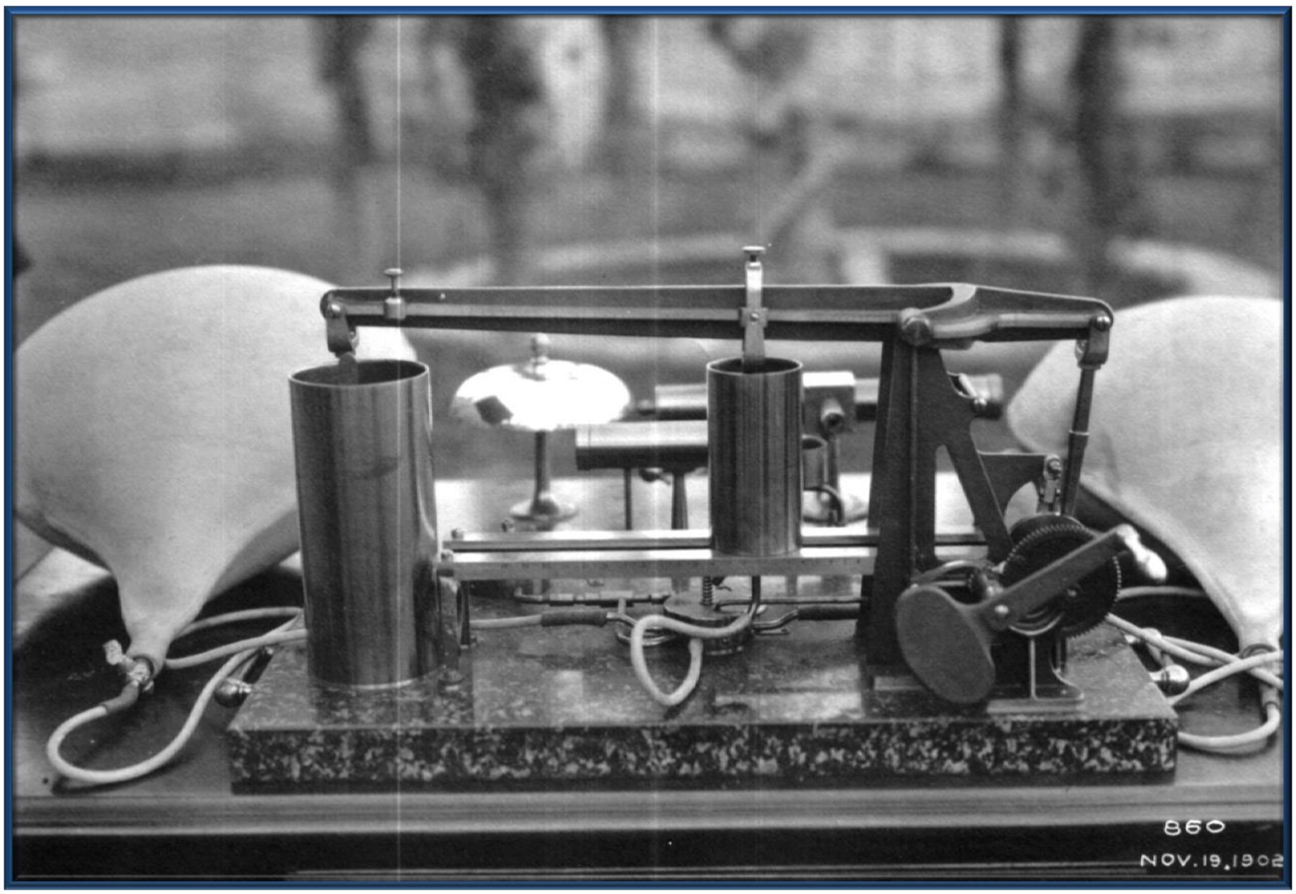
There's A Limelight Mystery Afoot

Used at the Cincinnati Water Works
Everything to do with lime
Nothing to do with water
In public with a female nude
Thrives on hydrogen

What is it?



By Leland L. Hite
Cincinnati Triple Steam
February 9, 2014

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A mystery has been afoot at the waterworks for many years. Pictures for the mystery item exist but not the device. Posted for many years on the CincinnatiTripleSteam.org website an invitation to solve the mystery went unsolved. Tour guests ventured many a good guess, but answers were elusive.

Not long ago a delightfully curious young woman, Liz Vesper, asked many good questions during a tour of Old River Station. Of particular interest was this mystery device. To solve the puzzle, Liz posted the mystery on a couple of blogs named "Ask Engineers" and "What is this thing?" In that process she carefully studied the mystery pictures and in the background noticed a nude female that appeared to stand in a fountain. She asked, "why the nude female"? While it is not uncommon for a "Fountain Lady" to occupy a public water fountain, it seemed out-of-place at the waterworks.

When the photos were discovered, I had exactly the same question as Liz but never expressed my concern to anyone. A female nude just seemed out-of-place at the water works. With Liz's observation it was now time to investigate where the picture originated. Assistant Superintendent Larry Moster kicked off another e-mail to several waterworks staff and friends asking if they knew about the device and the site depicted in the 1902 photo. Bill Reeves, a retired Superintendent, was quick to respond

Bill commented that, while he did not know the site for the photo, he was certain the pictures were not taken at the Cincinnati Water Works because the "New Water Works" was not complete in 1902. Additionally, he commented that he could not name the device but seemed to recall that it had something to do with lime—perhaps the heat generated from the slaking of lime. The water works has always used lime in the water treatment process to control ph and to soften water, and that practice continues today.

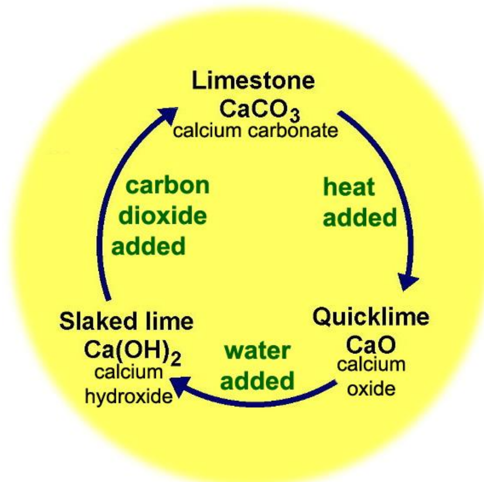


Fig. 1, The Lime Cycle.

Ignorance a Benefit. I had not a clue what Bill was talking about. I never worked for the water works, and I certainly never heard of slaked lime. Some internet time revealed that part of the "lime cycle process," shown at the right, produces slaked lime. When calcium oxide (called lime or quicklime) becomes mixed, or "slaked" with water, slaked lime is the name most often used, and that process generates an enormous amount of heat. See Figure 1.

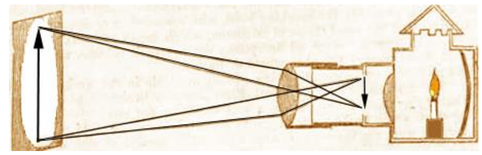
Armed now with two of Mr. Reeves' keywords, heat and lime, and more internet time, I began to unravel the mystery. Bill was correct! The device has to do with lime and with heat but not the lime used in the water treatment process and not the heat from the "slaking of lime"; instead, the device has to do with the heat required to produce a successful limelight in a magic lantern slide projector or a magic lantern spot-light. The device is a combination gas ratio tester and lime tester. The tester measured lime quality used for a limelight and the gas mixture ratio necessary to heat the quicklime.

An enormous project for the City of Cincinnati lasting 10 years at great cost was the New Water Works, which was under construction from 1898 to 1908. Often chosen was a public place for presentations describing the plans and details for the "New Works." Large audiences required an extraordinary light source to power the magic lantern slide projector. In addition, a magic lantern spotlight illuminated emergency nighttime repair work.

Retired Greater Cincinnati Water Works Electrical Engineer Paul Kraus once said, "For many years, the largest light bulb we had at the water works was 25 Watts." Consequently, the buildings for the "New Water Works" were built with large windows providing daylight for the workers. Nighttime work using light from a 25 Watt light bulb was a challenge and certainly not with enough lumens to power a magic lantern.

In the Limelight: To best understand our mystery is to study and understand the details associated with limelight. At a second glance the light is more complicated than I would have guessed.

Modern day digital projectors have roots with a candle as a light source for a magic lantern slide projector as seen in Figure 2. A candle placed behind a lens that focused the light into a beam of light could be used as a spotlight to illuminate large areas and as the light source for a slide projector.



Candle Powered Magic Lantern.
Fig. 2

Fig. 3

Over time, the light source evolved from a simple candle to an oil lamp, paraffin-oil lamp, limelight, electric arc, incandescent filament bulb, incandescent gas mantle, halogen bulb, cathode ray tube, LED and laser diodes.

The 19th century saw extensive use of the oxy-hydrogen limelight for theater spotlights and in magic lantern slide projectors. Discovered in the 1820s by Goldsworthy Gurney, limelight remained a significant light source for both the theater and outdoor lighting until the use of electric arc lighting.

