniter or flame snuffer.

[2] Over many years, many fire-damp indicators were invented that were based on the contraction in volume or the change of pressure caused by the combustion of the methane contained in an air sample. The indicators of Lewis & Maurice, Monnier, Coquillion, Le Chậteliar, and Burrell were all of this class. Although numerous, this class of indicator did nothing to displace flame indicators.

[3] Liveing's indicator actually saw many years of use. While it did not displace flame indicators, it was used as a comparison to other indicators.

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Because of the widespread use of the Davy lamp, Pieler recognized that it would be more accepted to use a gas measuring device that uses the physical appearance of a flame within a mixture of atmospheric air and firedamp. There had been prior attempts to make the flame safety lamp more sensitive to smaller quantities of methane, but there was not that great of success with oil-burning Davy or Marsaut type lamps.[4]

[4] Before the Pieler lamp was introduced there were numerous well-known studies, both in England and on the Continent, on the effect of small percentages of methane on the flames of the Davy, Marsaut, and Mueseler oil- burning lamps. Although small amounts (<2.5%) of firedamp could be detected, actual measuring was quite difficult due to the minute changes in the appearance of the flame.

Figure 5: Friemann & Wolf Pieler. Serial No. 80643; circa 1890. This lamp shows how F&W customized lamps for particular needs. This lamp has a removable bonnet, two (2) types of observation scales, a flame snuffer and magnetic lock. From the 1880's to 1900, F&W produced Pieler lamps with many variations. After 1900, the basic F&W models were the No. 700, No. 701, and No. 702.

Figure 6: Friemann & Wolf Pieler. Serial No. 201711; circa 1895. Classic Pieler lamp with 2 scales. Fitted with removable bonnet to be used for traveling in mine with the lamp lit. Bonnet has no slot for flame observation, so bonnet must be removed prior to testing. No igniter or flame snuffer. This lamp was exported to America, and has a brass tag on the font that says "Made in Germany."

Mallard and Le Chatellier, while working for the French Mine Ventilation Commission, observed how a hydrogen flame was far more sensitive to firedamp than an oil flame and gave good readings. They tried to manufacture a portable lamp with a hydrogen flame for testing underground, but failed because of construction difficulties.[5] Mallard and Le Chatellier totally gave up on using hydrogen for measuring methane in mine atmospheres. While not practical for tests underground, Pieler realized that constructing a stationary hydrogen burning apparatus, to be used on the surface, offered only a few minor difficulties. A hydrogen flame was easy to read and, with some practice, approximate determinations of the methane content of air sample could be made without a skilled technician. While not portable and could not be used underground, the instrument could be used to measure air samples taken in such locations as main air entries. Pieler describes the construction of a stationary hydrogen burner for testing in his paper.[6]

Mallard and Le Chatellier also tested the effects on the alcohol flame in firedamp atmospheres. It was observed that the alcohol flame was the most sensitive to very small amounts of methane. Since the alcohol flame exaggerates with minute changes of methane in the atmosphere, the height of the flame could be easily measured visually and correlated to a % concentration. Realizing this, Pieler designed a "Spirit Lamp" for underground fire-damp measuring, and introduced it in his 1883 paper (see Figure 1).

[5] In 1892, James Ashworth and Prof. Frank Clowes would patent an Ashworth-Hepplewhite-Gray type lamp with an attachment for a hydrogen gas cylinder for measuring small quantities of methane. This was the first practical and portable hydrogen gas testing device that could be used underground. It became commonly known as "Clowes' Hydrogen Lamp". While popular in England, it never gained popularity on the Continent.

[6] Pieler also illustrates and describes devices for collecting air samples in his 1883 paper.

Figure 7: J. Mills & Sons Newcastle bonneted and unbonneted Pieler lamps. Pieler lamps were not popular in England as Ashworths and Clowes Hydrogen lamps were preferred. Notice the bonneted lamp has no scale, and has a painted black standard on the viewing glass. The author doubts if another English make exists.

