

***PROCEEDINGS***

THE SIXTY-THIRD ANNUAL

**SYMPOSIUM  
ON THE  
ART OF SCIENTIFIC  
GLASSBLOWING**

**2018**



THE  
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*The Sixty-third Annual*

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on the  
**Art of Scientific**  
**Glassblowing**

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# Papers



# ICEMAG: (The Interior Characterization of Europa using Magnetometry) Constructing Magnetometers for a Journey to Find Life on Europa

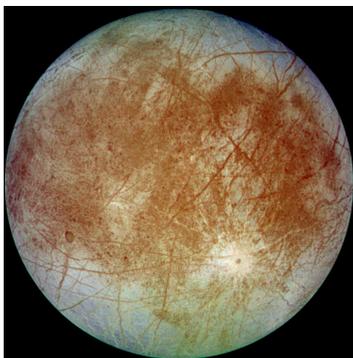
By  
Michael J. Souza\*

## ABSTRACT

*ICEMAG: The Flight Ready Process of Constructing Magnetometers for a Journey to Europa. The **Interior Characterization of Europa using Magnetometry (ICEMAG)** is a multi-frequency helium magnetometer made of aluminosilicate glass that will be flown on board the Europa Clipper mission to Jupiter's moon Europa. A glass cell filled with helium acts as a vector magnetometer that will be used for probing the subsurface and determining Europa's ocean depth, salinity, and ice shell thickness, as well as detecting erupting plume activity. The paper will discuss the mission outline and detail the certification process used by NASA and JPL.*

## INTRODUCTION

Perhaps one of the primary questions mankind faces is: *What other forms of life exist outside the confines of our planet?* Given the near infinite possibilities of our universe, the theoretical answer is that life is inevitable. However, the vastness of space makes empirical discovery difficult to prove. Nevertheless, scientists now have reason to believe that we may soon discover that life exists within our own Solar System. In an almost mystical coincidence, the source of this possible discovery comes from one of the Galilean moons of Jupiter. Four centuries ago, when Galileo used his telescope to gaze towards Jupiter and found four of the moons orbiting the giant planet, this incontrovertible evidence proved that the universe was not Earth centric and forever changed our civilization. Many historians believe that this historic moment established a place for scientific reason and methodology on which modern science and technology now stands.



## WHY EUROPA?

Europa is the 3rd moon closest to Jupiter and is about 3,160 kilometers (1,950 miles) in diameter, or about the size of Earth's moon. In late 2012, NASA's Hubble Space Telescope spotted what seemed to be 125-mile-high (200 kilometers) geysers of water vapor spewing from the poles of Europa.<sup>1</sup> (see Image 1) This was later confirmed by NASA's Galileo Jupiter probe. Could these geothermal vents provide heat and energy to sustain life? And what are those brown smudges?

**Image 1. Europa.** *This image or video was catalogued by Jet Propulsion Laboratory of the United States National Aeronautics and Space Administration (NASA) under Photo ID: PIA00502.*

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<sup>1</sup> <https://www.jpl.nasa.gov/news/news.php?release=2013-363>. Published December 12, 2013.

## CLIPPER MISSION & ICEMAG

On May 26, 2015, NASA announced the selection of ICEMAG and eight other investigations for the Europa mission's science payload for scientific instruments to fly onboard its planned Clipper spacecraft which would orbit Jupiter and conduct repeated close flybys of the small moon during a three-year period.

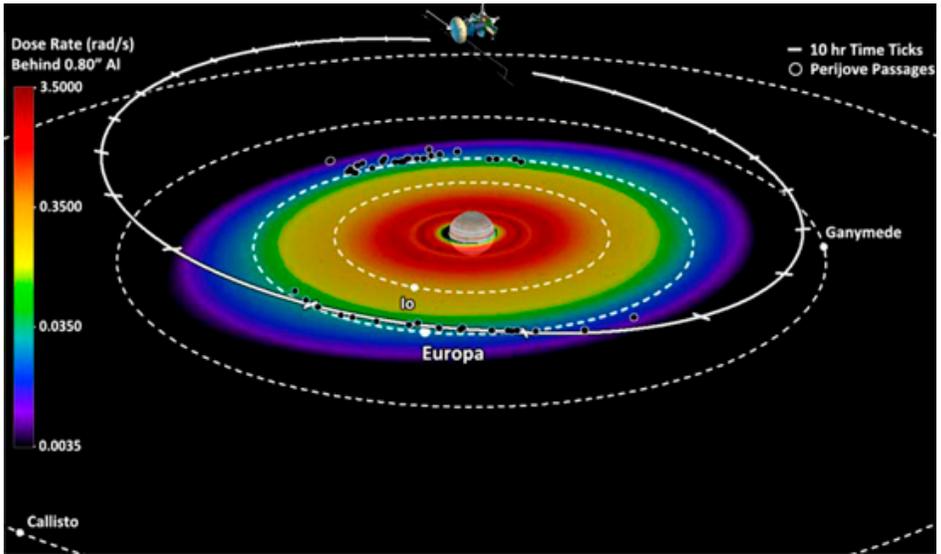
### SCIENTIFIC PAYLOAD

- **Plasma Instrument for Magnetic Sounding (PIMS)** - This instrument works in conjunction with a magnetometer and is key to determining Europa's ice shell thickness, ocean depth, and salinity by correcting the magnetic induction signal for plasma currents around Europa.
- **Interior Characterization of Europa using Magnetometry (ICEMAG)** - This magnetometer will measure the magnetic field near Europa and, in conjunction with the PIMS instrument, infer the location, thickness and salinity of Europa's subsurface ocean.
- **Mapping Imaging Spectrometer for Europa (MISE)** - This instrument will probe the composition of Europa, identifying and mapping the distributions of organics, salts, acid hydrates, water ice phases, and other materials to determine the habitability of Europa's ocean.
- **Europa Imaging System (EIS)** - The wide and narrow angle cameras on this instrument will map most of Europa at 50 meter (164 foot) resolution, and will provide images of areas of Europa's surface at up to 100 times higher resolution.
- **Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)** - This dual-frequency ice penetrating radar instrument is designed to characterize and sound Europa's icy crust from the near-surface to the ocean, revealing the hidden structure of Europa's ice shell and potential water within.
- **Europa Thermal Emission Imaging System (E-THEMIS)** - This "heat detector" will provide high spatial resolution, multi-spectral thermal imaging of Europa to help detect active sites, such as potential vents erupting plumes of water into space.
- **MASS Spectrometer for Planetary EXploration/Europa (MASPEX)** - This instrument will determine the composition of the surface and subsurface ocean by measuring Europa's extremely tenuous atmosphere and any surface material ejected into space.
- **Ultraviolet Spectrograph/Europa (UVS)** - This instrument will investigate the likely presence of water plumes erupting from Europa's surface. UVS will be able to detect small plumes and will provide valuable data about the composition and dynamics of the moon's rarefied atmosphere.
- **Surface Dust Mass Analyzer (SUDA)** - This instrument will measure the composition of small, solid particles ejected from Europa, providing the opportunity to directly sample the surface and potential plumes on low-altitude flybys.<sup>2</sup>

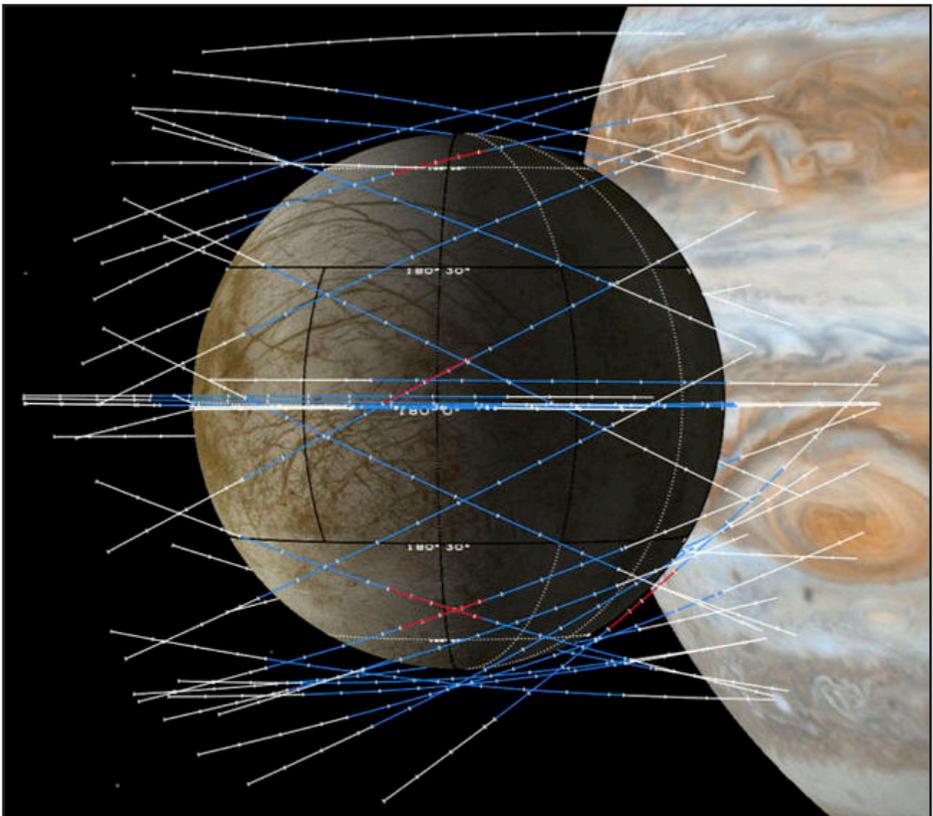
The Clipper will continuously orbit Jupiter to slingshot close to Europa at various depths and trajectories along the moon's surface. This will minimize the radiation exposure and provide a more complete geological study of the moon (Image 2). Each orbital by-pass takes two weeks. However, this will allow the spacecraft to conduct experiments close to Europa and then transmit its information data in high definition back to Earth. Adjustments to succeeding by-passes can then be programmed (Images 3 & 4).

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<sup>2</sup> <https://europa.nasa.gov/about-clipper/instruments/>. Accessed January 22, 2018.



**Image 2.** Radiation Map for Clipper Orbits<sup>3</sup>



**Image 3.** Orbital Mapping for Clipper Mission

<sup>3</sup> Courtesy of JPL/NASA. [https://commons.wikimedia.org/wiki/File:Europa\\_Clipper\\_orbit\\_away\\_from\\_Jupiter\\_radiation.jpg](https://commons.wikimedia.org/wiki/File:Europa_Clipper_orbit_away_from_Jupiter_radiation.jpg). 5 October, 2014, 21:22:13. Accessed: January 23, 2018.

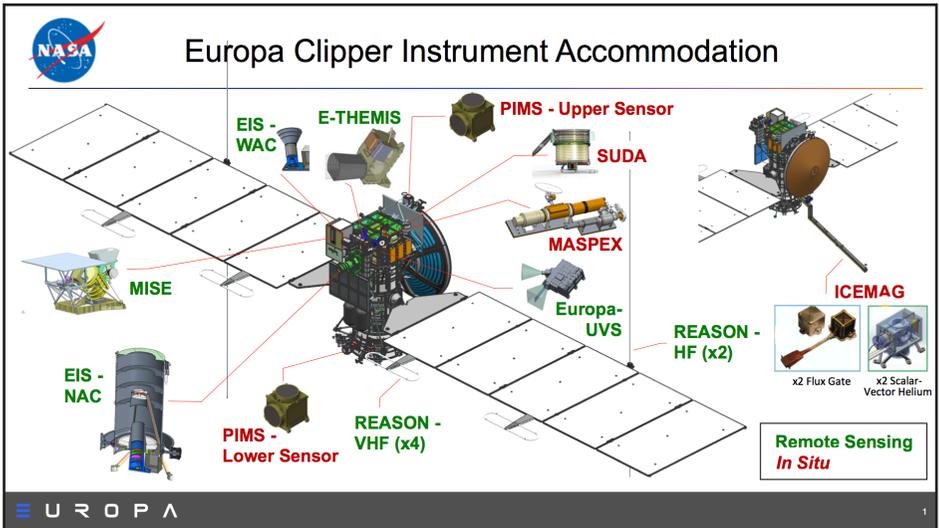


Image 4. Clipper Ship Configuration (Courtesy of Olivia Dawson at JPL)

## HELIUM VECTOR MAGNETOMETER

The heart of the ICEMAG experiment centers around a series of very simple glass cells, (19 mm o.d. x 32 mm long) containing pure helium gas. The cells are strung out on a tail-like boom at the rear of the spacecraft.<sup>4</sup> The principle is very similar to a typical compass. Whether you travel to California or New York City, it will always point north. The cell's helium atoms provide a highly sensitive and extremely precise compass that can measure the direction and the strength of magnetic fields around the spacecraft. This well-proven technology dates all the way back to 1958 when it was used on Sputnik 3.<sup>5</sup>

## CELL SPECIFICATIONS

NASA requires thorough certification of every part, every design and all of the revisions throughout the process for all of its projects. This process begins in earnest during a flight ready process as Project Leaders coordinate supply chains and design tests that evaluate performance and compliance to achieve the mission's highest standards. Early stages of the development began with scientist Dr. Neil Murphy at The Jet Propulsion Lab in Pasadena, CA who contacted the Glassblowing Facility at Princeton University due to the shop's familiarity with working aluminosilicate glass. Aluminosilicate glasses are relatively impermeable to helium.<sup>6</sup> Princeton's Atomic Physics Department is also world renowned in the field of Atomic Magnetometry and has established a spin-off company, Twinleaf, LLC,<sup>7</sup> that specializes in the development of small glass magnetometers.

<sup>4</sup> [http://www.lpi.usra.edu/opag/jul2013/presentations/Clipper\\_Summary.pdf](http://www.lpi.usra.edu/opag/jul2013/presentations/Clipper_Summary.pdf). 13 December 2013. Accessed January 25, 2018.

<sup>5</sup> Robert C. Snare, "History of Vector Magnetometers," Institute of Geophysics and Planetary Physics, UCLA. <http://www-ssc.igpp.ucla.edu/personnel/russell/ESS265/History.html>. Accessed January 20, 2018.

<sup>6</sup> V. O. Altemose, "Helium Diffusion through Glass," *Journal of Applied Physics* 32 (1961): 1309.

<sup>7</sup> Twinleaf, LLC was founded in 2007 as a result of patents developed for optical magnetic sensor at Princeton by co-inventor Tom Kornack. Twinleaf, LLC offers an innovative technique for measuring magnetic fields. It can be applied to a wide variety of applications.





