RELIGHTING THE LIMELIGHT

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In the 21st century the well-used term 'limelight' is redolent of a romantic age of breathtaking magical projection and theatrical entertainments in the 19th century. Books of that time on the uses and techniques of the magic lantern are full of both the apparatus and knowhow on its use and application. At that time limelight was the only way of getting sufficient quality of light for the professional lanternist. It made possible the transformation of the magic lantern from a small-scale entertainment or toy to an instrument of large-scale projection for large audiences prior to the electric arc lamp. Such was its profound impact that the very word has entered the English language and is still widely used today.

Using limelight as it was is now largely a lost art, and people are generally fearful of the risks involved in any lighting with inflammable gas. Many in Victorian times were used to handling gas lights and appliances in their daily lives. In fact the old 'town gas' (coal-generated) was largely hydrogen, piped into all homes and other premises. In the risk-averse age in which we live, playing with pipes, gas and naked flames is very much feared and frowned upon.

The principle of limelight is well known. When an intense pencil flame produced by burning a fuel gas with oxygen is directed onto a piece of lime (calcium oxide) it produces a bright white light. The lime itself does not burn, it glows much brighter than could be expected for the temperature, albeit high, to which it is raised. Practical techniques and precautions are well described in *Optical Projection* by Lewis Wright (Longmans, Green, 1891) which ran to four editions up to 1911.

Two main types of limelight burner or jet were marketed by all the main manufacturers (Fig. 1). The mixed jet combined the gases in a little chamber containing a flame arrestor below a single nozzle. The blow-through or safety jet had both gases brought up to the burner in separate pipes. This was the safer option. With the first, if the relative gas pressures were wrong, then oxygen could surreptitiously flow back into the hydrogen supply or vice versa turning the gas bag into a bomb. History tells of theatres destroyed and lives lost when this happened.

I was intrigued, having several lantern limelight burners (all safety blow-through types) in my collection, to get one working again and find out just how good and how bright the light was compared with modern illuminants. Before going into the practicalities of recreation, let's look at some more history and science.

According to Wikipedia and other sources the limelight effect was discovered in the 1820s by Goldsworthy Gurney. A Scottish engineer, Thomas Drummond, saw a demonstration of the lighting effect by Michael Faraday and realised that the light would be useful for surveying. Drummond built a working version in 1826, and such lamps are sometimes called Drummond lights after him. Lindsay Lambert in his 1991 *New Magic Lantern Journal* article[1] found that the earliest application to the lantern was at virtually the same time as its documented discovery by Drummond. Another excellent article to be found online is by Pierre Lauginie.[2]

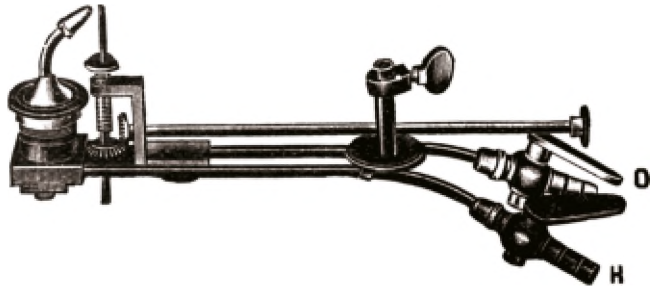
As recently as 2009 the Russian nuclear physicist, V.V. Kubarev did scientific research on how limelight really works.[3] This indicated that the lime 'turns on' at about 1,750°C producing light that defies the physics of ordinary black-body radiation, such as operates for an incandescent light bulb. His paper helpfully shows that the spectrum of limelight is very similar to the more familiar halogen lamp.

FINDING THE GAS AND THE LIME

On checking my selected limelight burner, I found that the gas taps still worked freely despite not having been used for maybe 120 years. The gearing mechanism that rotated the lime also still worked. So the first real problem was providing a suitable gas supply. The Victorian lanternists mostly used hydrogen and oxygen. Quite often these gases were made in their homes using dangerous chemicals. I did not fancy trying these potentially explosive methods. Storing gas as they did in devices like bellows (bags and boards) is also definitely a 'no-no' (Fig. 2). Gas pressure is also very important. This is relatively low but both gases have to be about the same. This is why the Victorians used the weights on double bellows gas bag devices.

I was fortunate in my education to have had some acquaintance with oxyacetylene for metalwork welding and I have a set in my engineering workshop. But acetylene is very unsuitable as a fuel for limelight. When the oxygen is low, it creates clouds of black soot that would pollute the inside of the lantern. When burning with oxygen the flame temperature is 3,480°C which is too hot as lime melts at about 2,700°C. In fact the oxygen-hydrogen flame is only slightly less at 3,200°C. Propane on the other hand is readily available and easy to use. The flame temperature is about 2,700°C and, in theory, hot enough, being over the critical 1,750°C, to get a lime to produce light by incandescence and (now debated) candoluminescence.