The “Spirit Lamp”, which would eventually be known as the “Pieler Lamp”, was for all purposes a large Davy-type lamp with some special design features to accommodate burning absolute alcohol. First, the font was made larger than an oil lamp to accommodate the amount of alcohol needed for operation, and was filled with cotton to stabilize the alcohol (minimize evaporation). Also, the wire gauze is taller than a typical Davy lamp to permit the full development of the flame cap. It was also necessary to design the lamp to avoid the effects of spirit vapors. Hence, the wick is contained in a long neck and all fasteners are well sealed. Air is admitted through a tube containing discs of gauze at the bottom of the lamp. This hallowed tube runs through the center of an Argand burner, which is adjustable by a sleeve moved by a screw in the base. The burner is fitted with a 30mm tall conical sheet-iron shield, “chimney”, which hides the flame in normal atmospheres. Pieler went on to write: “The testing of the mine air with the spirit lamp is exactly like the usual Davy lamp. The flame is standardized in pure air, and the height is adjusted to the top edge of the chimney. The cap that appears in air mixed with small quantities of firedamp behaves as follows:

- With 1⁄4 % of firedamp the flame is weakly illuminated; from bluish gray color to faded and approximately 30mm long.
- With 1⁄2% it is 50-60mms long, its lower end is clear while the top is still faded.
- With 3⁄4%, the blue color is more clearly defined; the limitation is sharper and the length of the cone is approximately 75mms.
- With 1% the cone is 90mms long; the limit is sharp and has an intense blue color. On higher amounts, the length of the cone further increases in length, and with 1 1⁄4% 100mms long, with 1 1⁄2% 120mms, and reaches the upper end of the wire gauze with 1 3⁄4%. The illuminating power grows accordingly, and the color becomes deep blue. With 2%, the cap widens at the top, and with higher percentages it continues to expand until the gauze is filled. In this concentration, the cap would

also be obvious in the Davy type oil lamp if one pulls down the flame until the luminous part disappears. The observations in this lamp are known.” [7]

Figure 8: French Cosset-Dubrelle Pieler. Notice scale measures length in centimeters, with no % methane indication.

Pieler’s Spirit Lamp received quite a bit of attention on the Continent when it was introduced in Westphalia in 1883. In the Prussian Firedamp Commission’s 1886 report, the Pieler lamp is mentioned extensively and several tests and comparisons to other flame safety lamps were performed. But, at the same time the Royal Commission on Accidents in Mine[8] final 1886 report quickly points to the lamp’s shortcomings:

“The Pieler lamp is obviously a most sensitive gas detector, but in its present form it is quite inadmissible for use in well ventilated mines for the following reasons: the flame is easily extinguished by a very moderate current, and if the lamp happens to come into an explosive mixture of gas and air, an explosion is almost certain to be caused in a few seconds. The lamp could be rendered less dangerous for general use by enclosing it in a case, and, as far as we have been able to observe, its power of indicating the presence of gas would be but little if at all changed.” [9]

Figure 9: Unmarked Belgium Pieler. Probably a Gilly. No scale or bonnet.

The Pieler lamp proved to have the following disadvantages:

- Since the lamp would fill with flame at 2.5% methane (for unbonneted lamps), there was a high risk of passing the flame through the gauze in explosive atmospheres with obvious results. It was necessary to test the atmosphere with a regular Davy prior to making a test with the Pieler lamp.

- The oil vessel heated up rapidly and caused excessive alcohol evaporation. Excessive alcohol vapor within the lamp caused false readings. Usually 20 to 30 minutes were required between tests for the lamp to cool down and the vapor dissipated.

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[7] See Figure 3 for flame observations from the Prussian Firedamp Commission (1886) of the Pieler lamp under changes in methane.

[8] The Royal Commission on Accidents in Mines 1886 Final Report contains an amazing amount of information about safety lamps and gas indicators. The Commission tested over 250 different safety lamps, and compiled all the tests results in the final report. The author has actually examined the two Pieler lamps that were tested. They were identical to that shown in Fig. 2, but without scales.

[9] In examining various varieties of Pieler lamps, it is obvious that enclosing it had an effect on the sensitivity. This is obvious by the differences in calibration of the fixed scales of an unbonneted vs. bonneted Pieler lamp.

• The flame from the Pieler lamp was mostly non-luminous and did not provide light for traveling underground. Therefore, it was necessary to carry another safety lamp for lighting.[10]

Figure 10: Belgain Mulkay Pieler. Invented in Lens, France, this particular lamp has the most sophisticated safety features of any Pieler lamp the author has seen. These features include a locking mechanism for the bonnet, double gauze arrangement, and a device to insure the gauzes have been inserted when assembling the lamp. It also has air regulators on the top and bottom of the bonnet. The scale is made of enamel.