Image 8. String manifold

## VACUUM BAKE-OUT

An UHV (ultra high vacuum) system using a turbo molecular pump, RGA (Residual Gas Analyzer) molecular getters, digital vacuum gauges with recording software and a top loading furnace is used to bake out the cells at 500°C for five days. Computer program software monitors and records the process and each bake-out graph is recorded and supplied to the JPL/NASA team (Image 9).

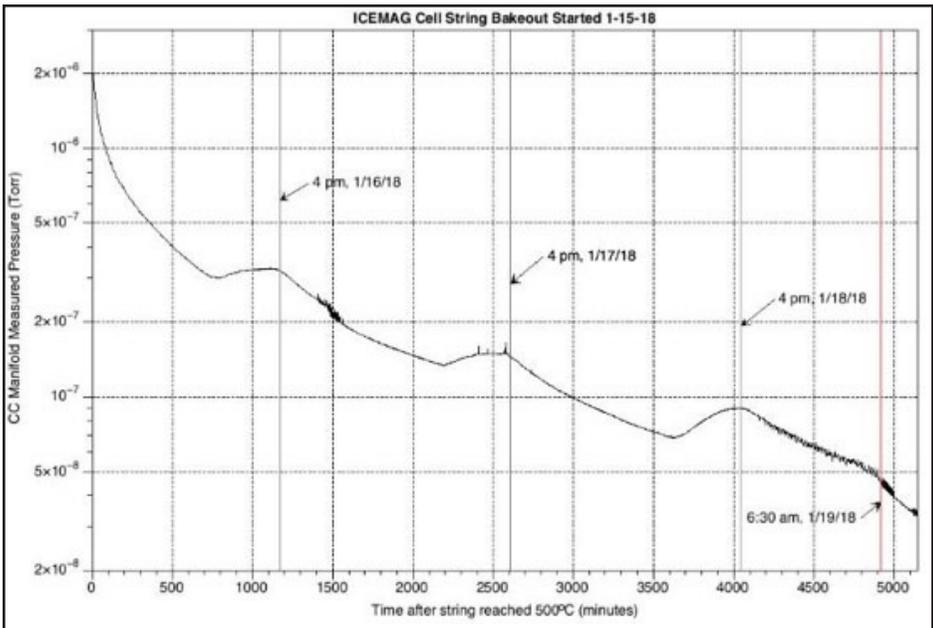
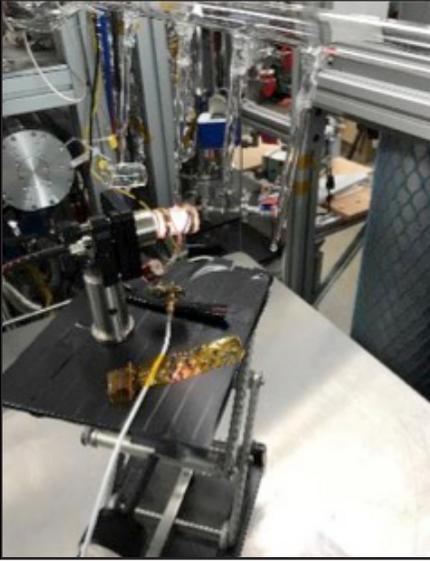


Image 9. Sample bake-out report, Twinleaf, LLC

## HELIUM GAS FILLING

Pure helium gas is run through a gas purifier, and the evacuated cells are filled at a partial pressure of 1-20 torr. Pickup coils are attached to the cell bodies, and an RF is applied causing the helium gas to form as plasma. The discharge produces a white pinkish light. Spectrophotometers measure the wavelengths of the light and a computer program records the spectrum in real time from the Twinleaf lab in Princeton, NJ to the team at the Jet Propulsion Lab in Pasadena, CA (Images 10 & 11 by Mike Souza).

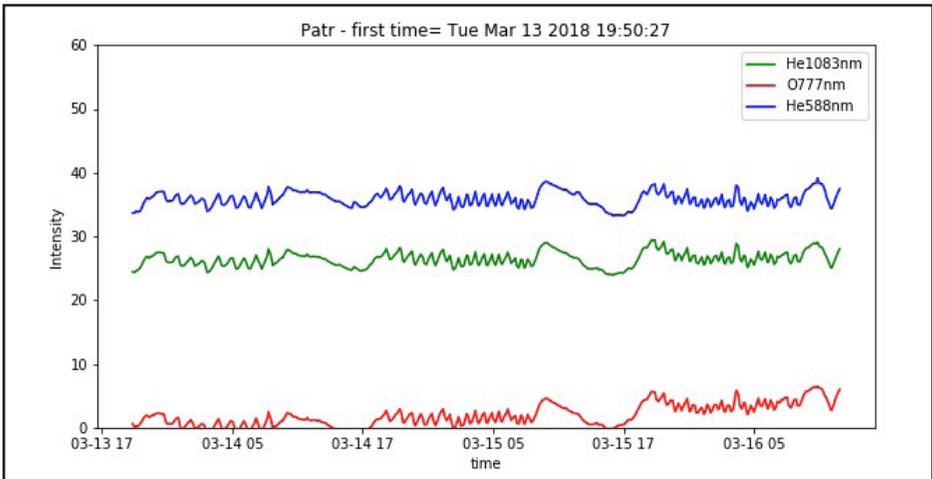


**Image 10.** Cell analyser



**Image 11.** Discharge close-up

Each cell is named and documented (See Images 12 to 14, by Twinleaf, LLC) so that JPL can monitor the process and evaluate every cell's performance on a daily basis. These measurements allow their team to continuously evaluate the progress and assure that optimum conditions have been achieved prior to the seal-off of the cells.



**Image 12.** Typical spectroscopy graphs for cell certification

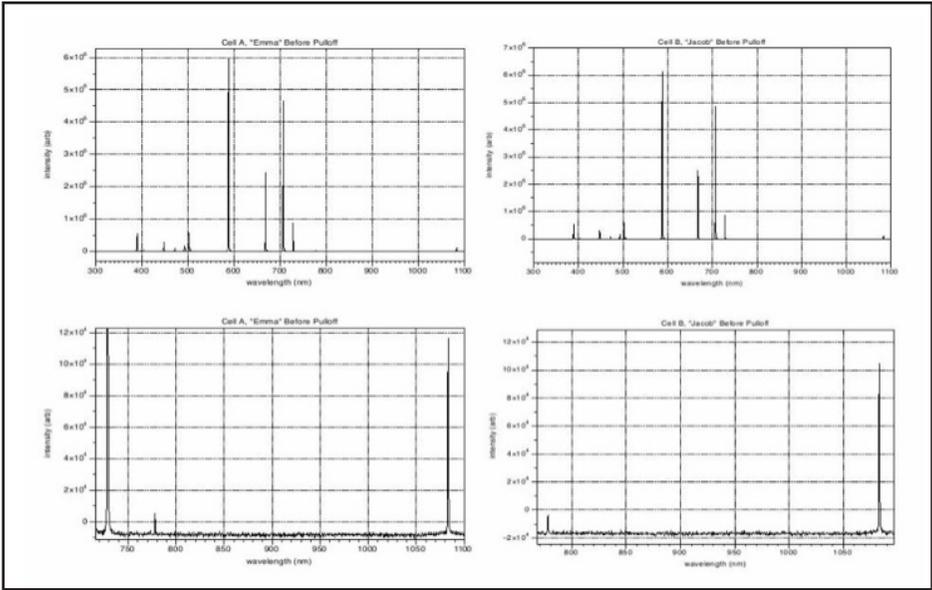


Image 13. Individual cell graphs prior to pull-offs

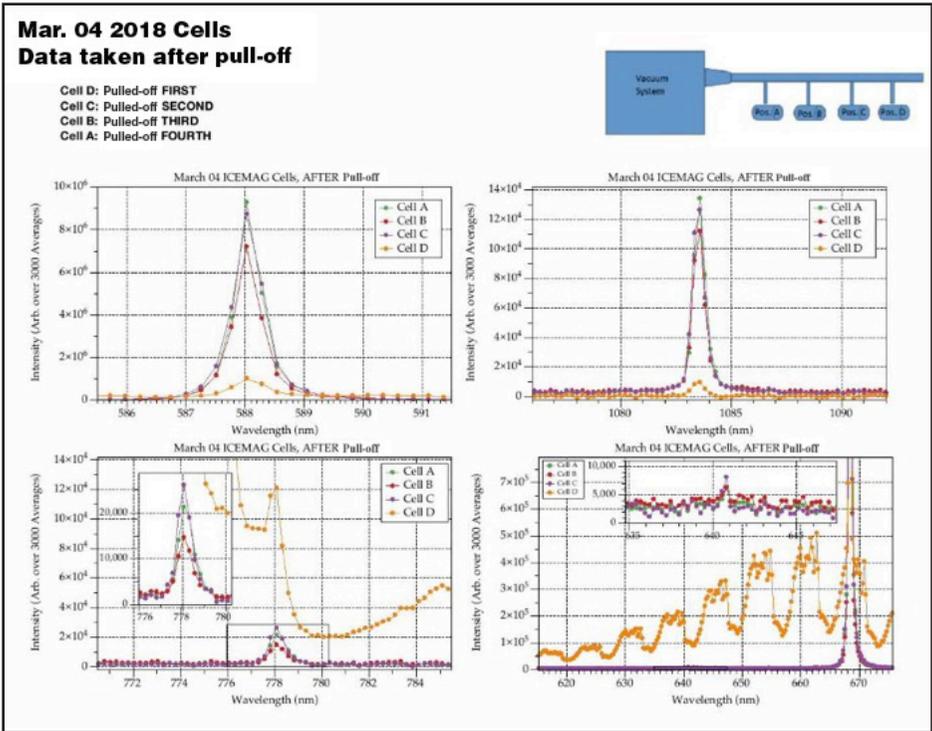
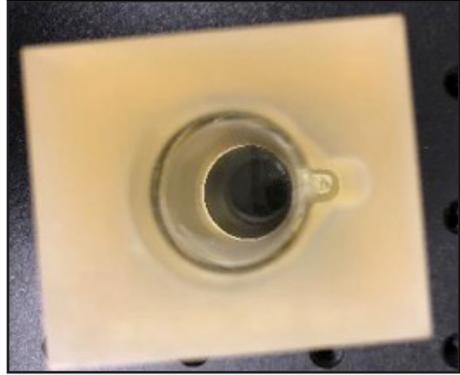


Image 14. Comparative graphs of cells from the string manifold post pull-off

Once a consensus has been made to seal-off the cells, the teams continue to monitor this process as each item is detached, a photo is taken of the filled cell under a polariscope to determine its strain intensity, and it is inserted into a gauge to assure that the pull-off



**Image 15.** *Strain certification*  
(Image by Mike Souza)

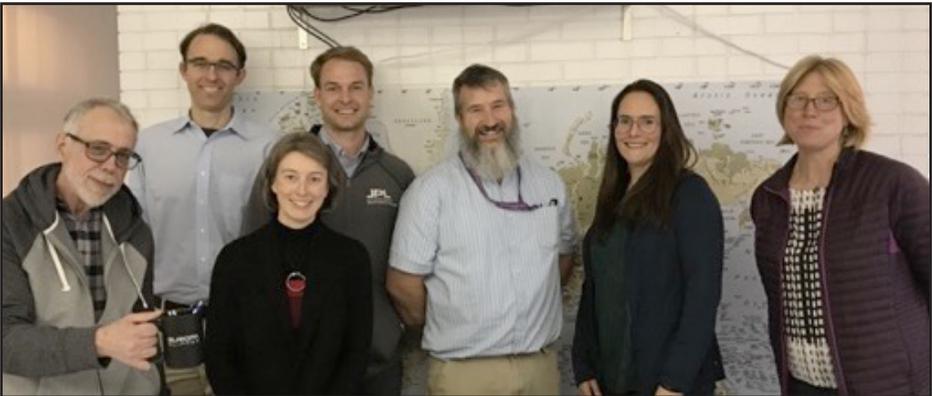


**Image 16.** *Foot space gauge assures that the height of the stem and the body of the cell is within dimensional tolerance*  
(Image by Mike Souza)

height is in compliance. Further spectroscopy measurements take place and documentation is provided.

## CONCLUSION

Outside of the aluminosilicate glass material and the technical difficulties presented in frameworiking this type of glass, the challenges faced in this project bring nothing very new to our field of interest. However, the certification process, the attention to detail and the use of real-time documentation has been enlightening. Though the process may appear burdensome, the stakes are quite high as space missions are costly. The series of experiments conducted on the Clipper Mission is set to launch in 2025. The spacecraft and cargo will roughly travel 400 million miles in the course of over eight years. The engineering feats have little room for error. The burden becomes trivial when you find yourself somewhat mythically connected to Galileo through a handmade glass instrument that you have been honored to make. Though I will be close to the age of 90 and may not live to see the completion of the experiments, it is a special honor to say, Bon Voyage...



**Image 17.** *ICEMAG Cell team*

(Left to right: Mike Souza (Princeton University), Tom Kornack (Twinleaf, LLC), Olivia Dawson (JPL/NASA), Dave Newby (Twinleaf, LLC), Lee Wigglesworth (JPL/NASA), Jill Foley (Twinleaf, LLC), Louise Hamlin, (JPL/NASA) (Courtesy of Twinleaf, LLC)

# Imagination of the Electrics

by  
Bryan Kekst Brown\*

## ABSTRACT

*At the 2017 ASGS Symposium, I participated in the making of a light bulb with Dan Davis, a scientific member. This experience has inspired more work and research related to electricity in the past year. The focus of this presentation will be the technical details of this project as well as some of the research and inspiration for exploring incandescence.*

At last year's 2017 Symposium, during the flame-off, I experimented with glass to metal seals in my first effort to create a source of incandescent light. This was also my first experience with The American Scientific Glassblowers Society. As an artistic member in the Society, I have come to admire the opportunity provided to artists to take part in an organization committed to the human technical understanding of this specific material, glass, and its uses. The function of this organization can be seen as a driving force within the process of human evolution. While I find artistic understanding far more elusive, I see the conversation that has occurred between these two disciplines throughout human history and the objects it has produced. This invitation to engage in this conversation is not taken lightly. I thoroughly enjoyed the experience of meeting everyone that I did last year, and I have gained information and perspective that has proven to be very valuable.

The experience of creating an object that converts electricity into light intrigued me and became a large part of the motivation for continued engagement with this project over the past year. The primary goal of this project is not to obtain quantitative data about incandescent bulbs. This exists to a degree that I am not capable of extending. Tangible experience of electricity, and phenomena such as incandescence, provide something far different. While engaged in this project, my research has focused on the history of understanding electricity in a tangible way as a supplement to my own technical explorations, continuing work started at the flame-off.