Limelight using a small torch to heat the quicklime. Fig. 4

A flame from oxygen mixed with a volatile gas heated the surface of a cylinder or ball of calcium oxide, aka quicklime. The intense heat of this flame heated the calcium oxide to incandescence and produced a small spot of white-hot light shown in Figure 4, which became the source of an intense white light focused on the lantern slide by condenser lenses in Figures 5 and 6. The spot of white limelight was often used as a nighttime point source light to illuminate a surveyor's mark at a great distance, such as from hill-top to hill-top.

Bright white light was necessary for good projection but not easily achieved. Producing a flame near 1,300° C was critical to cause the desired white light. Otherwise, undesirable colors appeared as shown in Table 1.

Magic Lantern Limelight Spotlight
Fig. 5

Magic Lantern Slide Projector
Fig. 6

Flame Temp.°C	Observed Color
525	faint red
700	dark red
900	cherry red
1,100	dark yellow
1,200	bright yellow
1,300	white
1,400	blue white

Table 1

The Flame: The high flame temperature was originally generated by blowing oxygen through a wicked alcohol flame as shown in the Oxy-Calcium Spirit Jet in Figure 7.

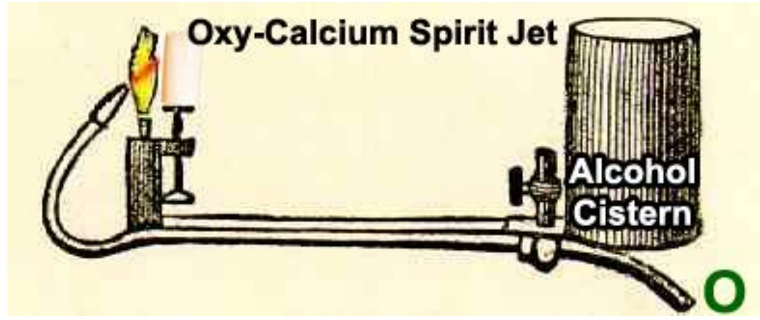


Fig. 7

Oxygen mixed with volatile gases, such as hydrogen, acetylene, coal gas, or ether provided a versatile selection to power a lime lighted magic lantern based on local supply.

An oxy-hydrogen flame requires a mixture of 1 to 2 respectively, while a flame from oxy-acetylene works best with a mixture of 1 to 1. Depending on the type of gas used with oxygen, the ratios were operator adjusted for the best white light performance.

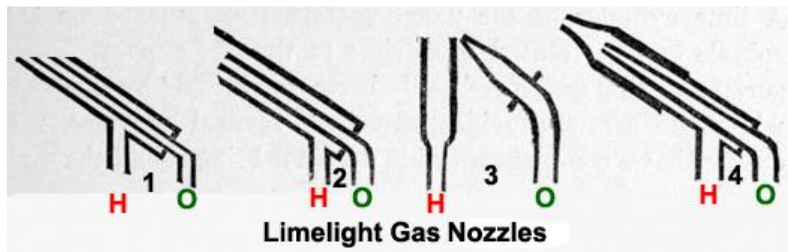


Fig. 8

Opinions differed on the best mixing jet for the two gases. An assortment of orifice configurations shown in Figure 8 illustrate the wide selection available to the limelight operator. Oxygen placed inside the hydrogen flame produced the hottest flame as shown in Examples 1, 2 and 4 in Figure 8 and Figure 9.

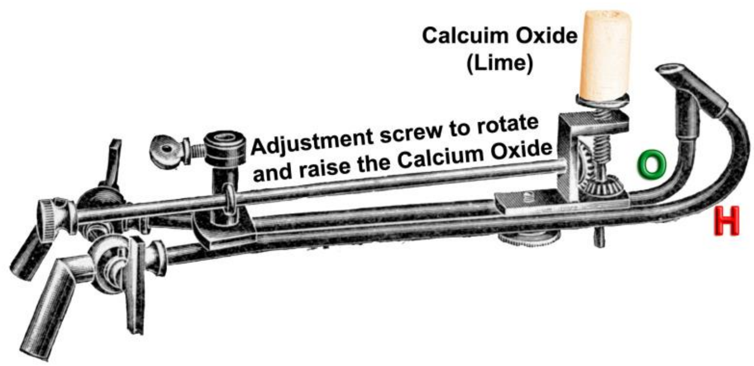


Fig. 9

A cylindrical slug of quicklime with a center-drilled hole was supported and burnt by a mechanism allowing for its rotation, its vertical height, and its distance from the flame.

Constant operator attention to adjustments assured the best burn condition existed. Often during a performance, the light would flicker as the operator struggled to maintain good adjustments.

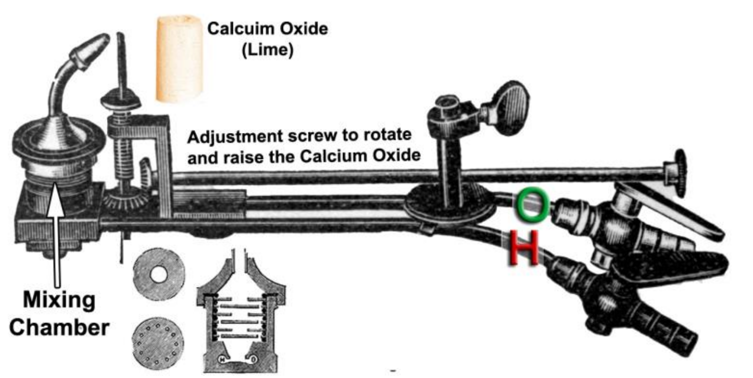


Fig. 10

A calcium oxide limelight, using an integrated mixing jet displayed in Figure 10, can produce an adequate flame heat by combining the two gases in a mixing chamber located directly below the burn orifice, and has the advantage of a simpler jet design.

The Limes: Storage details for limes were important because they required careful attention to maintain a dry environment. Even the slightest absorption of moisture into the cylinder of quicklime could cause an explosion when heated. Left exposed to the open air, calcium carbonate will deteriorate.

The center hole in the lime was not always accurately drilled, and tongs shown in Figure 11, were often used to make fine adjustments to its position. Metal near the lime was hot, and burns to the fingers occurred often.

A number of European companies made limes available shown in Figure 11.

Brass storage container for limes.

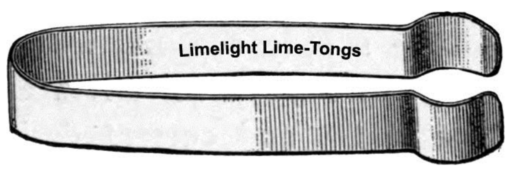


Fig. 11

The Fuel:

Oxygen gas was generated by heating potassium chlorate in an iron retort with manganese dioxide as a catalyst. Bubbling through water cleaned most of the gas before storage in a gasbag. See Figure 12.

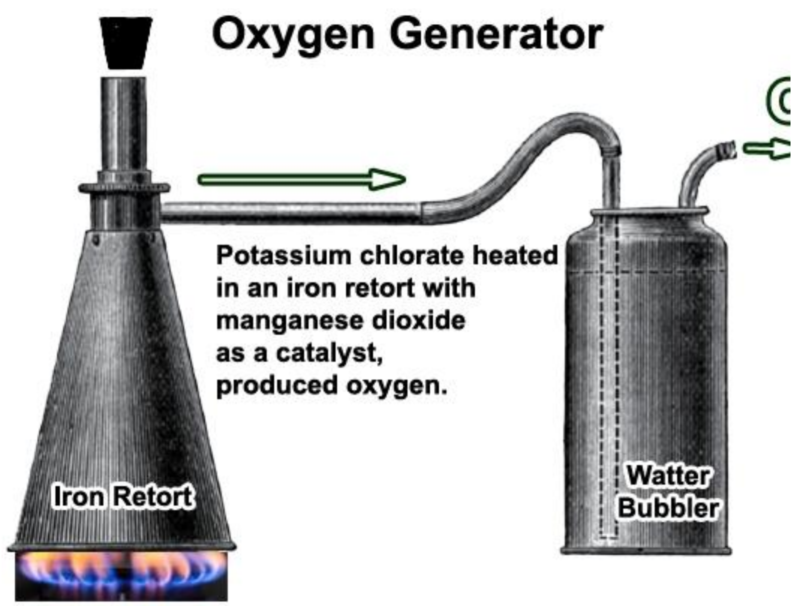


Fig. 12

Unfortunately, this process also produced chlorine that would destroy the rubber gasbags and caused a green deposit on the burn jets.

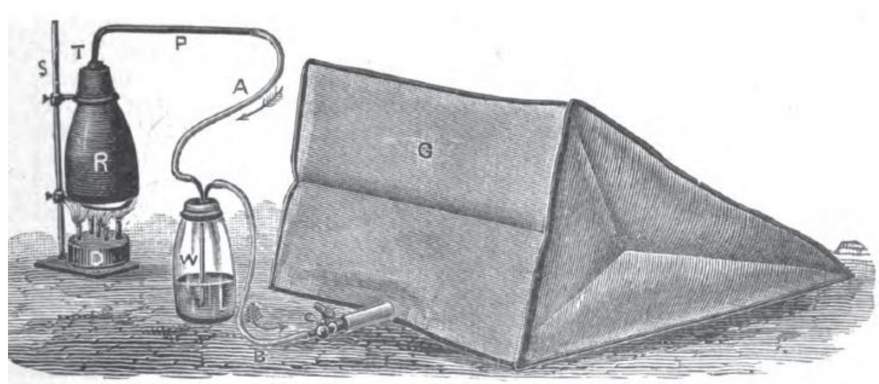
Between 1903 and 1907, a Paris professor, George Jaubert, invented Oxylithe, which is a form of sodium peroxide (Na_2O_2) or sodium dioxide (NaO_2). As it absorbs carbon dioxide, it emits oxygen and can be used as a rebreather for divers. When mixed with water, it will produce a healthy supply of oxygen to power a limelight. Perhaps familiar to some, Oxylithe was in the Sears Roebuck catalogue between 1905 and 1910.