There were many manufacturers of the Pieler lamp on the Continent, where the lamp was most accepted. Manufacturers included Friemann & Wolf (Germany), Wilhelm Seippel (Germany), Cosset-Dubrelle (France),.Mulkay (Belguim), Joris (Belguim), and A. Benitschke's Sohn, Joseph Jermar , Kubala (all of Ostrau, which is now part of the Czech Republic). In England, only John Mills & Sons Newcastle made a Pieler lamp, reflecting the lack of acceptance. There were no manufactures in the United States.

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[10] There were unsuccessful attempts to construct a combination oil and alcohol Pieler lamp. The theory being the oil flame would be used for lighting and measuring firedamp over 2.5%, and then the flame could be switched over to an alcohol burner for measuring firedamp under 2.5%. The closest that came to this was the Stokes lamp, which was fitted with a small alcohol burner and vessel for taking delicate readings.

Of all the manufactures, Friemann & Wolf was by far the most prolific. Friemann & Wolf probably started making Pieler lamps around 1883, when the Pieler lamp was introduced.[11] Surviving examples circa 1880's to 1900 indicate that many Pieler lamps were special order to the customer's specifications due to the large number of variations. It would not be until 1900 that Friemann & Wolf came out with the No. 700, No. 701, and No.702 that were dominant models.

Figure 11: All brass Pieler made by Joesef Jermar, Ostrau. Sliding bonnet with scale that measures up to 2 1⁄4% methane. Magnetic lock marked "Broucek Patent". Wick "snuffer."

While there were many modifications to the Pieler lamp during its 40+ years of service, the core design remained intact except for one feature. The air intake from the bottom of the lamp through a hallow tube running through the center of the wick did not survive. This was complicated to manufacture, and most likely very little air was drawn through it in comparison to the air entering the lamp through the gauze[12] Modifications/improvements to the lamp can be classified in two (2) groups: 1) Functional improvements were to enhance testing and general operation, and 2) Safety improvements were to enhance the safe use of the lamp.

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[11] The first mass manufacture of the Pieler lamp is a mystery to the author. These lamps have Pieler's original bottom feed design that obviously made manufacturing difficult and expensive. The copper cap on the gauze suggests a manufacturer of "Saarbrücken" type lamps. But lamp has none of the manufacturing characteristics of Friemann & Wolf. The author has examined the Pieler that was tested by the Royal Commission in their 1886 report. It is exactly the same lamp as illustrated in Figure 2, but without scales.

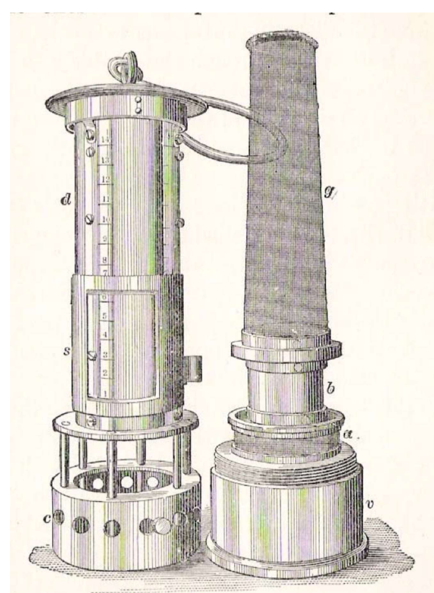
[12] It appears that only the first manufacture and production model of the Pieler lamp had the bottom air intake. The author has never seen another example of this feature from another manufacture.

Figure 12: Benitschke's Sohn was a well-know manufacturer of mining lamps in what was Bohemia (Czech Republic region). This particular Pieler lamp is fitted with a removable bonnet that has a sliding window for observation.

Functional improvements include the addition of a fixed graduated scale (to facilitate ease in visually measuring the height of the flame), internal igniters for relighting the lamp, and air dampers for regulating air sampling. Early references that the author has seen do not mention any type of fixed scale on the lamp for measuring flame caps, and there is no mention how the flame was supposed to be measured. The earliest example of a Pieler lamp with a scale that the author has examined, where the lamp's vintage could be verified, is 1888.[13] Scales became more numerous in the 1890's. Some scales just measured flame height (usually in centimeters), while some would indicate a % methane content, and some would show both the length graduations and % methane graduations. It appears that by 1900 all Pieler lamps were manufactured with some type of fixed scale. Internal igniters were introduced to Pieler lamps by Friemann & Wolf around 1900. To the author's knowledge, Friemann & Wolf was the only manufacture to provide internal igniters in Pieler lamps. Air dampers were added only to a few Pieler lamps. The previously illustrated Mulkay was built with both upper and lower adjustable air rings.