This event that took place at last year's Symposium is where the first attempt to make a light bulb was made. I was partnered with Dan Davis, who unfortunately was unable to come to the meeting this year. Dan is currently working for Phillips Healthcare in Hamburg, Germany. His work focuses on high voltage glass vacuum tubes for use in x-ray machines and



**Photo 1.** *Light bulb made with Dan Davis from ASGS Symposium 2017*

CT scanners. Some of the techniques he has been working with are glass to metal seals using Kovar and graded seals. I showed him some of the work I had been doing and some of the materials I had with me, and we split for some time to think about what we would be making (Photos 1 & 2).

Upon reconvening, Dan suggested that we make a light bulb. In retrospect, we did not quite have the proper materials. I had a small amount of platinum wire and some thin

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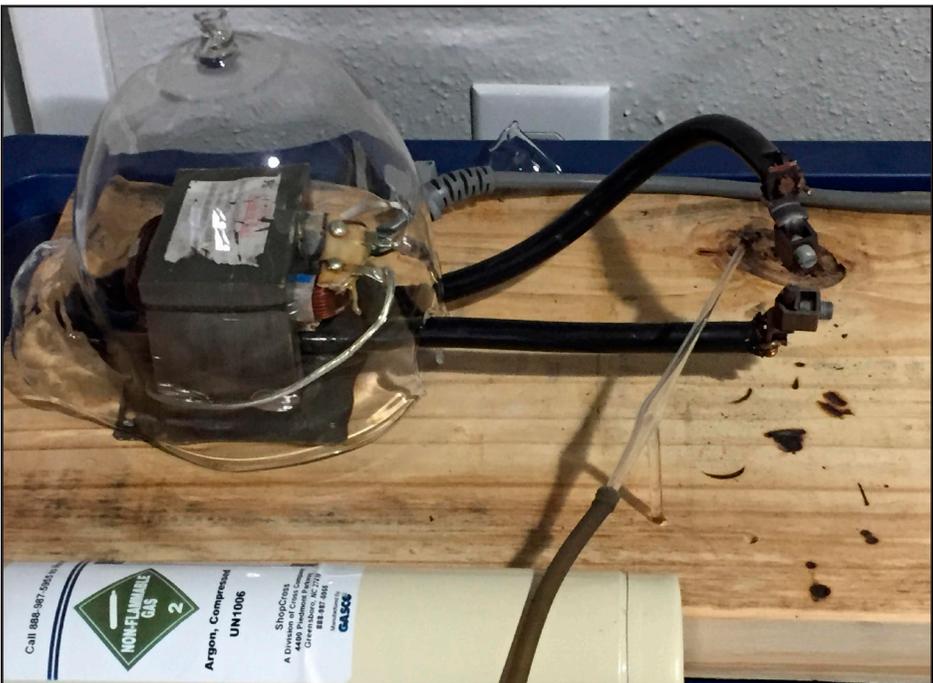
\*3747 Ridge Ave. Philadelphia, PA, 19132. Email: bryankekstbrown@gmail.com.



**Photo 2.** *Tungsten filament with uranium glass*

tungsten wire. We managed to find some uranium glass with which to make the seals and decided to use some of the graphite molds I had with me as the form. Tungsten was the metal of choice for the filament, but it was also acting as the lead wire. One light bulb was completed during the actual event. We were very fortunate to have the guidance of Bruce Suba and Roger Daniels, as well as their assistance in pumping the bulbs. The bulb was pumped and backfilled with neon. While this was an admirable attempt, I believe the lifespan of this bulb was about .5 seconds due to the filament and lead wires having the same amount of resistance and this wire having to operate in atmosphere. This number may seem less than ideal for an instrument designed to produce light, but the instrument itself seemed to contain some significance, or rather, the ability to use material to convert electricity into electric light. I came in the next morning to make another attempt to create this object. This attempt had a similar outcome. For a very short period of time, electric light was produced. This experience was certainly a highlight of my ASGS Symposium last year, and has been something I have thought about since.

Electricity is only perceptible in its effects. This quality caused the dissection of its nature to be quite a challenge as scientists and the curious began to notice its distinct properties. The period of time before the realization of the functional potential of electricity and its quantification has been fascinating to learn about. Since last year's Symposium, I have been engaged in a project that is a continuation of this attempt to create an object



**Photo 3.** *Spot welder made from microwave transformer*

that can convert electricity into light. I have been focused on viewing electricity as a visceral and tangible force rather than a quantity of the commodified force that keeps my fan running and my phone charged. The common understanding based on economics and function has created a distance from this critical understanding of a force upon which our bodies have been built. One goal of my exploration into incandescence is to create a tangible experience of electricity as a sensory object.

In September of last year, I was honored to have been invited to be an artist-in-residence at the University of Texas at Arlington. This program, led by Justin Ginsberg, seeks to acknowledge research and science within the context of art. I was invited to spend a week in the glass studio using their facilities to continue this study into objects that produce electric light. The goals for this time at UTAG were twofold: make progress on this issue of needing varying amounts of resistance in the materials used for the leads versus the filaments, and experiment with different materials for the filaments (Photo 3).

The glass department had just received an old Bethlehem Lathe from the science department that we were able to set up. There was some thin wall tubing available and I had brought various types and sizes of conductors to experiment with. Through the less than successful attempts made at the ASGS Symposium in 2017, I learned that I needed to have lead wires that could pass along the current without overheating and eventually failing. Part of my plans for this residency included using a microwave transformer to spot weld different types of metal to create a functional assembly for a light bulb. Through some trial and error, the combination of platinum and copper appeared to be the most stable weld with the limited material and equipment I had available. I set out with my plan to use platinum for the metal to glass seals, copper as an intermediary lead wire, and various types of conductors for the filaments. With the time available, I was able to create four bulbs. The filaments consisted of graphite, tungsten, titanium, and silver: graphite and tungsten because of their significance in the history of the development of the light bulb, and titanium and silver out of curiosity and my familiarity with the materials (Photos 4 & 5).



**Photo 4.** *Tungsten filament light bulb*



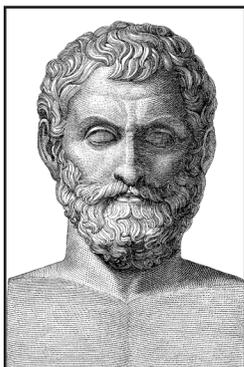
**Photo 5.** *Graphite filament light bulb*

The results of this time at UTAG proved to be more successful than the first attempt at making light bulbs. Two of the four bulbs had a life span of over 30 seconds. The first success consisted of a graphite rod for the filament, with copper lead wires spot welded to platinum and sealed into borosilicate glass with a uranium glass. Tungsten understandably produced success when used as the filament material, as this is the standard for modern

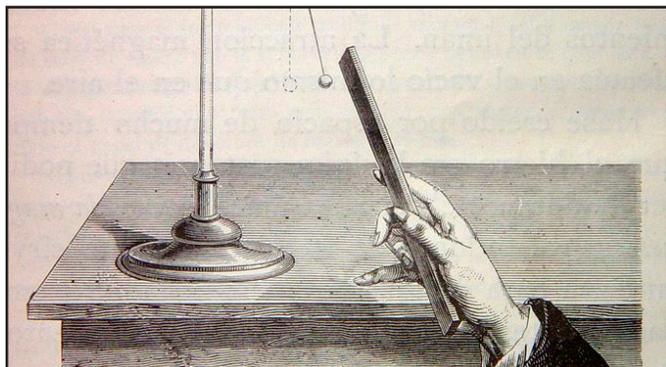
incandescent light bulbs. The tungsten filament was not the point of failure in this bulb; it lasted beyond my time at UTAG and only failed afterwards due to one of the welds breaking. The points of failure on the other two bulbs were the filament. Thin silver wire was far too delicate to produce much light due to its low melting point. Titanium wire proved to have too much resistance and very quickly became too hot and failed. The graphite was the most interesting bulb to me. It did incandesce, but also arced at the contacts between the copper and graphite. This object seemed to give a nod toward both the carbon filament incandescent bulb as well as the graphite arc lamps that were in use early on.

I find myself often looking backward in time to the history of certain materials and technology to understand how things have evolved into what I am trying to understand currently. The future of this project will include the refining of technique, aesthetic, and function. I plan to continue to work on a smaller scale and use the light bulbs as components in jewelry. My current artwork revolves around jewelry and adornment as a human behavior and method of assigning meaning to materials. While learning the technical skills necessary to make these bulbs, I inevitably began to research the history of the human relationship with electric light and electricity itself. In the rest of this paper, I will chronicle some of the ideas and moments in history that have stuck out to me while engaged in this research.

The earliest observation of any electrical effect can be attributed to Thales, the chief of the seven sages of Greece. According to ancient history, Thales detected and documented the existence of this “subtle fluid” around 600 BC.<sup>1</sup> He was the first to observe attraction as a distinguished property in amber, or in ancient Greek, elektron. The first scientific writing regarding what was known about electricity was titled *De Magnete* and written by William Gilbert in 1600. Although much of this writing turned out to fundamentally misunderstand the nature of this force, it did function to isolate electricity as a distinct force and scientific topic. The treatise contained “a great variety of electrical experiments... Gilbert imagined that electrical attraction was performed in the same manner as the attraction of cohesion.”<sup>2</sup> Electricity was viewed within the framework of the understanding of matter at that time,



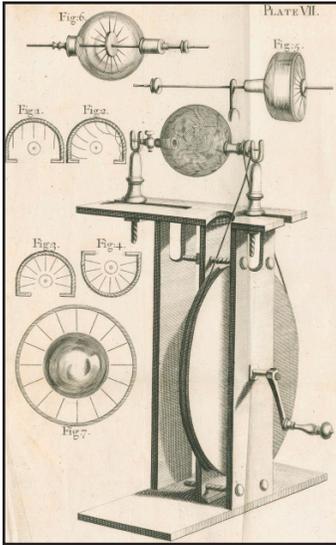
**Photo 6.** *Thales of Miletus*, Illustrerad världshistoria utgifven av E. Wallis. Volume I, 1875



**Photo 7.** *De Magnete*, William Gilbert, 1600

<sup>1</sup> Michael La Beaume, *Remarks on the History and Philosophy, But Particularly on the Efficacy of Electricity...*, 2nd edition (London: F. Warr, 1820): 29.

<sup>2</sup> Joseph Priestley, *The History and Present State of Electricity, with Original Experiments*. (London: C. Bathurst and T. Lowndes, 1775): 5.

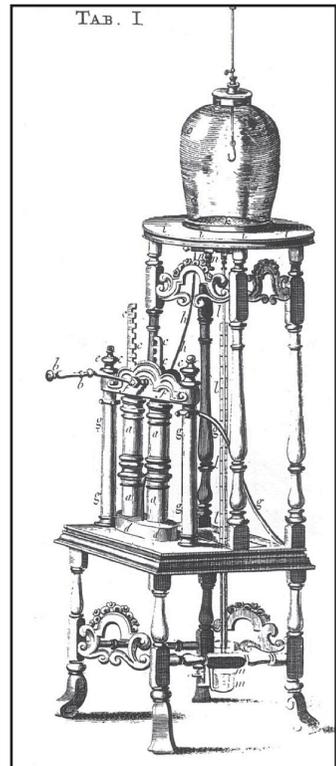


**Photo 8.** Francis Hauksbee's double-barreled air pump (1705), F. Hauksbee, *Physico-Mechanical Experiments*, 1709

which was based on Aristotelian concepts. The earth was seen to contain a succus or juice that manifested in moist exhalations drawn up from the earth by the sun, forming both the water and the air. This concept was applied to all matter. Dryness and moistness encompassed more than just relative degrees of humidity; it was a description of behavior, the tendency of material toward hardness and compaction versus that of dissolution and evaporation. This force that seemed to emanate from certain kinds of material certainly fit this understanding. This set the stage for electricity to be understood in terms of “varied airs, vapors, ethers, and effluvia”<sup>3</sup> (Photos 6 & 7).

This “pneumatic complexion”<sup>4</sup> of electricity remained the common understanding throughout the next century and a half. Around the turn of the century a

rather mysterious man, neither the date nor place of his birth is known, named Francis Hauksbee was working out of London as a demonstrator of experiments for the Royal Society.<sup>5</sup> His ability to engineer and develop new instruments and apparatus has significantly pushed the progress of science in many subjects. Glass maintained a prominent role in the two apparatus relevant to this discussion, one making the other possible. Hauksbee's vacuum pump was the technology that afforded him the ability to create his well-known electrostatic generator. Through friction, the evacuated globe was able to produce a light from within. This light was bright enough to read by, and this instrument allowed books to be read by electric light for the first time in human history.<sup>6</sup> The electrostatic machine gave the curious a method to produce static electricity on demand and the ability to experiment with electricity became far more accessible (Photos 8 & 9).



**Photo 9.** Electrostatic machine made by Francis Hauksbee, *Physico-mechanical Experiments on Various Subjects*, 1709

<sup>3</sup> Steven Connor, “Volts from the Blue,” *Cabinet Magazine*, Issue 21 (2006): 72.

<sup>4</sup> Connor, p. 72.

<sup>5</sup> Roderick W. Home. “Francis Hauksbee's Theory of Electricity,” *Archive for History of Exact Sciences*, 4, 3 (1967): 203–217. JSTOR, JSTOR, [www.jstor.org/stable/41133269](http://www.jstor.org/stable/41133269). Accessed May 4, 2018.

<sup>6</sup> David Herres, “Francis Hauksbee and Static Electricity Generation,” *Test & Measurement Tips*, 23 Jan. 2015, [www.testandmeasurementtips.com/hauksbee-generation-static-electricity/](http://www.testandmeasurementtips.com/hauksbee-generation-static-electricity/). Accessed May 15, 2018.

The 1740's proved to be an important decade in the development of thought regarding electricity. The notion of an electric atmosphere maintained its place in the perception of electrics. Albrecht von Haller, in 1745, published an account detailing that this atmosphere, when produced from very large globes, extended itself four or five feet in circumference, visible through its physical effect on gold leaf. Haller also reported on a distinction made by Georg Bose between "the *male fire* which is attended with crackling, and has considerable force, and the *female fire*, which is a luminous emanation, without violence or percussion." Although this electrical fire proved to be two manifestations of the same thing, this recognition of a duality was an important concept in the progression of understanding. Haller recounts the strangeness in the unexplainable dichotomy of this force that seemed "so moveable and incapable of rest,"<sup>7</sup> which turned out not to be the case for long.