In Figure 13 an ad displayed in a catalogue published in 1895 from the McIntosh Battery and Optical Co. for a Gas-Bag Oxygen Making Outfit boasts a price of $41.00.

The cost for the outfit depends on the index used for the calculation. For example, using the index from 2012, the relative worth of $41.00 is

$1,160.00	Consumer Price Index
$1,000.00	GDP deflator index
$5,400.00	Unskilled wage index
$8,830.00	Production Worker Compensation index
$9,430.00	nominal GDP per capita
$42,300.00	relative share of GDP index

THE "GAS-BAG OXYGEN MAKING" OUTFIT.



L. No. 137.

PRICE LIST.

1	Gas-Bag, 30x40x30	$25.00
1	Retort, sheet steel	6.00
1	Retort Stand	1.00
1	Alcohol Lamp or Bunsen burner	1.00
1	Wash Bottle	1.50
10	feet Rubber Tubing, @ 15c	1.50
1	pair Pressure Boards	5.00
		$41.00

Fig. 13, 1895 Ad, McIntosh Battery and Optical Co. Chicago, IL

Hydrogen: This gas we are most familiar with in the form of coal gas, which is not pure hydrogen but is a combination of hydrogen, methane, and other volatile hydrocarbons mixed with impurities. Coal gas was the primary source of gaseous fuel for the United States until the widespread adoption of natural gas during the 1940s and 1950s. Tapping into the local gas streetlight was an easy source to refill a hydrogen gasbag.

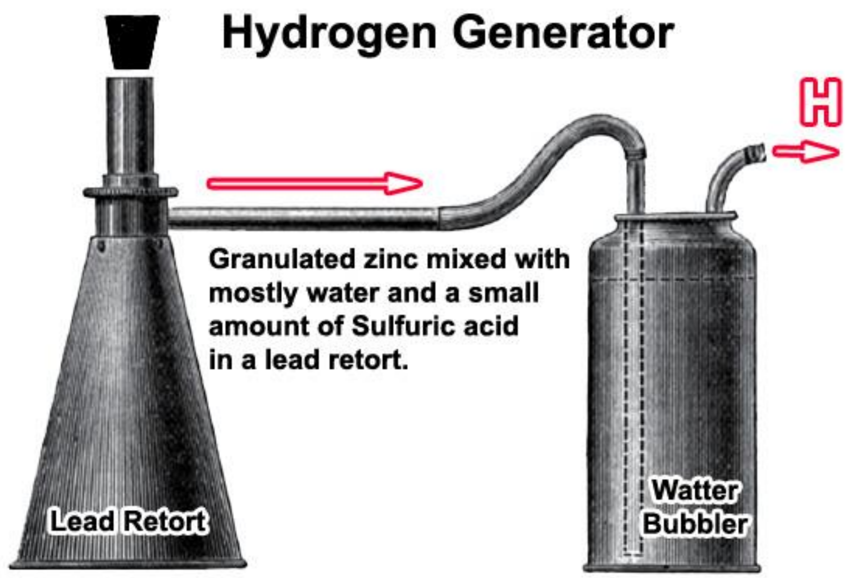


Fig. 14

Hydrogen gas could be made on site using a method similar to that of oxygen. Adding granulated zinc to a mixture of mostly water with a small amount of Sulfuric acid in an unheated lead retort produced hydrogen gas. The gas was then bubbled through water for some cleaning and into a gasbag for storage. See Figure 14.

Professor George Jaubert invented Hydrolithe (in addition to Oxylithe). The reaction of metallic calcium upon metallic salt produces a hydrate of calcium and, when mixed with water, produces hydrogen. Hydrolithe was often used for military ballooning because the small container size was ideal for battlefield conditions.

Acetylene is perhaps better known as carbide gas, or miners' gas, and could be used to replace hydrogen in a limelight but with a reduction in light output. Union Carbide Corp. provided calcium carbide packaged and available in tins shown in Figure 15. Water added to the Calcium carbide (CaC2) granules generates acetylene, which is an excellent gas for a miner's lamp and as a mixed gas in a limelight.

Water added to the Calcium carbide granules generates acetylene gas. Fig. 15

Correct gas pressure was a critical adjustment for producing a flame suited for heating limes. A weighted bag used to store and transport the gas worked well to control pressure as shown in Figure 16.

Since oxygen and acetylene are mixed at a ratio of 1 to 1, the two gasbags can be sandwiched between two pressure boards using a single weight as shown in Figure 18. Oxygen and hydrogen mix at a ratio of 1 to 2 respectively, thus requiring separate weighted bags as shown in Figure 16.

Fig. 16

Extended operation of a limelight may require more than one bag of gas, and an innovative refill method is shown in Figure 17. Note the connecting rod between the gasbag and the on–off lever for the compressed gas cylinder. As the bag empties, the connecting rod moves down, opening the gas valve and allowing a refill. Weights ranging from 56 pounds to 168 pounds cause a precalculated gas pressure for the limelight.

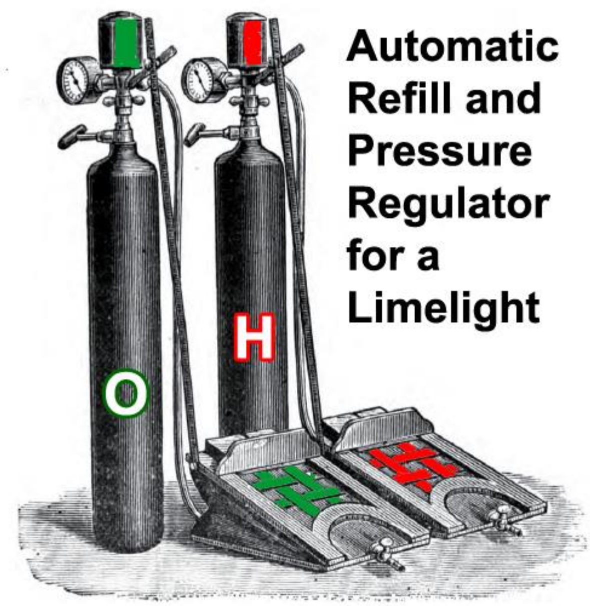


Fig. 17

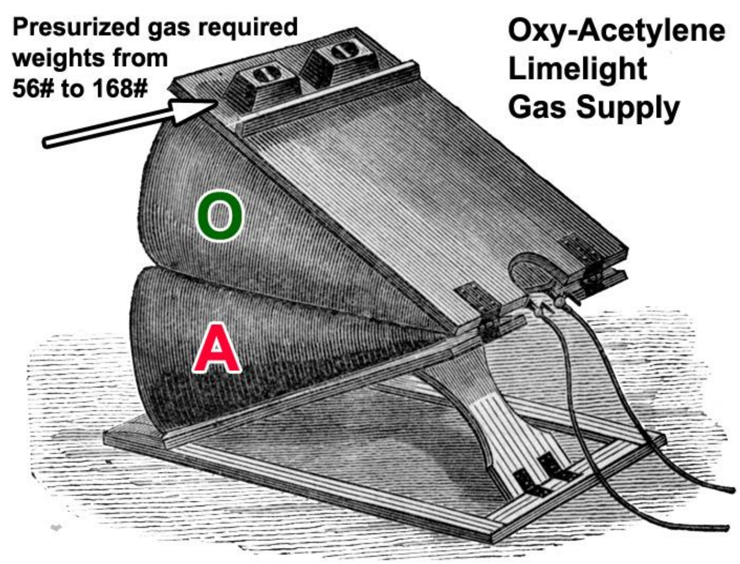


Fig. 18

A Multitasking Event: The limelight operator had to manage a multitude of issues to safely produce a white light for the projection screen, Figure 19, and not cause an accidental fire in the process. More than one theater burned to the ground from poor limelight management. The operator controlled the size of the flame, place of the flame on the lime, distance of the flame from the lime, the gas pressure, and the gas mixing ratio.

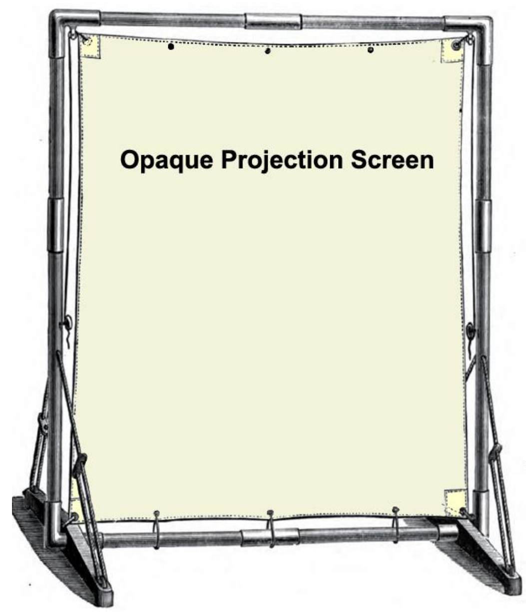


Fig. 19

Adjusting weights on a gasbag to regulate pressure was a pesky task that often required the handling of weights ranging from 56 to 168 pounds. When coal gas was the hydrogen supply, its purity varied day-to-day. Yesterday's ratio for an optimum burn may not work well today and required adjustment.