My oxygen comes in a highly pressurised cylinder from British Oxygen (BOC). The original company name was Brin's Oxygen and you can find Brin's advertisements in the back pages of many lantern books and the *Optical Magic Lantern Journal* – an historical source of supply still going strong. BOC also sell hydrogen but the cylinder rental is quite expensive and the gas needs a special regulator. In the old days town gas could often be used as a hydrogen substitute. But modern house gas is pure methane and probably not easy or legal to connect to a magic lantern. Propane, on the other hand, is easier to come by and a regulator can be 'borrowed' from a gas barbecue. Both the oxygen cylinder and that of the propane have modern pressure regulators fitted that greatly reduce the pressures going to the (still obtainable) red rubber pipes that feed the burner (Fig. 3).



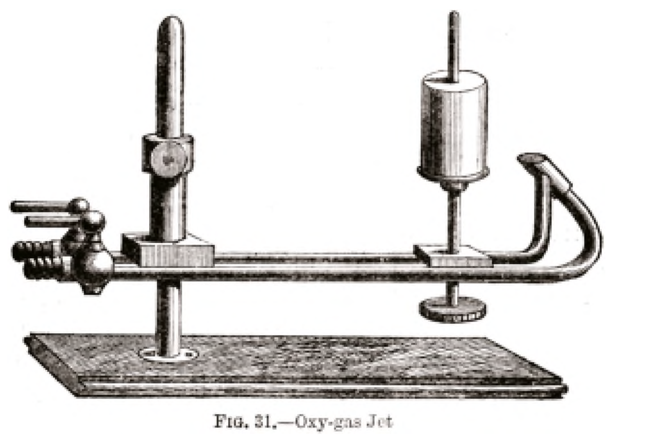


Fig. 31.—Oxy-gas Jet

1. (a) Mixed jet burner (above) and (b) blow-through safety burner (right)

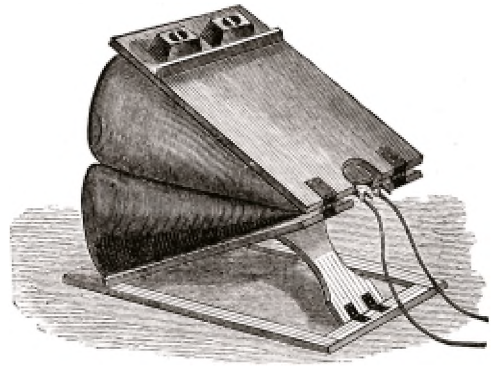


Fig. 33.—Double Boards

2. Lethal device for storing oxygen and hydrogen
3. Modern oxygen cylinder and regulator (right)

Lime as required for limelight is actually calcium oxide (CaO). This is a caustic unstable material which is why it was sometimes supplied to lanternists in an evacuated glass vial. Most 'limes' start off as a little cylinder, cut out from either limestone or marble – chemically this is calcium carbonate ($CaCO_3$). Once this is fitted in the lantern burner and initially heated to well to over 800°C (hot but not bright), the carbonate decomposes to calcium oxide. Then the lime is ready for a performance.

I did not want to use a genuine antique lime as heating would eventually destroy a museum piece. Luckily, some years ago I acquired some marble slabs from a stone yard that closed down. All that was needed was a circular cutter, as used by bathroom tap installers, suitable for drilling through stone. Ideally this should be done wet as it helps cool the blade and produces a better finish. With the help of an ordinary battery electric drill, a marble cylinder of the right sort of proportions was cut. The pilot hole produced down the centre of the cylinder is just what is needed for fitting it onto the limelight burner.

4. Homemade lime cylinder just cut from marble

5. Eroded lime after use

EXPERIMENTS

Because of the unknown and possible hazards, all the live tests were done outside on a yard patio. Naturally a fire extinguisher was near to hand as were thick gloves, goggles and other PPE. The first job was to mount the cut marble cylinder on the burner spindle and attach the red rubber tubing to spigots fitted at the outputs of the gas regulators. Then, with each gas in turn, I checked that there were no possible leaks and that all gas taps functioned correctly.