Ewald Jürgen von Kleist and Pieter van Musschenbroek separately discovered, in 1745 and 1746 respectively, a specific assemblage of materials with the ability to arrest this enigmatic effluvium. This device, named by Jean Nollet after its birthplace in Leyden, was able to store and release electric charge. The Leyden Jar was imagined out of the concept of electricity as fluid. Human imagination was able to unlock a critical material technology using the mechanical function of liquid storage in glass as the physical model, although these electrical glass jars did not function the same way. "When Musschenbroek described this experiment, he said, 'I've found out so much about electricity that I've reached the point where I understand nothing and can explain nothing.'"<sup>8</sup> Capacitors, as they are known today, remain one of the most important devices in electric and electronic technology. Due to this discovery, "the accumulated force of the electric fluid, was found subservient to chymical [sic] uses — to the deflagration and revivification of metallic substances. Hence the cause of many phenomena both meteorological and atmospherical, were now distinctly traced to the laws and attributes of an electric principle."<sup>9</sup> Electricity remained a mystery, but the phenomena that this object demonstrated was able to be seen and felt across the world.

Benjamin Franklin became further focused into the study of electricity as he received information and objects from European sources. The first was simply a glass tube that was being used to study electrostatics. This device fueled an interest in Franklin that went beyond the effort to understand a physical phenomenon. Electricity represented a rational egalitarian approach to understanding the world, a sentiment that seemed to span across the various interests and fields of study with which Franklin was engaged. In line with his revolutionary spirit was the notion that electricity could not be controlled by a single individual. This force, that Franklin believed could be rationally dissected and understood, was fundamentally democratic. Franklin's hypothesis that lightning consists of the same electric matter as that which came from friction served to solidify the notion that this singular force's qualities were more a function of geometry rather than varieties of electric matter. The famous lightning experiment, although not actually performed by Franklin himself, confirmed his hypothesis. Franklin spent considerable energy try-

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<sup>7</sup> Connor, p. 74.

<sup>8</sup> J. A. Leo. Lemay, *The Life of Benjamin Franklin*, Volume 3 *Soldier, Scientist, and Politician*, 1748-1757. (Philadelphia: University of Pennsylvania Press, 2014): 65.

<sup>9</sup> La Beaume, p. 42.

ing to understand glass, and encouraging glassmakers in Europe to come to America. He understood the role a glass industry could play in economics as well as scientific discoveries, and spent considerable time and effort promoting “the vital importance of glassmaking. Unbeknownst to many, Benjamin Franklin played a sustained and influential role in the formation of the American glass-making industry”<sup>10</sup> (Photo 10).

As light bulb technology came to and surpassed a point of true function, there became a need to apply this technology to see rather than dazzle. Light and knowledge have always been linked, exemplified in language with phrases such as “seeing the light” and “dim understanding.” Electric light in some of its earliest iterations did not result in illumination, but rather dazzlement, the inability to see, and in some cases physical harm. “Elec-

tro-enthusiasts aimed to eradicate the shadow completely, to march into the twentieth century in a blaze of unadulterated light.”<sup>11</sup> Arc lamps in specific, but also carbon filament light bulbs, could be dangerously bright. Louis Bell’s *The Art of Illumination* was published in 1902 in an attempt to correct the course of electric light to become a genuinely useful and beneficial technology. “Bell insists that the current application of electric light lacked both wisdom and taste, to grave consequences.”<sup>12</sup> This publication included aesthetic tips on lighting different kinds of rooms, the use of lampshades, and recommendations for paint colors. A few years later the Association of Illumination Engineers was formed and made their mission to protect the eyesight of electric light users and allow people to truly make use of the light bulb. Illumination engineering proved to be a success and the widespread use of the light bulb came along with the need to connect to a power source. The electricity industry’s birth directly coincides with the widespread use of electric light (Photo 11).

Unfortunately, this is not the proper stage to dive into the development of the electricity industry, the fight and subsequent victory of privatization over public control of this utility, and the question of where all of this energy is coming from. Just as with any other commodity, money seems to have the opposite effect of light in regard to electricity. Mystery and wonder are left in the dark as function and convenience become the main concern. The instrument developed to take on this task has become the largest piece of apparatus humans have ever assembled, manifesting in pylons, power stations, insulators, and immense



**Photo 10.** *Recreation of Benjamin Franklin’s Electrostatic Machine. Collaboration with Nate Ricciuto, 2017*

<sup>10</sup>Paul Engle, *Franklin and Glass*. <https://www.conciatore.org/2016/08/franklin-and-glass.html> (August 22, 2016). Accessed April 23, 2018.

<sup>11</sup>Sasha Archibald, “Blinded by the Light,” *Cabinet Magazine*, Issue 21 (2006): 97.

<sup>12</sup>Archibald, p. 98.



**Photo 11.** *Light bulbs made by Joseph Swan and Ludwig Boehm, 1878-1879*



**Photo 12.** *Platinum/Tungsten light bulb*

lengths of wire. As we all engage with this history and apparatus, the incandescent bulb can be seen as a poignant message in the form of an outdated material technology. This mode of electric lighting is wildly inefficient, with energy largely being converted into heat and comparatively very little light. The incandescent bulb has earned its place in the history of human progress, but the future of this project reflects the way I understand its place in contemporary society. The word jewel can be traced back to the Latin word *iocus*, meaning jest, game or minor amusement<sup>13</sup> (Photo 12).

The story I have told about electricity is inexcusably incomplete. The parts and pieces of this history that I have stumbled across and highlighted in this paper have exhibited the innate human pursuit to understand the material world and to extract some sort of meaning from this experience. This is the place where I believe that the artist and the scientist coexist. The characters in this story have certainly been some of the most creative and intelligent humans in history. Understanding and discovery do not always take place simultaneously, but within this story, the use of imagination has proven to lead to discovery and insight, and consequently understanding. “What its abstract nature and essence may be, cannot

<sup>13</sup>Marjan Unger and Suzanne Van Leeuwen, *Jewelry Matters*. (Rotterdam: nai010, 2017): 57.

fully be ascertained; but it is perfectly well known that it resides more or less in all bodies in different states, and in various modifications – that its agency is felt in every department of nature, throughout the animal, vegetable, and mineral kingdoms—thus possessing the delegated attribute of a philosophical ubiquity”<sup>14</sup> (Photo 13).

Electricity maintained its role as an object of enigma and amazement but did not fully cross the line of functionality until the work of Michael Faraday. The discovery and understanding of the relationship between magnetism and electricity allowed humans to conceive of this force being put to work in a tangible, physical form. Electricity had become a force rather than a sensory object or a substance. Attraction and repulsion defining different types of electric matter, resinous and vitreous, was no longer the way of understanding the force at play. Franklin, with his experience in finance, saw this as a matter of accountancy and changed the terminology to positive and negative. The era of quantification had begun. The mysterious nature of electricity went out of focus as “it was no longer necessary to decide quite what electricity consisted of: all that mattered were its varying quanta, the economies of its energetics.”<sup>15</sup> Since this point in history, electricity has all but defined the trajectory of contemporary society. It has evolved from a philosophical ubiquity to a functional ubiquity. Electric light has changed the human understanding of day and night, allowed exponential growth and evolution in knowledge, and allowed us to see things we did not know were possible. Electricity can be seen as “that material soul, which inhabits this system or world, and is to its motions and revolutions, what the heart is to the human frame—‘the well-spring of life,’ and the vital source of action and re-action.”<sup>16</sup> This conception of electricity as being a vital component of this system, and in specific human society, continues to become more relevant as we become further in union with the electrics.

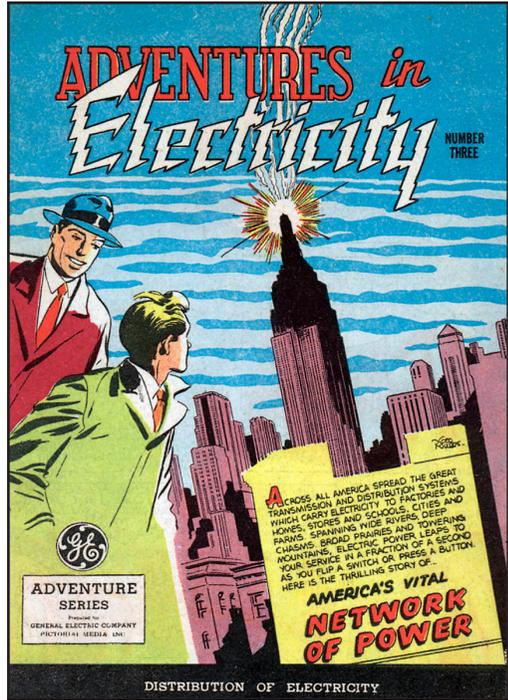


Photo 13. *Adventures in Electricity* #3, George Roussos for General Electric, 1946

<sup>14</sup>La Beume, p. 28.

<sup>15</sup>Connar, p. 75.

<sup>16</sup>La Beume, p. 46

# A Look into Volcanology Through the Glass Fluidization Cup

by  
Elayne Ashley\*

## ABSTRACT

*This paper describes glass fluidization cup fabrication and deconstruction and how it applies to volcanology. The rheological, fluidization, and de-fluidization experiments that were able to be completed due to the research provided by the cup are also discussed.*

Volcanology is the study of volcanos. When Dr. Eric Breard first came to me about fabricating a glass fluidization cup, I was not terribly familiar with the concept of fluidized beds. Yet, the fabrication was simple enough and since Breard knew what he wanted, I was happy to complete his request. In the end, his experiments ended up taking on a few different paths: rheometer experiments that would study granular rheology, and fluidization-defluidization experiments to study the permeability to granular mixtures.

The design consisted of a glass tube with a fritted disc inside that would be attached to an aluminum base during experimentation. As usual, my game of twenty questions ensued, trying to determine if I could improve upon the design. Yet, not being able to modify the design to contribute to the scientific process, we settled on a product closer to the original, as he seemed steadfast in his desire to have nothing more than what he was requesting. The part was fabricated and Breard left with the device seen in Image 1. Fellow glassblowers will identify this as a tubulation with a fritted disc. This was to be used for the first stage of his rheology experiments. Using 2 mm Ballotini glass beads with a plate on top, Breard was able to investigate the effects of shear force applied to the fluidized mixture by rotating the top plate with and without gas-fluidized beads at various rates (Image 2).

The first experiments were conducted for granular rheological studies. Rheology, the study of the flow of matter, is used to observe matter acting as a liquid. This can be actual



**Image 1.** Rheology experiments—using 2 mm glass beads

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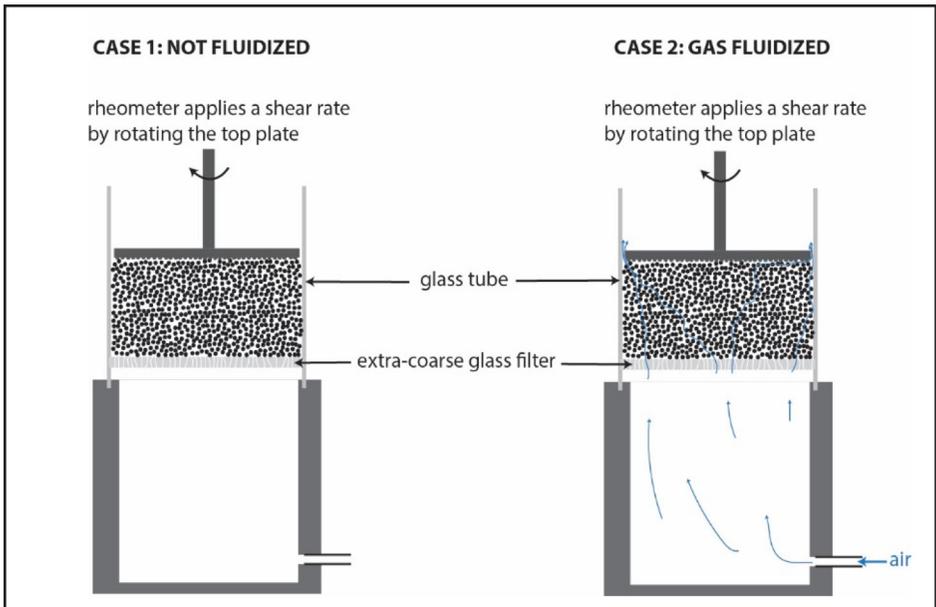


Image 2

liquids or solids acting in a liquid state. The latter describes the fluidization experiments that would follow. Breard was specifically investigating shear thinning. The fluidization cup that I had built would be filled with 2 mm glass Ballotini beads, then have a plate apply pressure to the beads and determine if the shear rate had changed between fluidized and non-fluidized states. His results showed that these two states had very similar rheology. As the shear rate increases the viscosity decreases, and this trend is similar for both samples, indicating a shear thinning effect. While more work is still needed on non-spherical mixtures, Breard was able to show, with our device, that the granular bed can be used as a simplified viscous fluid.

“Geophysical flows such as pyroclastic flows are very hazardous flows that can often be composed of a basal dense granular avalanche where gas streams upward in similar fashion to that of fluidized beds. Prediction of their runout distance and inundation area are primordial to prevent fatalities, and numerical modeling is involved. In these models, the right rheology needs to be used to effectively describe the flows motion.”<sup>1</sup> (Images 3<sup>2</sup> & 4<sup>3</sup>).

Katia and Maurice Kraft were two Volcanologists who were famous for getting dangerously close to their subjects and getting amazing camera footage of the volcanoes and lava flow rivers (Image 5).<sup>4</sup> They both lost their lives along with 41 others to this type of pyroclastic flow. The temperature of the fluidized particulate can reach up to 800 degrees Fahrenheit and have devastating effects on the surrounding communities.

<sup>1</sup> Dr. Eric Breard. Personal interview, May 29, 2018.

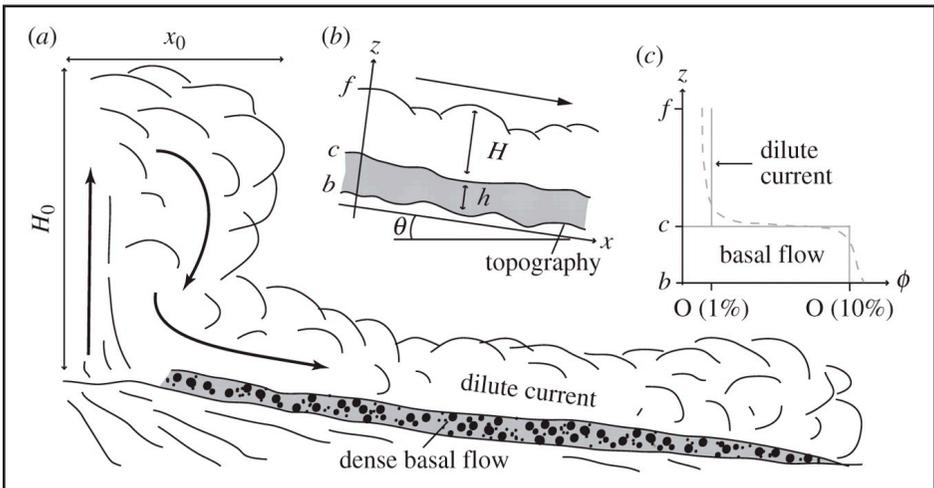
<sup>2</sup> <https://www.britannica.com/place/Mayon-Volcano>. Accessed May 20, 2018.