The hole through the center of the lime cylinder was not always drilled accurately and, when rotated in the holder, would cause an unnecessary change in brightness. Using lime tongs, the operator would make slight adjustments to correct the misalignment.

Challenges Ahead: As mentioned before, when oxygen and hydrogen mix to heat the lime, the best mixing ratio was 1 to 2, but it was 1 to 1 when using acetylene. The operator faced an extra challenge because of impurities in the gases.

For instance, coal gas has a number of other volatile gases besides hydrogen and varies in purity from batch to batch. The proper burn ratio for oxygen and hydrogen from coal gas could vary from the 1 to 2 ratio. Using this gas tester, the operator could predetermine the exact ratio for a given batch of coal gas when mixed with oxygen.

In addition, each batch of oxygen varied in purity. If a small amount of air was in the gasbag before filling with oxygen, the concentration could vary from bag to bag.

If these weren't enough variables to cause operator frustration, it turns out not all limes are equal. Quicklime directly from the kiln has driven off carbon dioxide from the limestone, thus making it quicklime. If, because of improper storage, the quicklime was in to humid air, moisture and carbon dioxide could be reabsorbed, causing the lime to burn differently than when it was completely dry. Explosions from a moist lime cylinder were not uncommon. Notice the lime safety shield displayed in Figure 37, in the appendix.

As you probably suspect, the task of operating a limelight was at best frustrating and at worst nearly impossible to get a consistent white light illumination. Many of these issues could be minimized if the operator knew in advance the lime quality and the best gas ratio to use. To predetermine the correct mixing ratio for a specific batch of gases and the condition for specific batch of limes, pretesting

Gas and Lime Testing: As the crank in Figure 21 rotated 5 times, it moved the pistons in Figure 20 from bottom to top, thereby causing each cylinder to inhale gas from its gasbag shown in Figure 24. (The small cylinder was for oxygen, and the larger cylinder was for hydrogen.) At the rear end of the geared shaft in Figure 21 was a small flywheel that attached a lever arm to the gas router as shown in Figure 22. After each cylinder had taken suction, the lever arm finished rotating the gas router into place for exhaling gas from each cylinder.

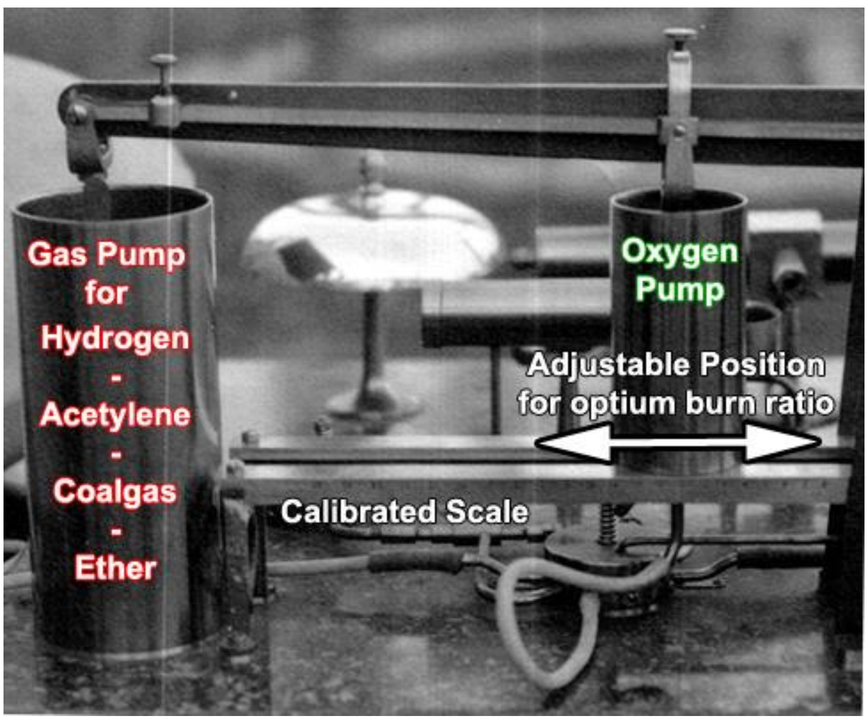
Another 5 turns of the crank caused each cylinder to exhaust its gas by moving its piston to the bottom of the cylinder. Shown in Figure 22, the gas valve piped the two gases to either the burn tray shown in Figure 25 or the burn Jets in Figure 26.

The burn jets provided a visual observation for the operator to decide the best flame quality. A burn tray held the lime sample under test.

If the burn was successful, the operator would calculate the amount of weight required for each gasbag to produce the best burn for that specific batch of limes and batch of gases. Calculations used the scale on the oxygen cylinder and the depth of the piston in the large cylinder using the scale shown in Fig. 29.

When the burn was unsatisfactory, the operator would adjust the mixing ratio by moving the oxygen cylinder along the horizontally calibrated scale and repeat the suction and discharge cycle.

You can look at the detailed mechanisms more carefully in the pictures that follow.

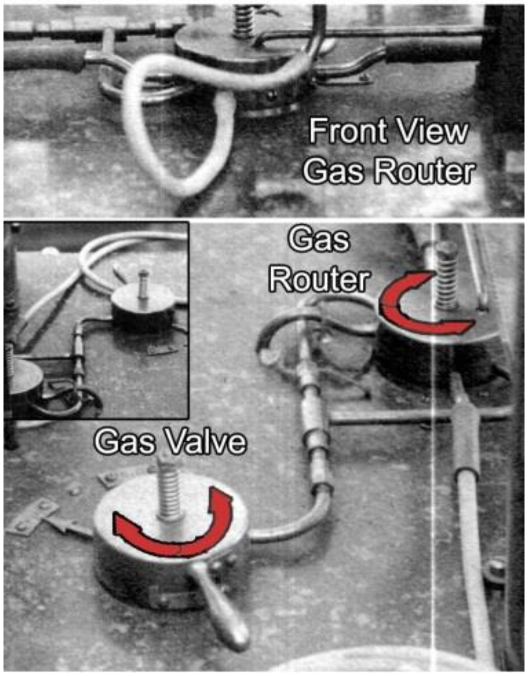


As the crank in Figure 21 rotated five times, it caused the pistons to move from the bottom to the top causing each cylinder to inhale from its respective gasbag (the small cylinder for oxygen and the larger cylinder for hydrogen).

Fig. 20

At the rear end of the geared shaft was a small flywheel that attached a lever arm to the gas router.

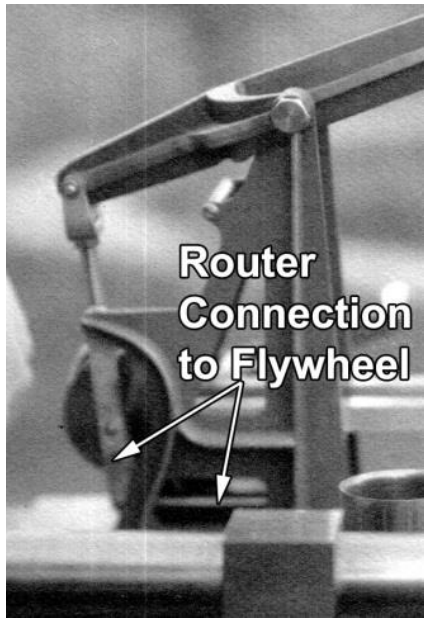
Fig. 21



The gas valve piped the gases to either the burn tray shown in Figure 25 or the burn jets in Figure 26.

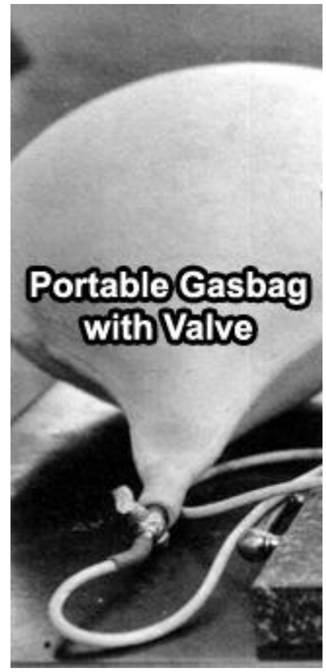
After each cylinder had taken suction, the lever arm finished rotating the gas router into place for exhaling gas from each cylinder.