Safety improvements to the Pieler lamp were driven by local regulations or requirements These improvements included locks, bonnets and shields, and flame extinguishers. From the first introduction of the Pieler lamp, it was realized that there was a potential for the flame to blow through the gauze in well ventilated mines. Early examples indicate that simple shields, which surrounded half the circumference of the gauze, were probably first used to prevent this from occurring.[14] Bonnets appeared to have been introduced in the 1890's.

Figure 13: The Chesneau Lamp (right) was a hybrid Pieler lamp.



[13] The lamp was a Friemann & Wolf. Serial numbers on these lamps give an approximate date of manufacture. The scale on this example was a simple brass square bar, soldered vertically to one of the standards, that was etched in 1 cm graduations. There were no numbers on the scale. The lamp was very similar to the 1888 F&W lamp pictured previously.

[14] The author has examined two (2) Friemann & Wolf lamps of 1888 vintage that have shields.

Figure 14: Friemann & Wolf No. 700, 701, &702. These are the three "classic" and most advanced models from F&W. All have igniters and flame "snuffers."

Usually, the bonnet would have a slot for flame for observation that was covered with glass or mica, with an adjacent scale for measuring the height of the flame. Some bonnets were fixed, others could be removed. Another problem that had to be solved was how to prevent the flame from passing the gauze when the lamp filled with flame at methane >2.5%. Flame extinguishers, or "snuffers", were installed in lamps to quickly extinguish the flame when the operator observed the lamp filling with flame. "Snuffers" were installed at least as far back to

1890, and appeared to be standard in lamps made after

1900. There was at least one manufacture, Mulkay, which installed a device that insured the gauzes were inserted when the lamp was assembled. The Mulkay also had a double gauze arrangement.[15]

In 1892, a hybrid of the Pieler lamp was invented by M. Chesneau, who was the President of the French Firedamp Commission. The Chesneau was basically a Pieler lamp with many improvements to overcome the Pieler's weaknesses. The Chesneau lamp was made heavier duty for rough service, and had a fixed bonnet that allows it to perform safely in air currents up to 2000 ft. per minute. Like the Pieler, the lamp burned alcohol and has a tall gauze surrounding the burner. Instead of using a conical shield around the burner, the Chesneau used a cylinder as a standard for adjusting the flame. Gas measuring was identical to the Pieler. The elongation of the flame while in a firedamp atmosphere is observed through a mica window, and measured with scale attached to the bonnet. The lamp is also fixed with a sliding shield protected the mica window from wind currents that would cause condensation on the mica. To more easily read the caps, copper nitrate and ethylene chloride dissolved in the wood alcohol fuel to give the flame a greenish tint. As in the Pieler, the accuracy of the test result depended on the condition of the cotton being the same as when the lamp was standardized. Besides being safer in greater air velocities, a great improvement was that the Chesneau only required 30 to 90 seconds to cool down between tests instead of 20 minutes.[16]

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[15] To the author's knowledge, Mulkay was the only manufacture that installed automatic extinguishers and double gauzes in Pieler lamps.

[16] It is important to note that while the Chesneau had many important improvements over the Pieler, it did not make the Pieler obsolete by any means. The Chesneau was not as sensitive as the Pieler and cost almost twice the price.

Figure 15: Friemann & Wolf. Detail of flame "snuffer" and igniter.

Judging from where examples are acquired today, it appears that Pieler lamps were most popular in Germany, Poland and what was known as the Austro-Hungarian region.

There is not an exact date that the Pieler became totally obsolete, but it appears that they were not in much use past 1930.[17] Its use diminished for many reasons. In some mining districts, safety regulations made them obsolete when Davy-type lamps were outlawed. The main reason for the Pieler's demise was probably the introduction of various electrical devices that were deemed safer and more accurate.

From the perspective of a mining artifact collector, Pieler lamps are quite rare. Since the Pieler lamp was an instrument, and not a lighting device, they were handled carefully by trained people. They were expensive, costing at least five (5) times the price of an ordinary Davy lamp. Mines that use them only purchased a few, and kept them many years. Although it is unknown how many were made, today they are considered a prized piece of coal mining history.

The author would be interested in hearing from collectors who have additional information about the Pieler lamp.

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[17] The Pieler lamp is mentioned in US Coal Mining reference books through the late 1920's.