<sup>3</sup> <http://rspa.royalsocietypublishing.org/content/467/2129/1348>. Accessed May 20, 2018.

<sup>4</sup> <https://www.mnhn.fr/fr/visitez/agenda/rendez-vous-museum/projection-film/maurice-kiatia-krafft-rythme-terre>. May 26, 2018.



**Image 3.** Pyroclastic flow at Mayon volcano (Phillipines)



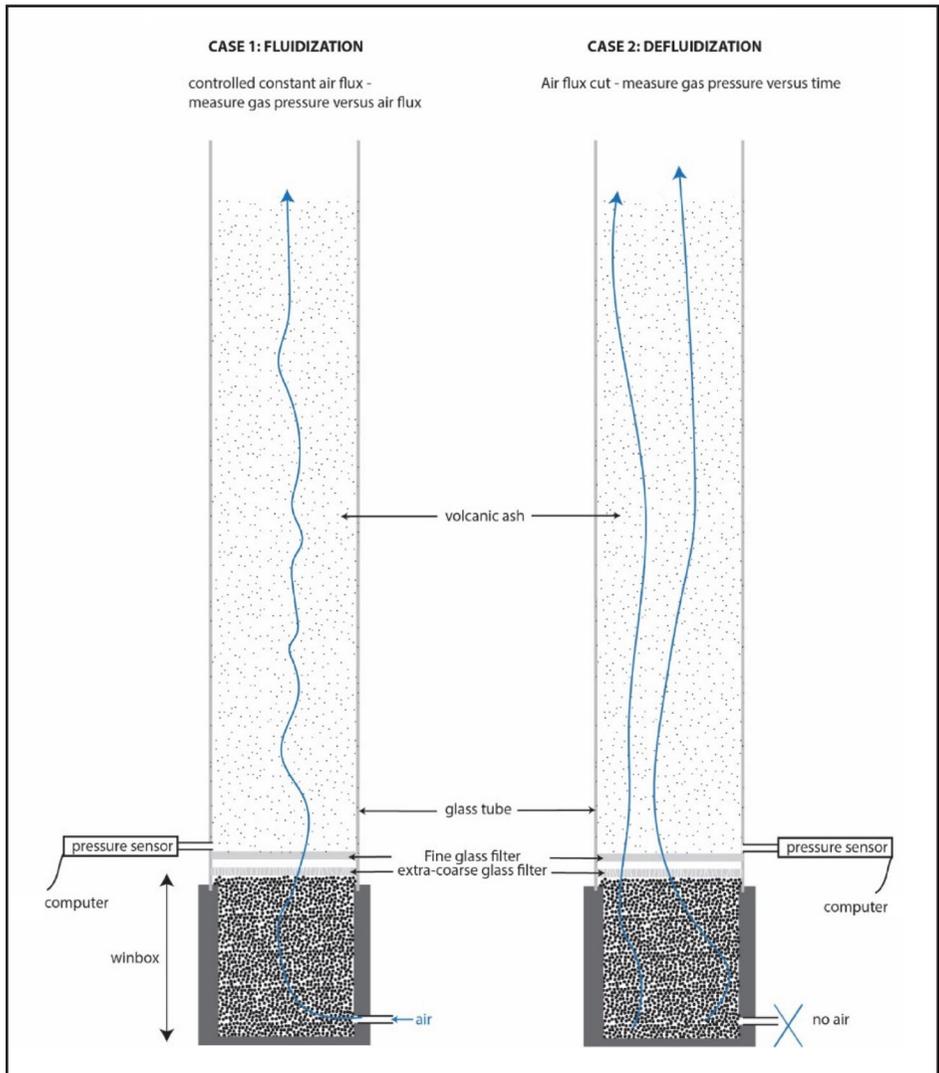
**Image 4.** Pyroclastic flow simplified structure



**Image 5**

The next phase of study brought the fluidization cup back to the shop for some upgrades. We drilled out a few holes with a dental drill and added some small hose barbs with a bit of mesh fabric (to keep the particulate out of the sensor) and silicone sealant (so they could be easily removable). The hose barb allowed Breard to use a pressure sensor on either side of the frit disc to allow him to more accurately gauge gas pressure on either side of the disc during fluidization. Additionally, since the next set of experiments required smaller beads to simulate a fine sand, we needed to add a finer grain frit, and add length to the cup to increase volume availability. Since Breard wanted to be able to remove the length and fine frit afterward, we used the same silicone sealant to add the tubulation as opposed to hot sealing (Image 6).

As I was only generally familiar with the concept of fluidization I found it fascinating to watch. Fluidization is when a solid is able to act as a fluid due to an upward gas pressure



**Image 6.** Fluidization and defluidization experiments

that is able to give a particle, or solid, buoyancy and balance the effects of gravity. An example of this can be found through a quick online video search which I highly recommend.

Breard’s final experiments were to study the permeability of volcanic mixtures. He would study the fluidization and defluidization of simple gas bead mixtures and sand from dunes to learn about complex volcanic mixtures.

“Fluidization experiments consist in setting a gas flux and measuring the gas pressure. As gas streams upward through the granular mixture, the drag force applied by the gas upon particles yields an upward force that partially to totally balances gravity. The gas pressure increases as the gas upward velocity increases, to an extent where the basal gas pressure of a fully fluidized column equates the bed weight. At any time, when gas is streamed through the bed, the gas source can be cut and thus all the excess pressured gas will diffuse upward. The pressure decay measured can be predicted from diffusion equations and allows us to predict the diffusion timescales of the gas pressure.”<sup>5</sup> (Images 7<sup>6</sup> & 8<sup>7</sup>)

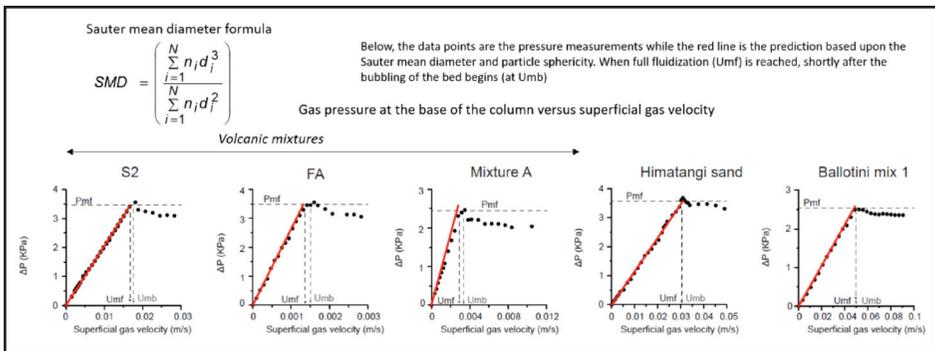


Image 7. Breard et al. in review, *Journal of Geophysical Research*

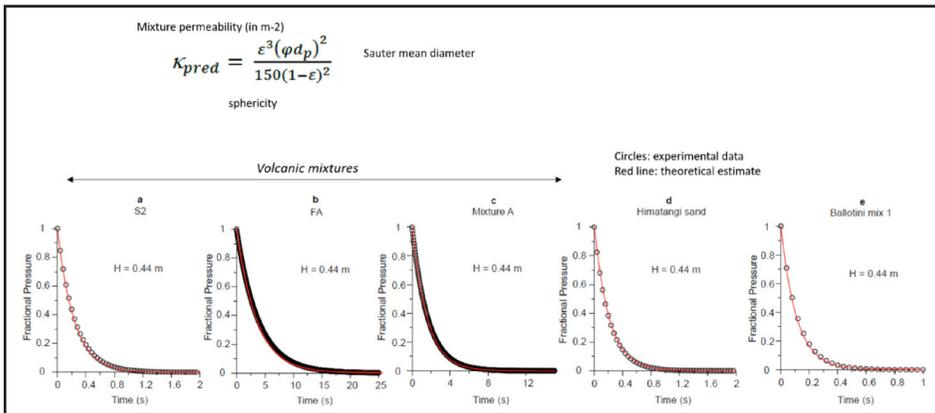


Image 8. Breard et al. in review, *Journal of Geophysical Research*

<sup>5</sup> Dr. Eric Breard, et al., “The Permeability of Volcanic Mixtures – Implications for Pyroclastic Currents,” *Journal of Geophysical Research*, article in review.

<sup>6</sup> Dr. Eric Breard, et al., “The Permeability of Volcanic Mixtures – Implications for Pyroclastic Currents,” *Journal of Geophysical Research*, article in review.

<sup>7</sup> Dr. Eric Breard, et al., “The Permeability of Volcanic Mixtures – Implications for Pyroclastic Currents,” *Journal of Geophysical Research*, article in review.

Breard states that his work backed up the implication that pyroclastic flows contained gas pressures for very long periods of time. The diffusion duration scaled with flow height and bed permeability. Because the pyroclastic flows are large and fine grained, they retain gas for a long time. The high gas pressure forced the pyroclastic flows from the volcanoes at an alarmingly fast rate creating a low flow viscosity which translates to a slow diffusion time.

One aspect that differentiated this work from a lot of our common assemblies was that after the original fabrication of installing the first frit, the majority of the fabrication and modification was adhesive work and clean up or de-construction. I get a lot adhesive work in my shop and was recently reminded by a colleague what an uncommon talent that is; it is a continuous request in my Glass Shop. While this type of work is not a huge earner for the shop, every little bit helps, and in a research setting, showing the diversity of your talents can set you apart. Do not underestimate the contribution your skills have to the community you provide for.

While the fabrication was simple, even with its various modifications, and the concept was simple, there was a much deeper practice at work here: science. Breard was using this device to evaluate and reevaluate a concept to study rheology, fluidization, and de-fluidization as they pertain to volcanology and pyroclastic flows, with our favorite material: glass. Not only as the vessel, but also as the measuring device. All in all, the project was very insightful in creating a fascination with the phenomenon of fluidization that I had not previously known. This project also enlightened and fascinated my curiosity to a field of research, volcanology, with which I was not familiar. As scientific glassblowers, is this not what we all aim for in our reach as supporters of research? To participate in the scientific endeavor by way of our hands and with the tools at our disposal? While my part may be small this time, I know it to be crucial and I am happy to continually contribute.

# Point of Excellence: Machine Shop

by

Tracy O. Drier\* and Steve Myers

## ABSTRACT

*Similar to the glass shop, the department instrumentation machine shop works closely with graduate students to create instruments for their research. This talk will focus on the many ways the machine shop assists the glass shop with its mission, from building, modifying and fixing glass-working equipment, to creating jigs and fixtures for holding glass parts for specific projects. We will focus on specific examples with drawings to illustrate how the machine shop enhances the glass shop's ability to meet the needs of our researchers.*

## INTRODUCTION

Having on-site access to an instrumentation machine shop is as crucial to faculty research as the glass and electronics shop. These services not only provide the necessary hardware for research, they also provide the researchers with knowledge that they might not necessarily have or insight into options they might not have considered.

This talk will focus on the ways the machine shop has helped push the boundaries of the glass shop's capabilities.

## THE MACHINE SHOP

The machine shop has four employees, including the supervisor. When I arrived in 2000, the work was sketched/drawn and submitted as a work order. Similar to the glass shop, no electronic records of drawings were made or kept.

Photos 1-11 give a small overview of projects that were made for the glass shop during that period.



**Photo 1.** Tubing holders for a variety of manifold configurations

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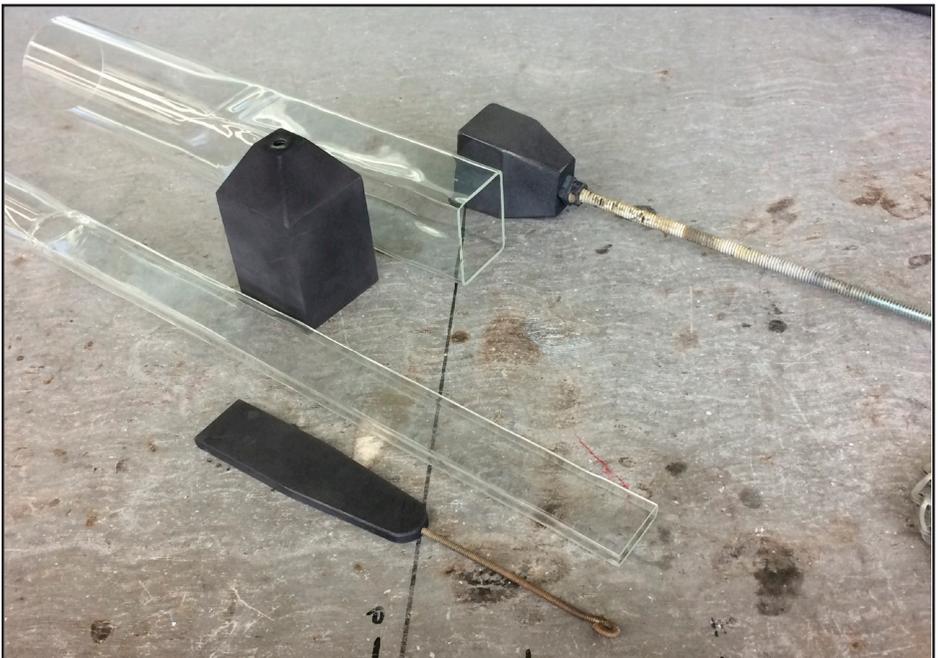
**Photo 2.** *Coil winding Mandrels*