Fig. 22



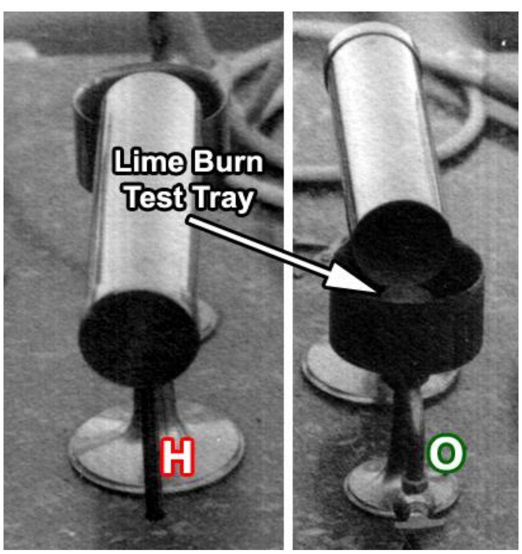
This lever arm connected to the gas router causing a change in the direction of gas flow to and from the cylinders.

Fig. 23



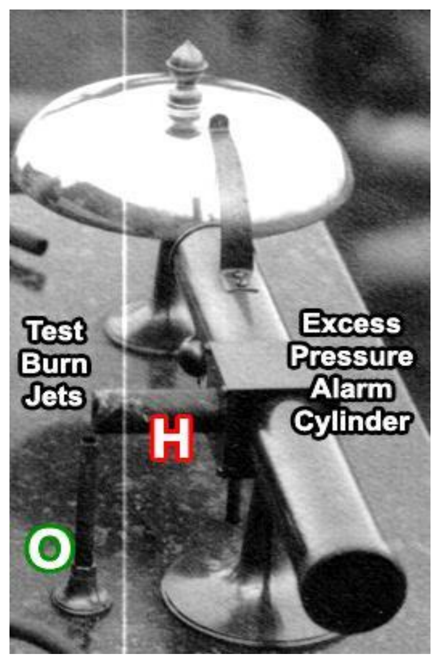
Portable Gasbags were equipped with valves.

Fig. 24



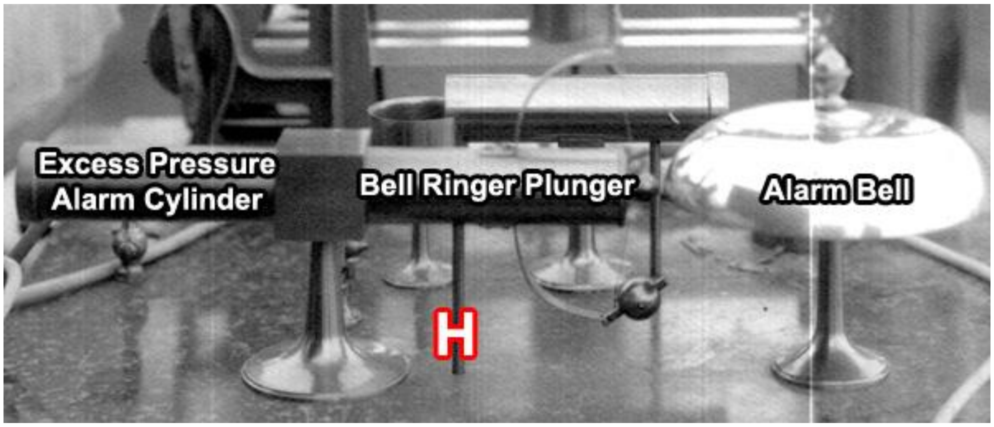
A burn tray held the lime sample under test.

Fig. 25



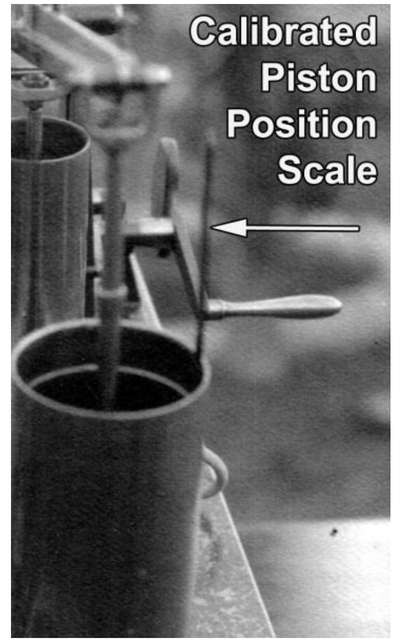
The burn jets provided as a visual observation for the quality of the flame.

Fig. 26



An explosive backfire condition could exist from an improper gas mixture. When that occurred, the operator would hear an alarm bell from the excess pressure cylinder.

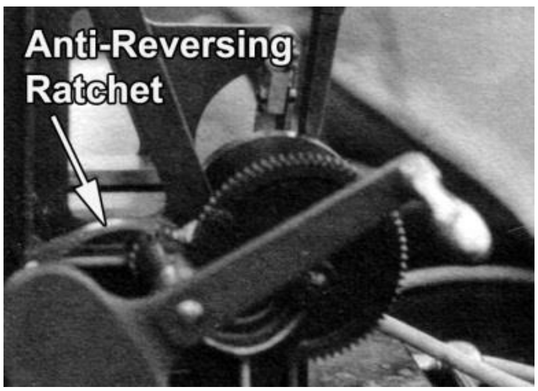
Fig. 27



Gasbag weight calculations for the best mixture used the position of the oxygen cylinder on its scale and the depth of the piston in the large cylinder using the scale shown.

Also, the dynamic range of the large cylinder piston could be adjusted to further accommodate a variety of mixing ratios.

Fig. 29



An anti-reversing ratchet prevented backward rotation of the crank that could accidentally cause inhaling of the flame back into the hydrogen chamber, thereby producing an unintended explosion.

Fig. 28

By the way, the irony to this discovery is that we just completed scanning several boxes of magic lantern glass slides made for the water works by L. B. Folger on Glenn Blvd. in Cincinnati. Little did I know the glass slides were connected to this mystery. See Figure 30.

A magic lantern glass slide made for the Cincinnati Water Works by L. B. Folger, Cincinnati, Ohio.

Fig. 30

Now deceased, I had the honor of meeting the last surviving licensed stationary steam engineer, Jim Hoctor, who operated the engines at River Station. One day Jim gave several of us a detailed explanation of how he operated the engines, and I asked him if he knew anything about this mystery device. He answered, “I heard someone say it has something to do with testing lime,” but he did not know any details.

At that time, Jim’s comment kicked off some research, but I incorrectly assumed he was referring to lime used in the water treatment process.

Both Jim Hoctor and Bill Reeves were correct with their comment about the mystery connection to lime. Bill added the keyword “heat,” and that led to unraveling the mystery.

Not dissimilar to the labor intensive effort required for steam engines to pump water in 1906 was the effort to successfully operate a magic lantern. It took many good people to accomplish what we can do today with the flip of a switch. This again demonstrates the extraordinary effort required by the Greater Cincinnati Water Works to ensure that an ample supply of safe water continued to flow.

Quite often, the water works would have a custom designed and manufactured apparatus to help their efforts to deliver high volumes of safe drinking water. I suspect, but have no proof, that this lime and gas tester may have been one of those special devices. I checked with The Magic Lantern Society of the United States and Canada and was not surprised when they indicated this device was unfamiliar to them.

Another Mystery:
We do not know the manufacturer for this tester or the location in Cincinnati for the 1902 photos.
If you have clues about the unanswered questions or further details regarding the device, I would be very interested in what you have to say. Please contact me through the CincinnatiTripleSteam.org website.

Acknowledgements:
A special thank you to all of you who have ventured a guess about the purpose for this mystery device. In particular, I want to thank Liz Vesper, Larry Moster, Bill Reeves and Paul Kraus for providing valuable insight to the surrounding details. I thank Matthew Maley from the Delhi Historical Society for facilitating the donation of their Power’s Cameragraph Model 6E Carbon Arc Light. Also, I thank Dr. Robert T. Rhode for his important help in editing this document. Check his site where you will find many fascinating books and eBooks, as well as several free documents to enjoy, including original sumi-e art.