Next, with the burner in the open air, the propane gas (deputising for hydrogen) was turned on with no oxygen. The nozzle was lit with a modern gas lighter producing a gentle flame. When hydrogen burns in air, the flame is virtually colourless with no smoke or smell. With low gas pressure and in air only, propane burns with a yellow flame, similar to a candle, as a result of incomplete combustion, producing tiny particles of carbon which burn in the upper part of the yellow flame. This condition cannot be tolerated for long as the lime will start to soot up. Once the oxygen is introduced, the flame burns fiercer and the yellow disappears, turning blue. The relative gas pressures needed to be adjusted to get a steady blue pencil of flame, which was still a little unsteady at times. The tricky part is to adjust the distance of the lime to be at the cone of the flame where it is at its hottest. After some adjusting of pressure, distance and height of the lime – hey presto, we get the full limelight effect! To the eye the intense bead of light in the surface of the lime looks as bright as a halogen QI (quartz iodine/halogen) lamp. But no light meter was on hand on this first occasion to check the real luminous output. The observed colour of the light was tinted towards yellow rather than the pure white described in 19th-century literature – but they had never seen a white LED.

PROJECTING WITH LIMELIGHT

A large Newton mahogany single lantern was chosen for the next part of the experiment. This did not have any asbestos in the inner lining but did have a protective inner iron shield. To pre-check the optics, a 100W Celsun LED lamp was first put into the lantern and adjusted for an optimally bright projected focused image using a test slide and a modern screen about 15 feet (5m) away. The position of the lamp relative to the internal condenser lens was marked and measured so that the limelight could be substituted in the same set-up position. The lime flame centre was in the same place as the centre of the LED. The limelight burner simply slid in on the usual rails in the base of the lantern to achieve this setting. So with everything set up as before without a lantern, the gases were turned on and the lime began to glow brightly (Fig. 6). Some 3¼ inch slides were projected using a wooden slide carrier (Fig. 7). These seemed to project satisfactorily although the light did flicker slightly during the run. The pressures might not have been 'tuned' precisely or, being outdoors, there could have been a very slight breeze affecting the flame. The slides were quite cool as they came out of the lantern.

6. Limelight working in the lantern

7. Projecting with limelight

8. (a) Jane Conquest *by LED* *(b)* Jane Conquest *by limelight* *(c)* Jane Conquest *by quartz halogen*

Once the performance was finished – only six slides or so – the burner was shut down. Immediately the inner parts of the lantern were checked with a non-contact infrared thermometer. This only registered at most 68°C. With the ambient temperature being about 16°C, this was a modest temperature rise indeed. When I touched the condenser lens I found it was not hot at all, as one might have expected. All this was filmed and available to view online.[4]

A day or two later the lime on the burner was examined and found to be disintegrating. This phenomenon was well known by the old lanternists. The deterioration is caused by the fact that the lime, now converted to calcium oxide, is hygroscopic and absorbs water from the atmosphere, gradually converting to calcium hydroxide which then crumbles. If you leave it long enough, carbon dioxide from the air will eventually turn the lime back to calcium carbonate again in the form of a fine powder. Mabor 'limes' were sold with a claim that they lasted longer. This was because they were made of magnesium oxide and not conventional lime as I had used. The reason why the flame from the jet had been a little unsteady was found by microscopic examination. It seems that my burner jet was rough and quite uneven having been worn out by its previous Victorian owner.

A THIRD EXPERIMENT

Some while later another test was set up to test the light output compared with modern illuminants. As well as the original limelight with its burner cleaned up, we had the Celsun 100W LED and a 150W quartz halogen lamp running from 15 volts. A mobile phone app called 'Sensors Multitool' has a very useful light meter function to measure the relative brightness. This was placed at the screen location facing the beam. This best the limelight could manage was 174 lux whereas the QI lamp with optical reflector measured 630 lux. The LED beam looked much brighter because it contained far more blue than the other two and recorded 660 lux. This means the limelight looks about half the brightness of modern lamps. But, of course, it is much brighter than its candle and oil lamp predecessors. The photographs taken of these tests with a *Jane Conquest* slide (No. 4 of the set) give some idea of the relative colour using the three different illuminants (Fig. 8).

Using propane is reasonably safe and practical for a single lantern with modern cylinders and gas regulators. However, doing dissolves with a biunial would be very tricky. The main problem I could foresee is with using a gas dissolver tap. There are two tiny extra side taps to bleed gases to the burners, just like a pilot light on a gas cooker. Thus the flame is maintained alight on the 'off' lantern until it is needed. A hydrogen flame is colourless but propane without oxygen is not which would spoil the dissolve effect and soot the lime. This could be quite difficult to tackle. To perfect a single-handed triunial performance with limelight must have been as difficult as mastering a Stradivarius.

It would be a great challenge to try and do a complete show in the 21st century using only real limelight. However, I doubt any public facility could be persuaded to allow all the gas paraphernalia – we could always try the car park!

REFERENCES

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3. V.V. Kubarev, 'Features of the Drummond Light of Calcium Oxide', *Optics and Spectroscopy*, Vol.106, no.2, 2009
4. *www.youtube.com/watch?v=d_NUtRNZBRg* (also available in the *Past Events* section of the MLS website)