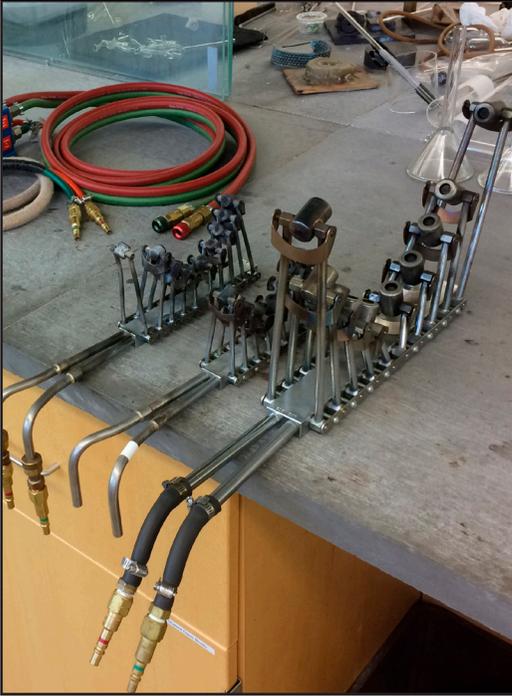
**Photo 3.** *Plunge molds*



**Photo 4.** *Miscellaneous wire holders*



**Photo 5.** *Graphite forming dies*



**Photo 6.** *Crossfire modifications*



**Photo 7.** *Foot pedal with quick connects*



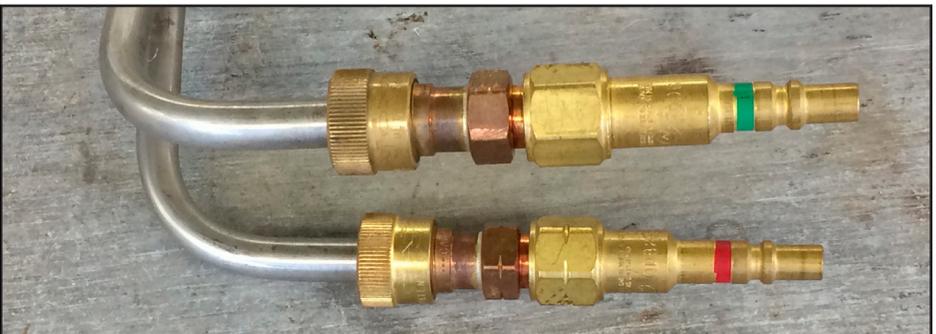
**Photo 8.** *Crossfire adapter without a machine shop*



**Photo 9.** *Crossfire adapter with hard-soldered tubing*



**Photo 10.** *Crossfire adapter with 3/8" UltraTorr adapter/quick connect fitting*

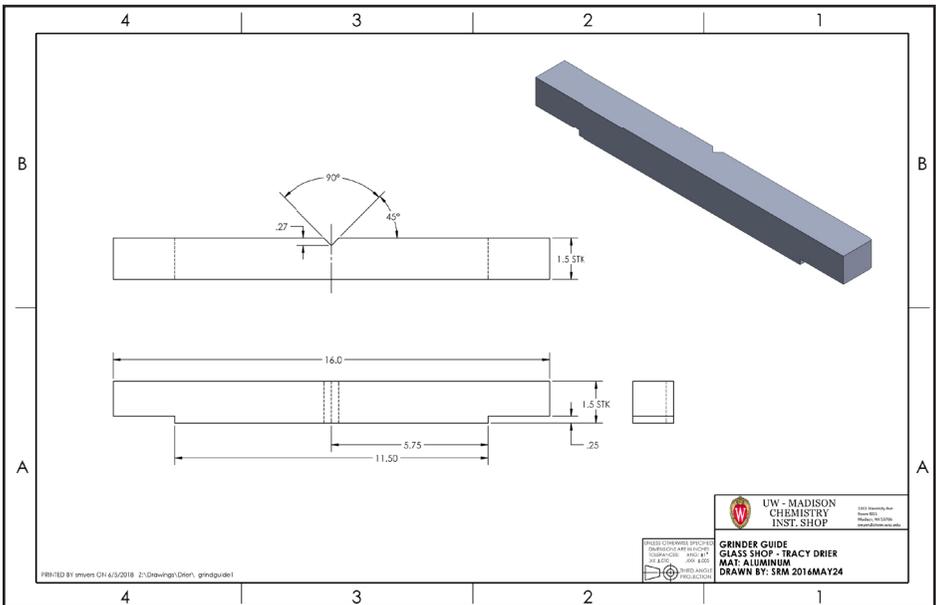


**Photo 11.** *3/8" UltraTorr adapter/quick connect fitting, detail*

The drawing program Solidworks was implemented in the machine shop in 2014. This software provides a beautiful 3-D rendering along with relevant dimensions and details. These easily convert to machine code for their CNC mill and lathe tooling operations. It also provides a record for later use or modification. In the case here, it provides you with working drawings to submit to your own machine shop.

The intention of this talk is to highlight interesting projects using the machine shop as well as to provide the detail drawings for these projects.

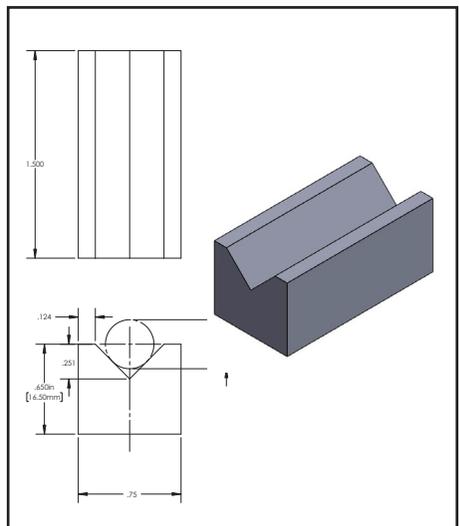
Photos 12 and 14 show drawings of a couple of the more simple examples.



**Photo 12.** *Drawing of Flat-lap grinding jig*

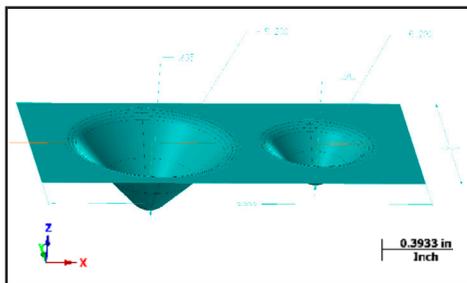


**Photo 13.** *Jig in action*



**Photo 14.** *V-block drawing*

The infinity contours of Photo 15 were transferred to a graphite block (Photo 16) used for producing round objects



**Photo 15.** *Infinity mold contour drawing*

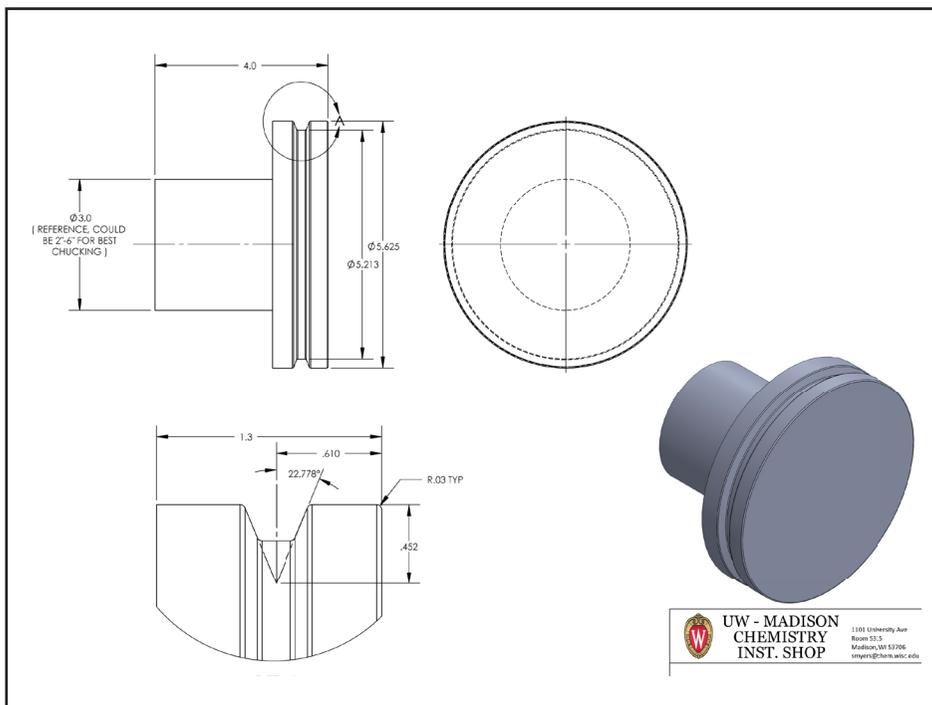


**Photo 16.** *Graphite mold*

## LATHE CHUCK ADAPTER

Some years back, I bought a new scroll chuck for the tailstock of my lathe, and have never been happy with its performance. It did not hold glass true, and it tended to break my tubing if I did not use wrap. Investigations by the machine shop showed that the chuck jaws were not parallel and would need to be trued up.

They took dimensions off my lathe and built an adapter in-place in their machine lathe (Photos 17 & 18). This adapter held my lathe chuck in their machine lathe as though it was on my lathe, as shown in Photo 19. Since the adapter was machined in place, everything was square.



**Photo 17.** *Drawing of lathe chuck adapter*

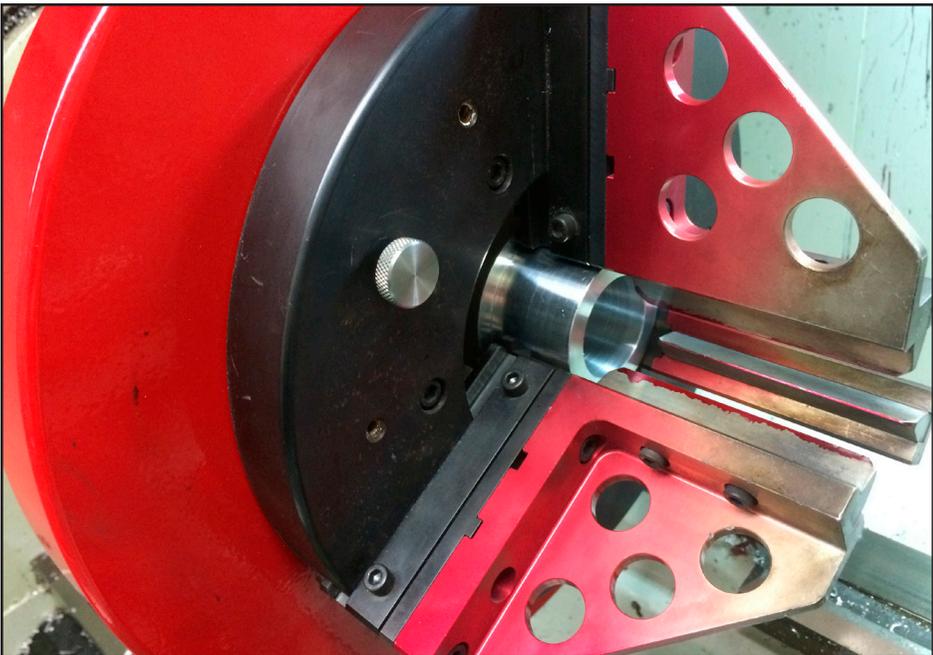


**Photo 18.** *Mounting glass lathe chuck*

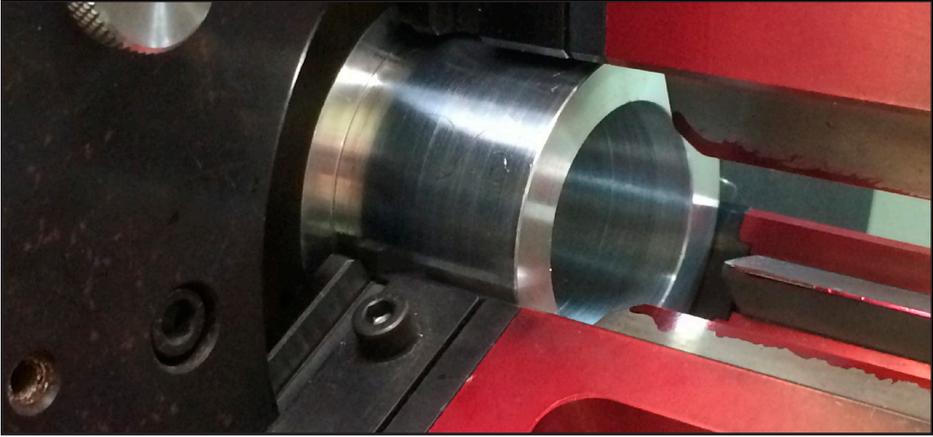


**Photo 19.** *Adapter in the machine lathe*

The jaws of the chuck in Photos 20 and 21 were clamped down onto a machined stainless steel cylinder and locked with the locking screw to prevent movement and deflection during the boring operation. The detail of Photo 21 highlights the red marking dye that has been applied to each of the three jaws. The jaws would be skim-bored only until all the red dye has been removed off the three jaw surfaces.

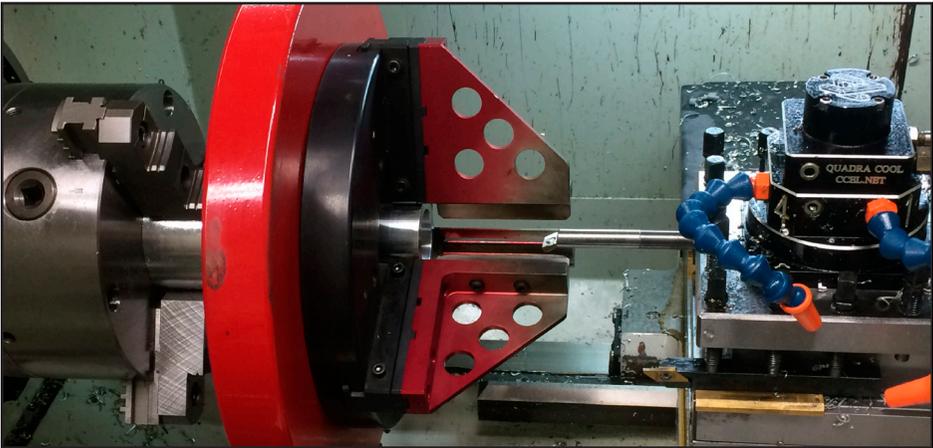


**Photo 20.** *Clamping down onto a machined cylinder to prevent jaw movement and deflection*

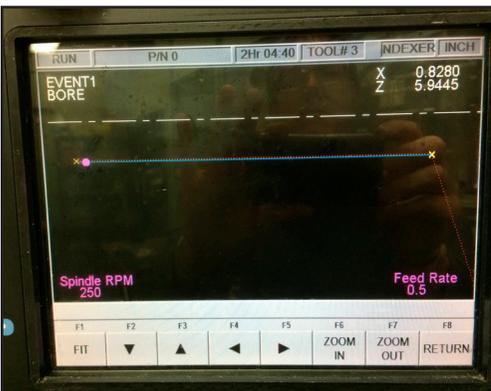


**Photo 21.** Detail of clamping showing the red dye on the jaw inserts

The lathe was run without coolant. This necessitated a slow rotation and feed to prevent overheating or deflecting the jaws.