Fig. 31, Front View

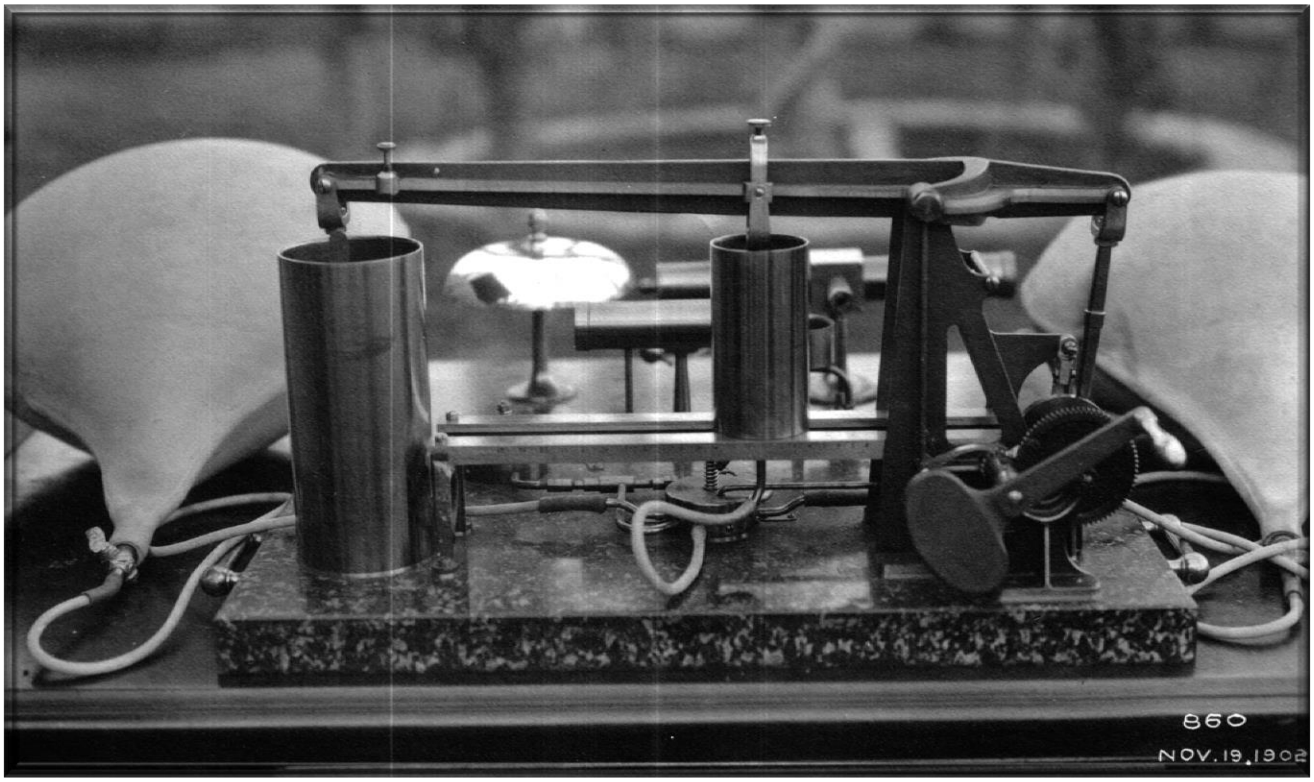


Fig. 32, Rear View

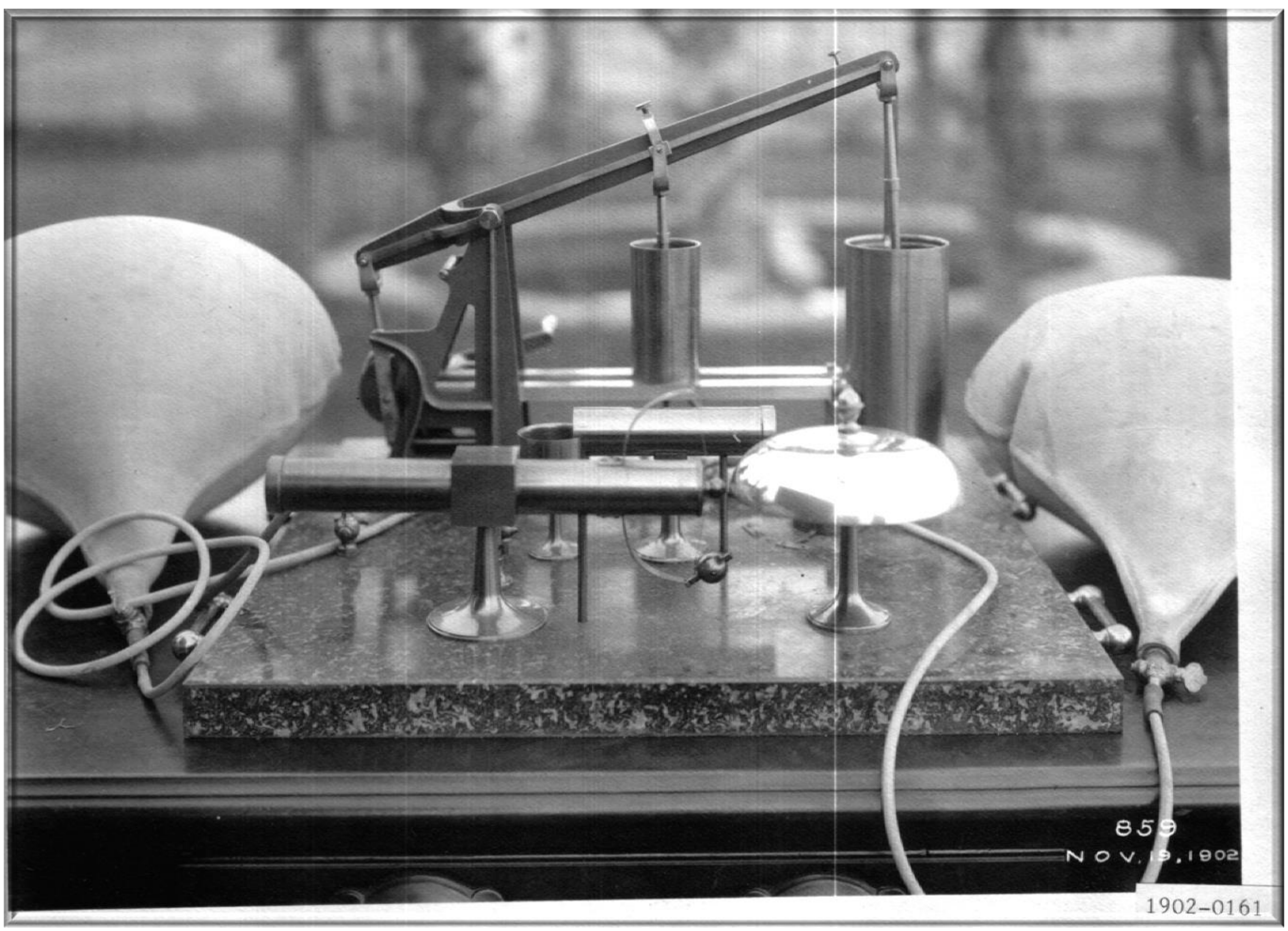


Fig. 33, Right Side View

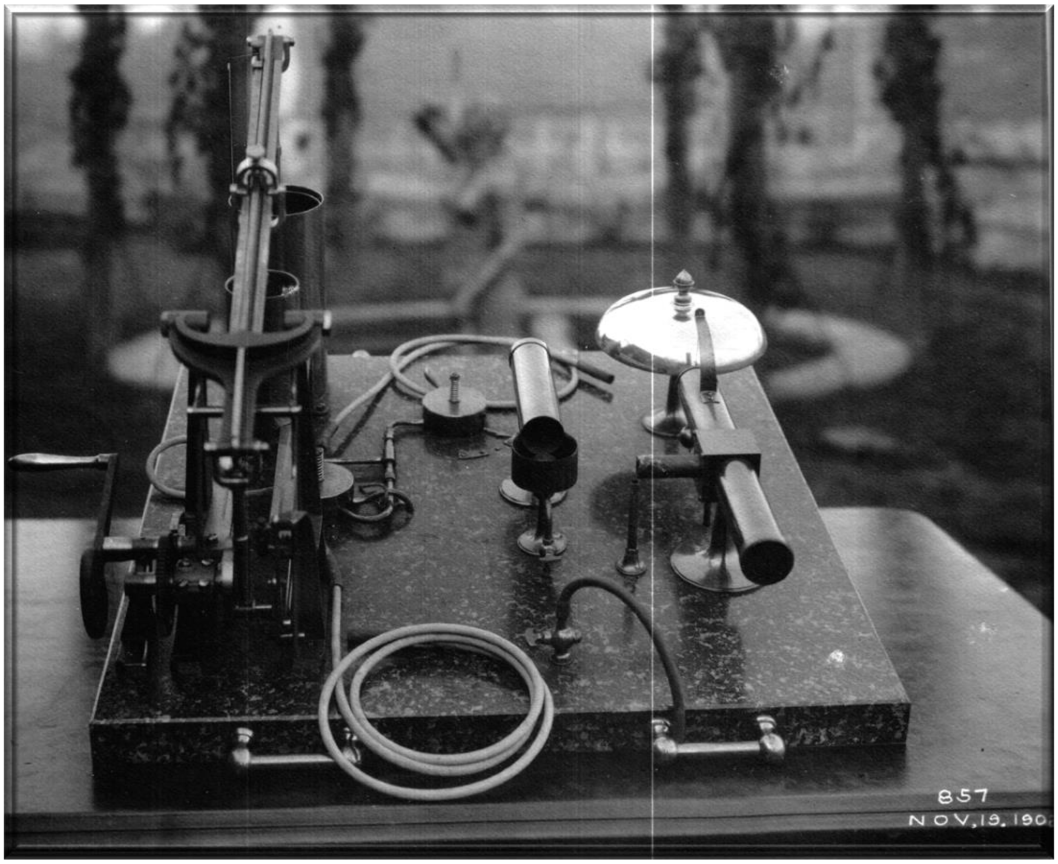
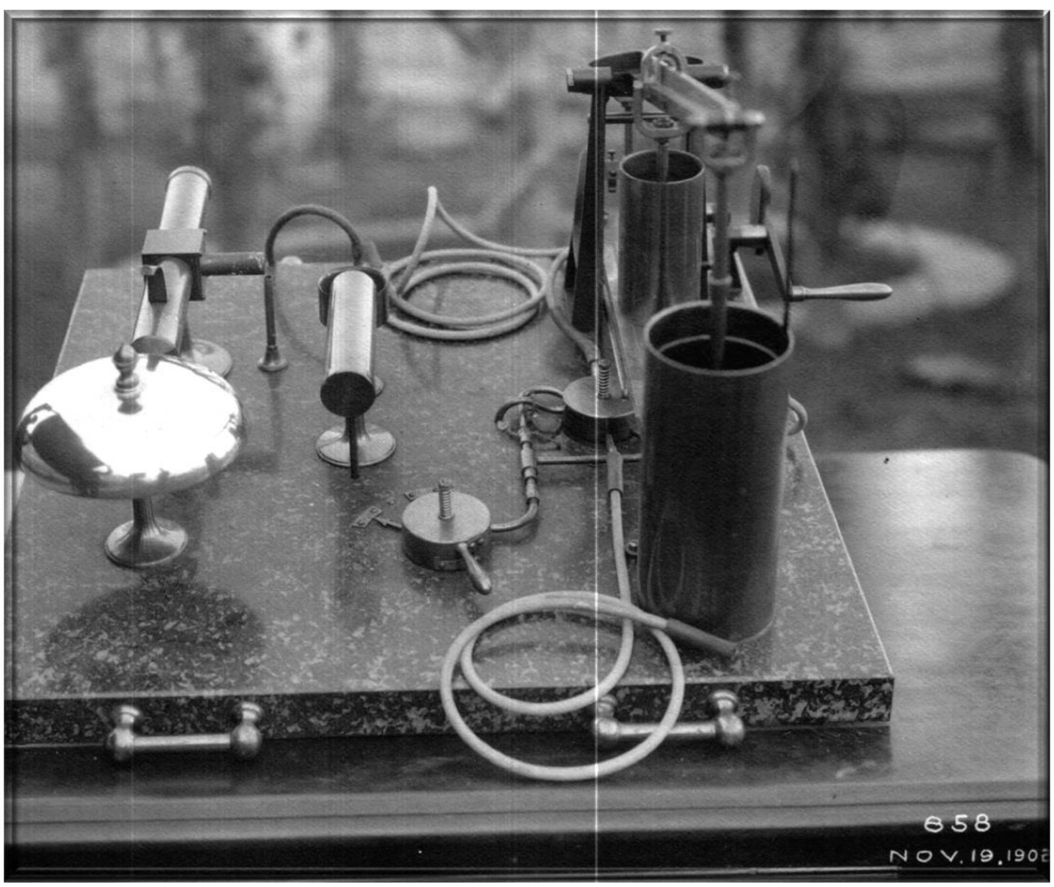


Fig. 34, Left Side View



Appendix

Fig. 35,
A gas limelight powers this
spotlight / work light.

Fig. 36, A typical lead weighted
gasbag used for a limelight.

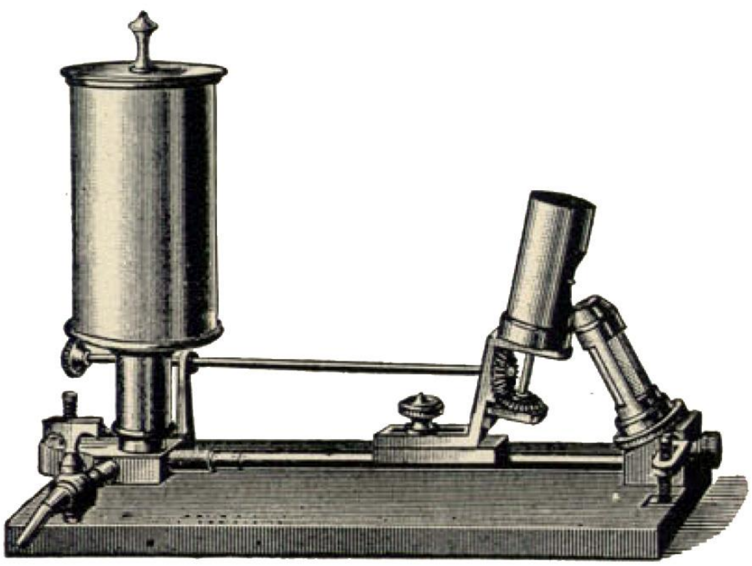


Fig. 37, An Oxy-Calcium Jet with onboard Oxygen generator
and a lime safety shield.

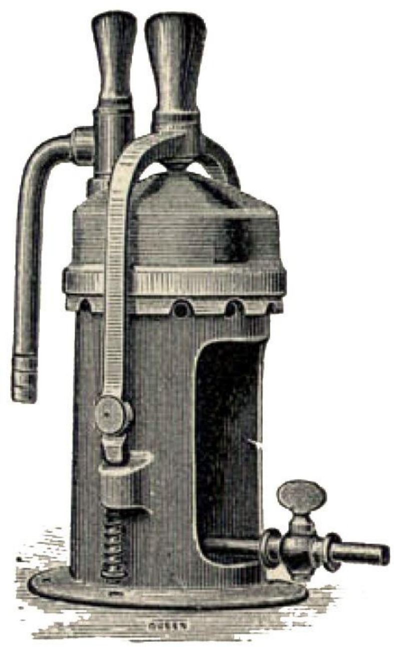


Fig. 38, An easy loading Iron Retort
used to make Oxygen.

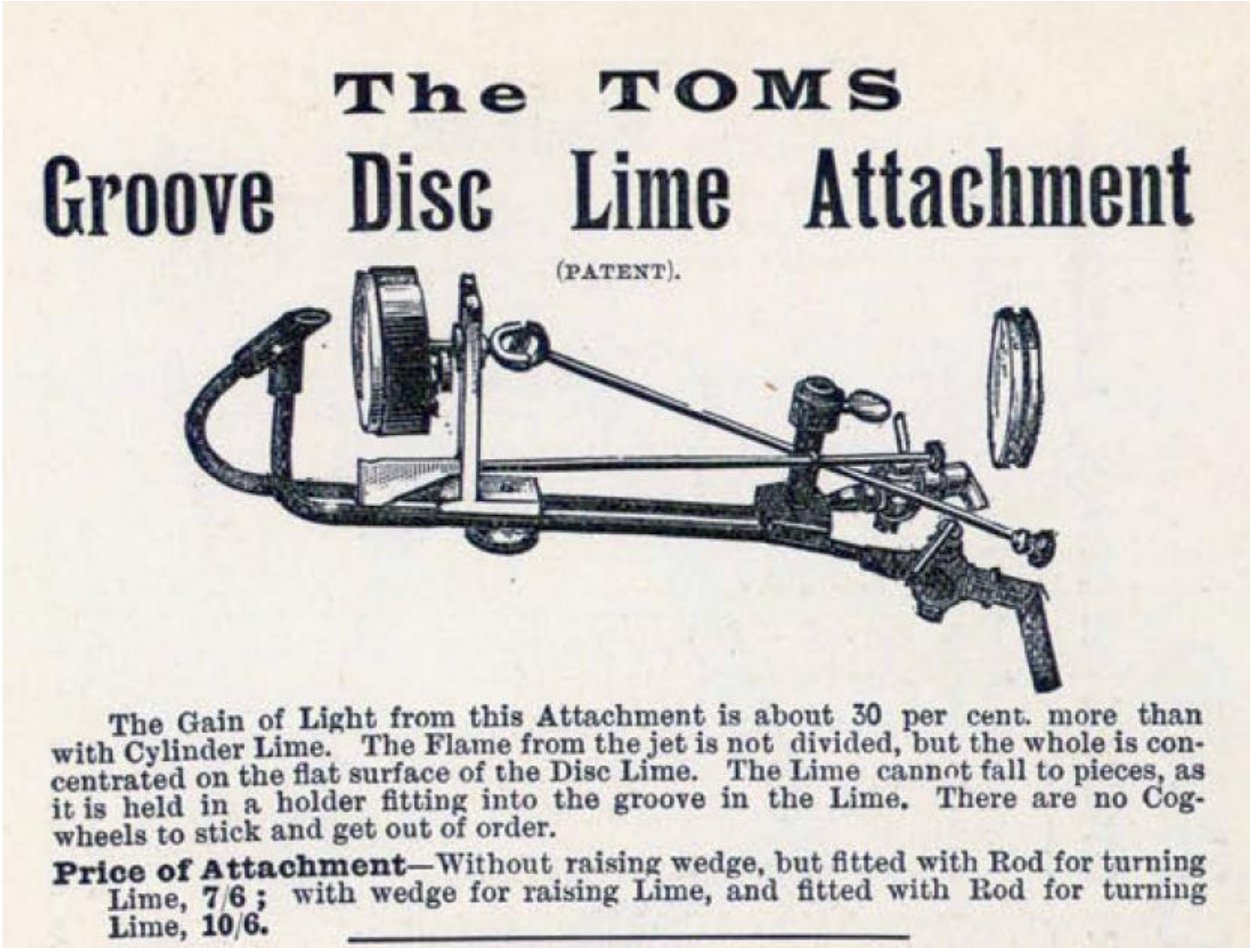


Fig. 38, A grooved-disk lime is more efficient compared to cylinder lime.