**Photo 22.** Boring operation



**Photo 23.** Speed and feed rate read-out

## UNIVERSAL HOLDER

A request came in for a large number of bioreactors. They were modified 250 ml Erlenmeyer flasks with two internal drop tubes, 180 degrees apart, with a septum take off at the 100 ml mark. They wanted the bottoms of the internal drop tubes to be at the 50 ml line. The finished reactors are shown in Photo 24.

A holder was designed by the machine shop to create the degrees of freedom necessary to have an infinitely adjust-



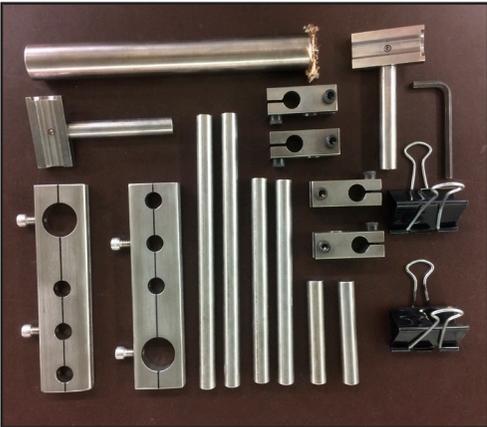
**Photo 24.** Photo of 250 ml bio reactors.

able holder to provide repeatable glass part placement (Photo 25).



**Photo 25.** Holder in position

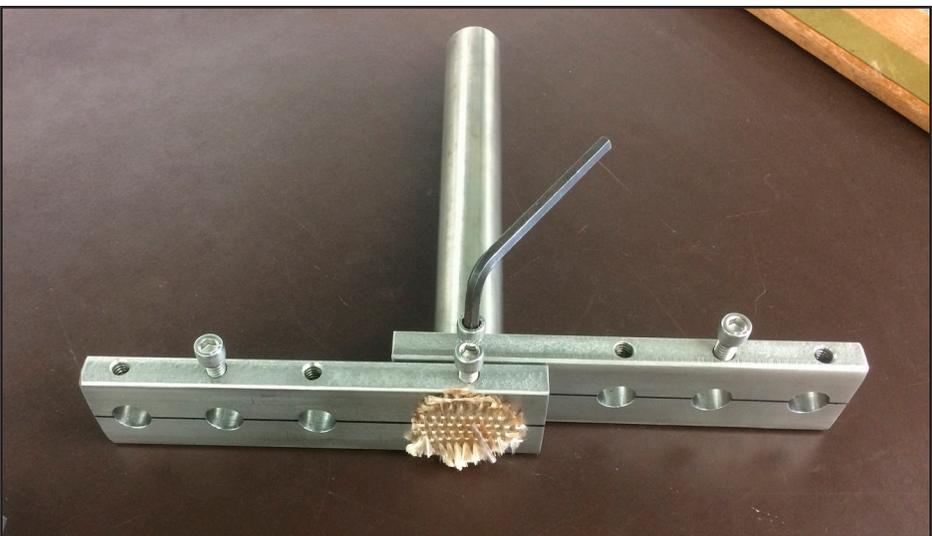
A breakdown of the holder components is found in Photo 26. A large binder clip holds the glass work in position in the V-block channel. Photo 27 illustrates how the holder pieces are assembled. The main shaft is a one inch diameter by 8 inch long piece of stainless steel rod that is clamped in the chuck. One of the wing plates is secured onto the end of this rod (Photos 28 & 29). Half inch diameter rods and knuckles are used to place the V-block channel out into space in the correct position. A variety of lengths of half inch round stock (3, 6 and 8 inch) allow for versatility. One of these half inch rods is inserted into one of the three holes in the wing plate. A knuckle (Photo 30) is attached to this, followed by another rod into the other hole in this first knuckle. A second knuckle is added onto this second rod. The shaft with the V-block channel is inserted into that second knuckle (Photos 31 and 32). Each of the intersections of rods and knuckles provides one degree of freedom. Three degrees of freedom defines an infinite range of motion in the X, Y and Z planes which allows for an unlimited range of motion to precisely place a glass piece for sealing.



**Photo 26.** *Layout of holder parts*



**Photo 27.** *General configuration of holder*



**Photo 28.** *Wing plates attached to one inch stainless shaft*

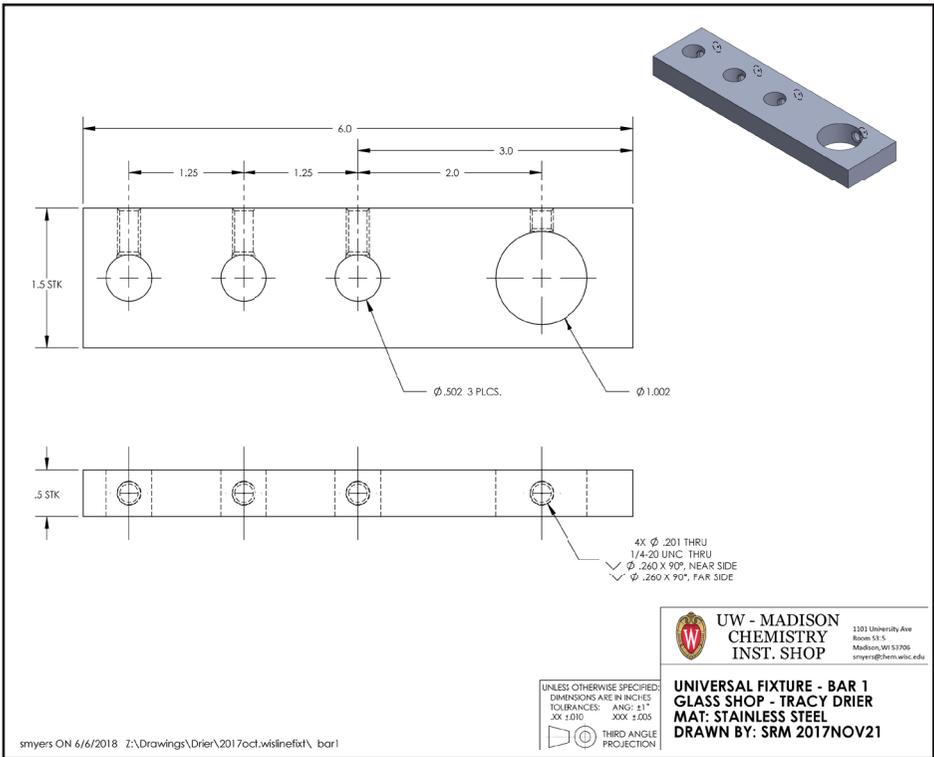


Photo 29. Drawing of wing plate

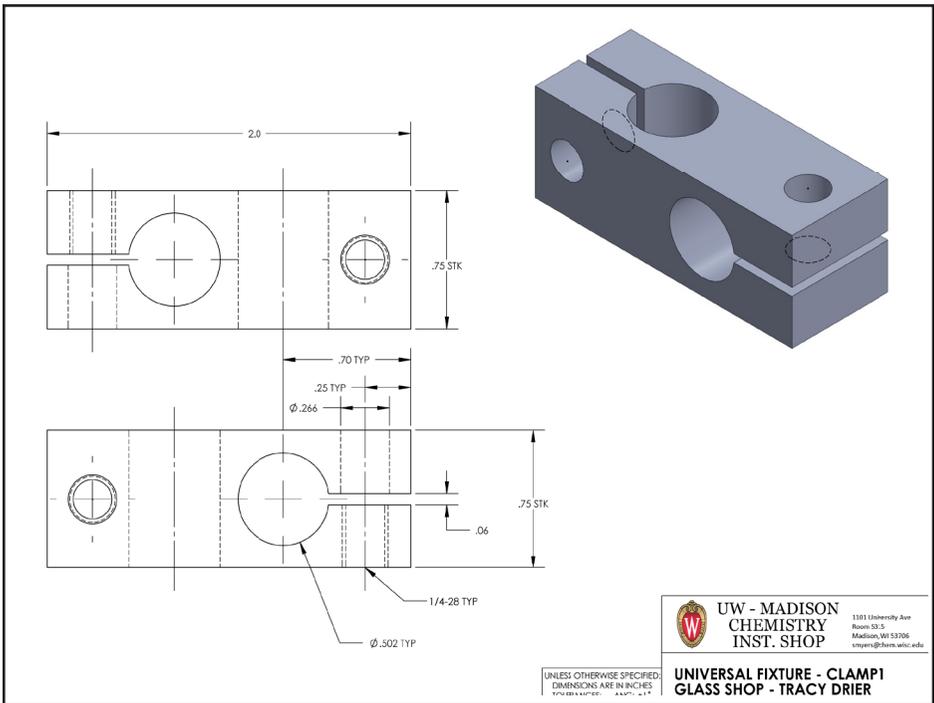
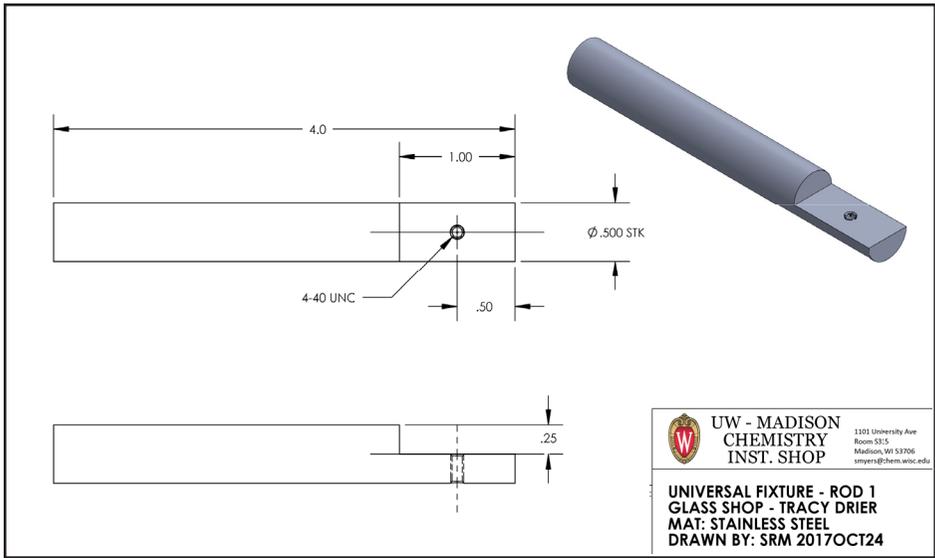
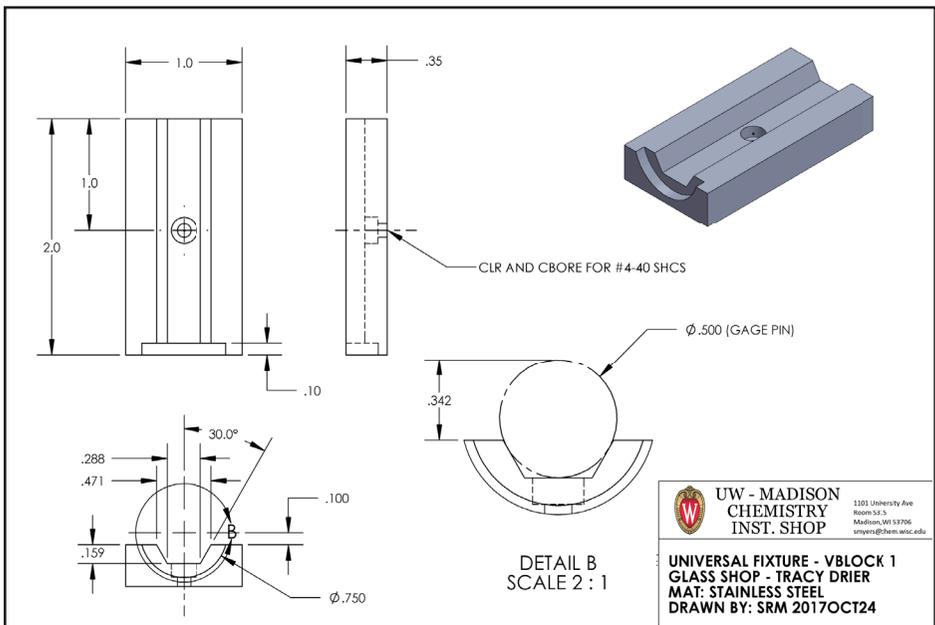


Photo 30. Drawing of a stainless steel knuckle



**Photo 31.** Drawing of shaft for attaching V-block channel



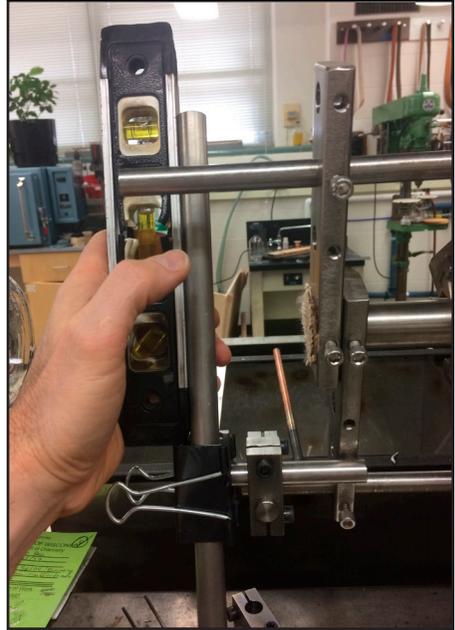
**Photo 32.** Drawing of V-block channel

The V-block channel as drawn allows for a limited range of glass tubing diameters. This can be modified or rebuilt by your machinist to fit any specific tubing requirements.

## CONFIGURATION OF HOLDER FOR BIOREACTOR PROJECT

The holder is held in the tailstock with the Erlenmeyer flask in the headstock. Use a Sharpie® and mark the center of the bottom of the flask. The wing plates are secured to the one inch rod 180 degrees apart (Photo 28). Align the holder with the flask to place

the thru-seals in a consistent position (for example, away from the flask decals). The one inch rod is pressed to the bottom of the Erlenmeyer and the V-block channel is arranged so that it is positioned where the thru-seal ring seal is made. A metal rod is clamped into this V-block channel with a binder clip, and a bubble level is used to make sure the insert seal will be at 90 degrees to the centerline of the lathe (Photo 33). Now, adjust the V-block channel so that it also runs through the center of the flask (Photo 34). This might take some iterations to get everything lined up true. Once everything on one side is set and tightened, use a binder clip to set the second V-block channel into position against the rod (which is still clamped into the first V-block channel). Use the rods and knuckles to connect that to the second wing plate. The finished holder set-up is shown in Photo 35 – it still shows the alignment bar clamped between the



**Photo 33.** *Squaring the V-block channel to the lathe axis*



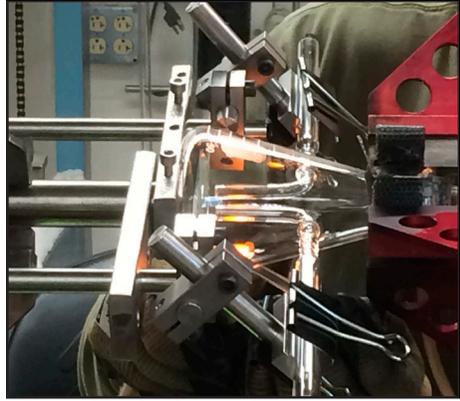
**Photo 34.** *Centering V-block channel to flask*



**Photo 35.** *Completed set-up*



**Photo 36.** *Marking side holes placements*

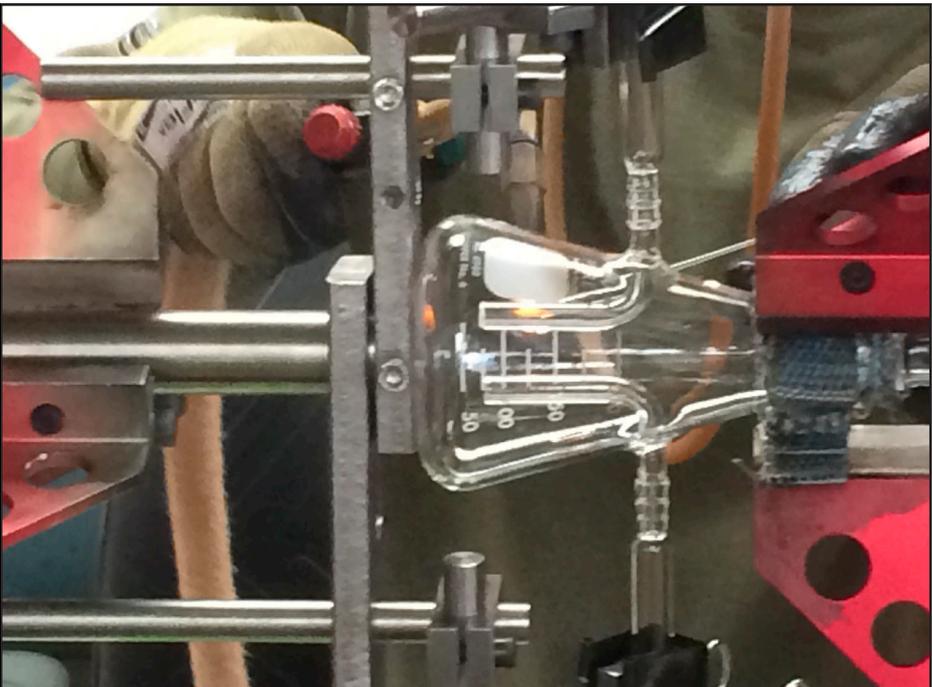


**Photo 37.** *Holder in action*

two V-block channels. After removing the alignment bar, a Sharpie® is used to mark where to set the thru-seal holes (Photo 36). Photos 37 and 38 show the holder in action.

This holder was recently reconfigured to build 10 bioreactors with a single angled sidearm. This provided exact replication for each reactor.

Thank you.



**Photo 38.** *Holder in action*

# A Repurposed Rotovap for Peptide Synthesis (From Sketch to Completion)

by

Jim Hodgson\*

## ABSTRACT

*One of the pleasures of scientific glassblowing is working with researchers and colleagues to determine how to meet their needs with a well-designed piece of glassware. The interaction and sharing what the possibilities are with glass and glass components can be one of the most important parts of your job. This paper addresses the process with a nice collaboration and a successful conclusion.*

## SOLID PHASE PEPTIDE SYNTHESIS

Solid phase peptide synthesis uses an inert resin as a framework to grow long chains of amino acids. This is usually a multistep process which involves attaching an amino acid to the resin, protecting the next amino acid to be attached, coupling it to the previously attached amino acid, de-protecting, and then repeating the cycle until the desired peptide is built. Very small (microliter) quantities are available commercially, but midscale quantities (ml) are very expensive. Synthesizing these midscale quantities can be a time consuming process and requires stirring or agitation.

In an early iteration, this agitation was accomplished using a repurposed rotovap and a holder for basic, small scale peptide flasks. Loading and unloading multiple flasks for each of the steps was time consuming (Photo 1).



Photo 1. Agitation with rotovap

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## THE IDEA

The original design worked well, but the researcher felt that it could be improved upon and came to me with this sketch (Photo 2).

Like the original design, this one utilizes often readily available older rotovaps for the slow, controllable mixing. Reversing the angle of the rotovap allows the condenser flange portion to be used for solvent recovery. An “upside down” Erlenmeyer flask is used as a mounting device for multiple peptide flasks.

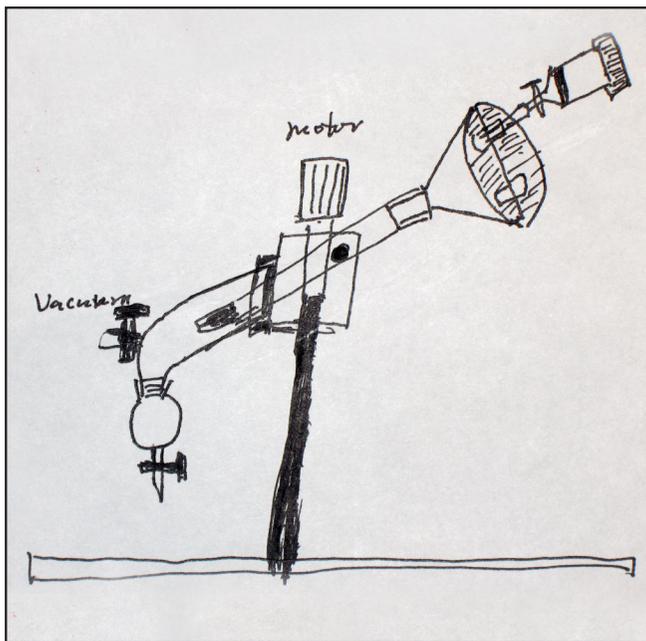


Photo 2. The idea

## DESIGN CRITERIA

During the discussion on the design, the following six criteria were important: inert materials, a strong robust design, complete and rapid draining, easy to clean, as compact as possible, versatility.

## INERT MATERIALS

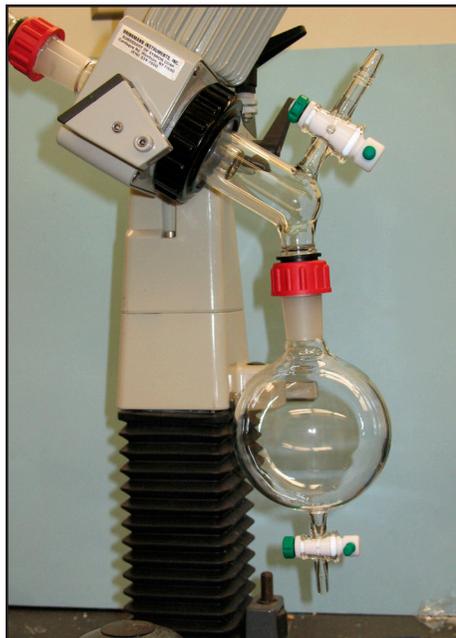
The solvents used to de-protect the chain and cleave the end product are often smelly (Piperidine) and strong (Trifluoroacetic acid). This makes glass and PTFE the ideal materials to use in constructing apparatus for peptide synthesis.

PTFE stoppers are inert and very quick to remove and replace, likewise with PTFE stopcocks (Photo 3).



Photo 3

Rodaviss joints are a good way to join the various components. They require no grease, are vacuum tight with very limited exposure of the sealing O-ring, and hold the components together securely with the capability of separating them with even pressure thus reducing the chance of breakage (Photo 4).



**Photo 4**

## **STRONG, ROBUST DESIGN**

Keeping the glass components as short and beefy as possible reduces the chance of breakage by reducing leverage and using the strongest possible components within the space criteria.

A 1-arm larger, 4 mm PTFE stopcock is the strongest configuration for the bottom end of the peptide synthesis vessel. A 1-arm larger, 6 mm PTFE stopcock is used for the vacuum attachment on the collection flange.

The separation between seals is as short as possible without distorting any ground surface. This can be seen on the vapor duct tube, the 14/20 joints on the top of the Erlenmeyer, the 24/40 Rodaviss joint on the bottom of the Erlenmeyer, and the 24/40 Rodaviss joint on the bottom of the collection flange (Photos 5-8).



**Photo 5**



**Photo 6**



**Photo 7**



**Photo 8**

## RAPID, COMPLETE DRAINING

The tapered sides of the Erlenmeyer flask and the angle of the rotovap allow for complete draining of the peptide synthesis vessels attached at the top. The large bore 4 mm stopcocks can be rapidly opened, and, utilizing the large bore 6 mm stopcock with the vacuum attachment, the vessels are drained quickly and completely. The solvent collection flask holds the drained solvent which can be emptied independently during the next cycle (photos 9 & 10).

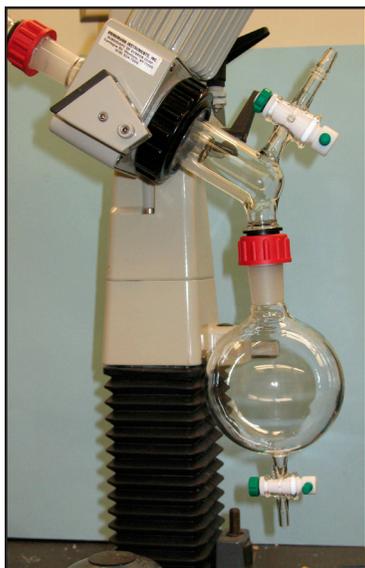


Photo 9



Photo 10

## COMPACT AND EASY TO CLEAN

The size of the Erlenmeyer can be varied to accommodate different sizes of peptide vessels. Using the smallest possible Erlenmeyer decreases the overall footprint of the apparatus.

Everything disassembles and the components are simple, so most areas can be cleaned with a brush and soapy water or cleaning solution.

Rodaviss joints used for assembly do not require grease, so there is no potential nasty residue to deal with.

## VERSATILITY

Using standard taper Rodaviss joints allows you to utilize any size of peptide vessel as long as it will fit within the confines of the Erlenmeyer top. A complete assortment of plugs gives you the option to only use one peptide vessel or as many as there are ports.

The peptide vessels can still be used in a stand alone configuration, much as a normal peptide vessel (Photos 11-14).



Photo 11



Photo 12



Photo 13



Photo 14

## CONCLUSION

Taking a design from a sketch or conversation to a finished apparatus is very satisfying. Along the way are understanding the function or end use of the apparatus, sharing ideas, offering glass component options, and finally arriving at a useful piece of apparatus which moves research forward (Photo 15).

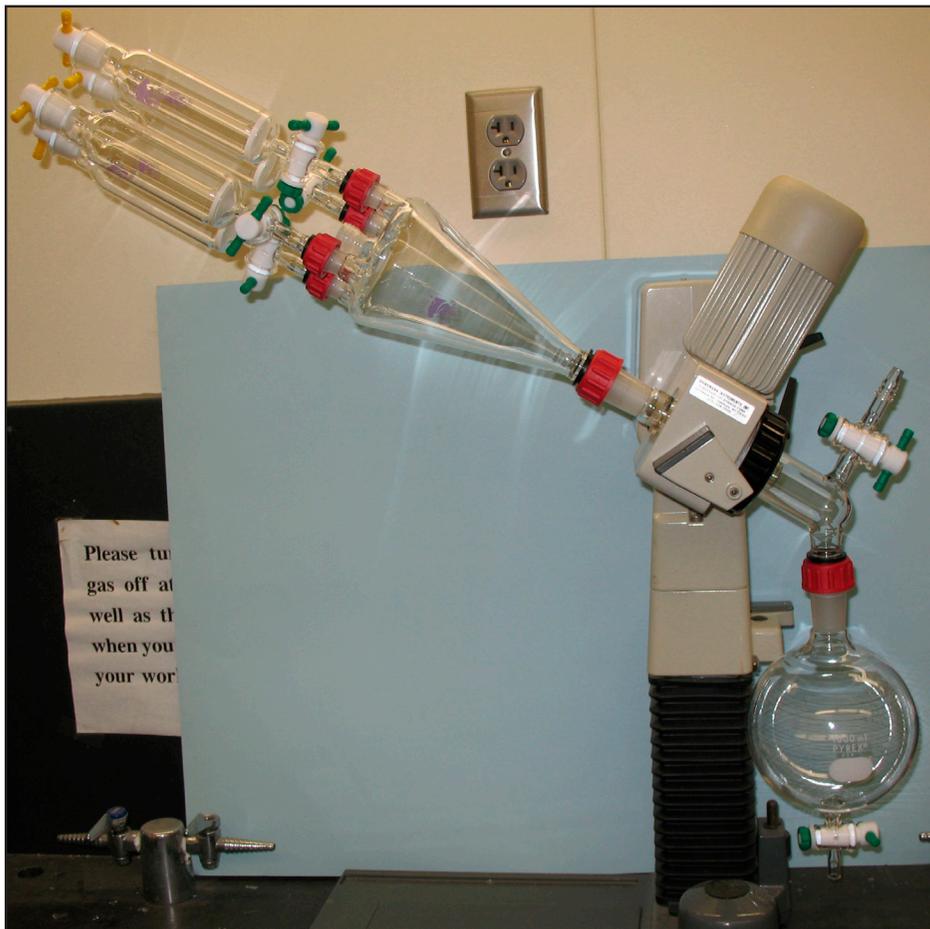


Photo 15

## ACKNOWLEDGEMENTS

I would like to express my appreciation to Kansas State University and the Department of Chemistry for their support of the scientific glassblowing facility and their continuing encouragement of my professional endeavors. I would like to especially thank Dr. Hongwang Wang for his ideas, collaboration and collegiality as well as those glassblowers, who by example and teaching, encourage a desire to do good, professional work.

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