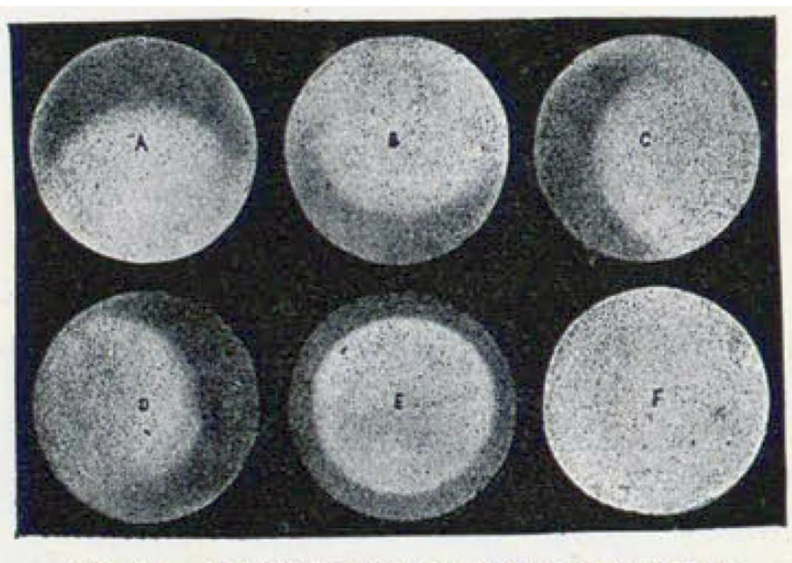
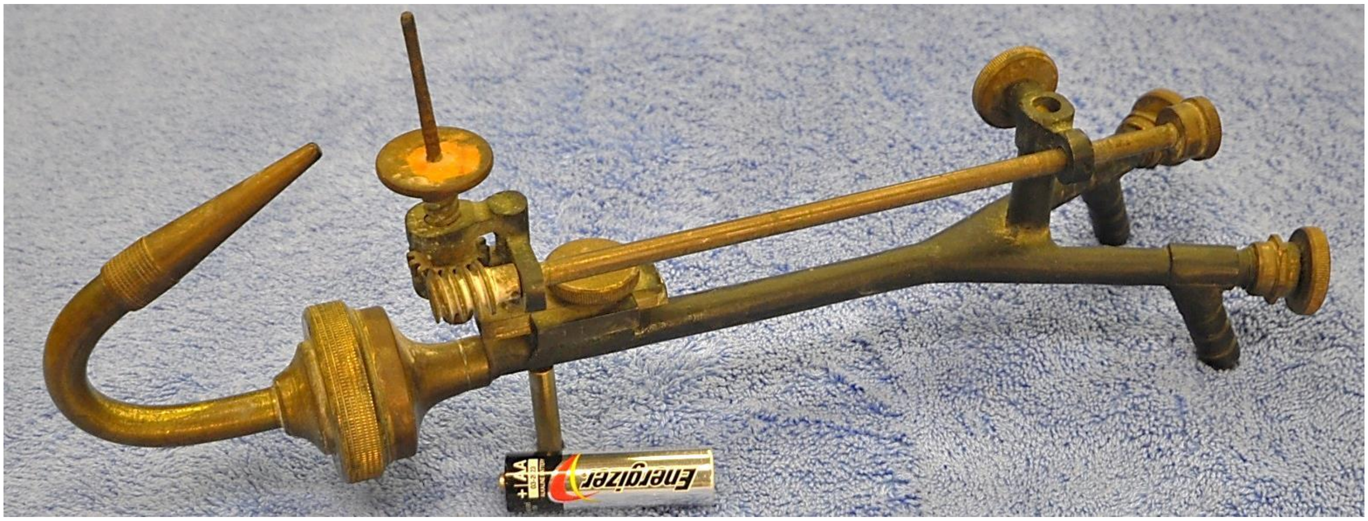


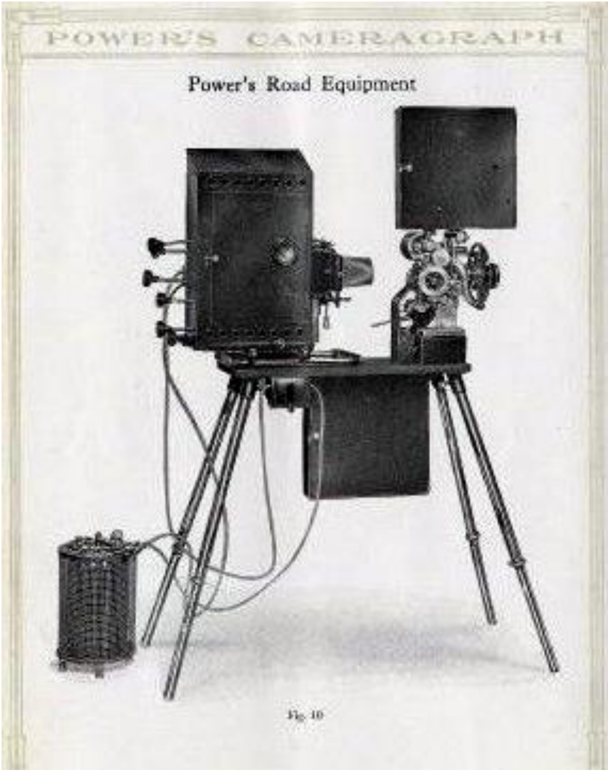
Fig. 59. PHOTOGRAPHS OF THE SCREEN WITH THE JET IN AND OUT OF POSITION.

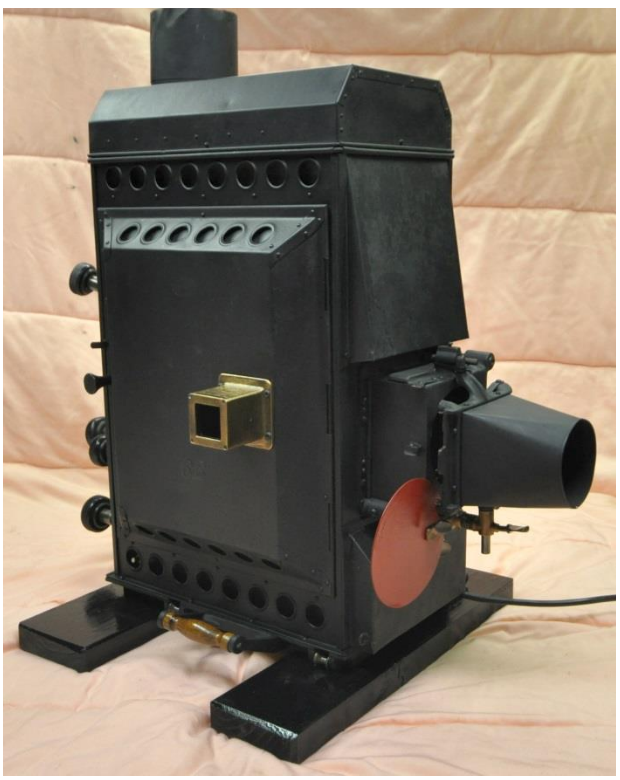
Fig. 40, Constant adjustment is required by the operator to maintain proper positioning of the flame for good lighting.

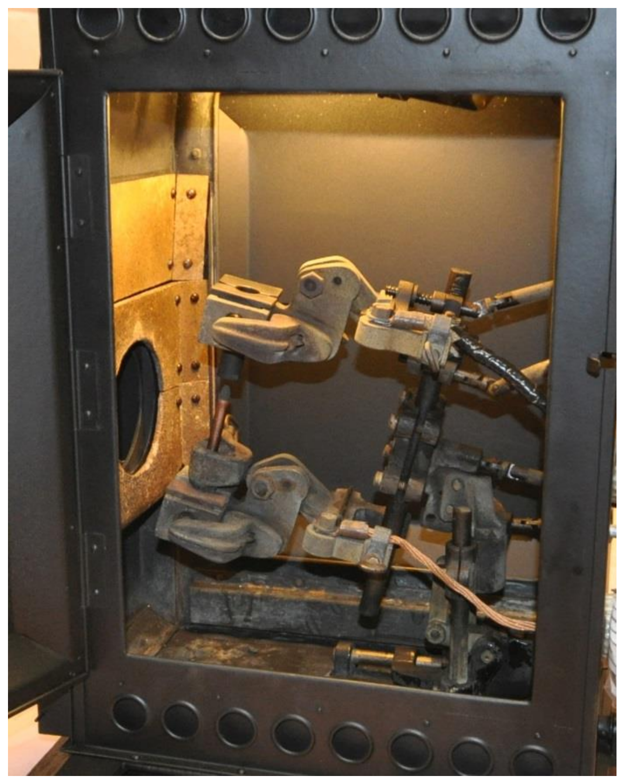
Images on this page are from a limelight mechanism owned by GCWW employee John Schlachter.



Carbon arc lighting replaced the limelight used in movie projectors. This Power's Cameragraph Model 6E Carbon Arc Light was donated courtesy the Delhi Historical Society. Pictures for the restored projector are below.







Disclaimer:

The opinions, the analysis, and the conclusions are mine alone and are not intended to reflect those of the Greater Cincinnati Water Works. I have stitched together research information, observations from photographs, circumstantial evidence, and experiences from my engineering background to draw conclusions that rely on guesswork. While I have made every effort to be accurate, indirect evidence without direct evidence can lead to wrong conclusions, and I could, of course, be wrong! I expect this document to remain fluid and undergo updates as additional information becomes available.

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