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THE
AMERICAN SCIENTIFIC GLASSBLOWERS SOCIETY
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The BSSG and the ASGS: Perfect Fusion

by
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Abstract

Several ASGS members have discovered the benefits of dual memberships in both the American and British Scientific Glassblowing Societies. Learn the different techniques of the British Society with regards to training, dress codes at banquets, publications and the marvels of touring the UK and Europe.

Glassblowers are curious people. If there is a better tool, torch or challenge, we want to learn about it. Joining the British Society of Scientific Glassblowers will open new channels for the imagination. They have an interesting mix of the traditional European trade apprenticeships along with some very creative, new perspectives on glassblowing. Because of Britain's former colonial empire, members are found around the world.

The British Society of Scientific Glassblowers was founded in 1960; the rules were written on November 22nd and the first meeting was eight years after the establishment of the American Scientific Glassblowers Society. The first BSSG Symposium occurred on September 20, 1961 with 70 attendees and was held at Albright and Wilson of Oldbury. The following year it was at the Imperial College of London and attracted 150-200, much like the rapid growth of the early ASGS. The goal of the BSSG is the sharing of knowledge used in scientific glassblowing, very similar to that of the ASGS. It is not a trade union. Bill Baker of AIE Central Research Laboratories was the first Chairman of the BSSG. Other founding members include D. Ivin of the National Coal Board and Les Haynes of Jencons.[1] Ian Pearson is both the current Chairman and Editor of their scientific journal.

The membership of the BSSG has a much greater international influence than the ASGS: they have 200 members, 30 of whom are from other countries. Glassblowers come from the USA, Canada, Germany, Holland, Sri Lanka, France, Australia, New Zealand, Portugal, Hong Kong, Japan, Iran, Greece, Israel, Belgium, Finland, South Africa and Zimbabwe. Ease of travel to and within Europe makes it attractive to vendors and several members of the VDG (German Glassblowers Society).

The easiest way to access the BSSG is to receive their Journal which is published quarterly. It starts off with Ed's Crack, a humorous editorial that rambles through life and glassblowing written by Editor Ian Pearson. A recent copy featured the interchange between Ian and the Crown Prince of England, part of which related the following:

> What would you say to the heir of the throne, who on looking at some wooden sculptures in an art exhibition, asked if they are glass? It was my dubious honor recently, when on meeting His Royal Highness,

[1] W. Baker, "Formation of BSSG," *British Society of Scientific Glassblowers Journal* 42.3 (July 2004): 107-108.

> Prince Charles, to explain politely that the glass items were on the next table. Actually I never had time to fully explain this to him as quicker than a sword can land on one's shoulder (or neck), one of his minders stepped forward to save the day. I can only presume that this gentleman belonged to the "embarrassment protection police" and was employed solely to make sure no feet were placed where they shouldn't be, and that no words were said that would appear in the media causing red faces. The "minder" obviously had the courage to move certain people on to "save face."[2]

The Journal features Section reports of their meetings and the activities of the organization, much like the ASGS. The review of the annual symposium includes photographs for people who were unable to attend. Articles featured in the Journal are very diverse. Some of the best I have found are:

- "Clearly James Mobile Glassblower." An adventurous group makes a pot furnace and drags it behind their 4 wheeler to artistic events; getting there was half the fun. They built the furnace in James' parents' back garden; later it had to be carried through the house before being put on wheels.[3]
- "From a Grain of Sand to Duran Tubing" by Dr. Bernd Straube describes the process to make tubing including an incredible list of materials and energy resources.[4]
- In "International News—Zimbabwe," Roger Waring writes about the adventure of setting up shop in Zimbabwe (formerly British Colony of Rhodesia); primitive equipment combined with long freight delays made for high stakes glasswork. One project involved making equipment for a rescue of over a hundred trapped miners. High ambient temperatures create the need to increase length of standard condensers.[5]
- "Fusion of Graphite Rods with Glass" by Konstantine Kraft: simply putting a groove in the graphite rod with a wet saw helps the Pyrex holder grip the rod.[6]
- Graham Reed (Chairman of the Board of Examiners) wrote a good article on how to construct a jacketed stopcock addition funnel entitled "Constructing a Jacketed Dropping Funnel."[7]

The Board of Examiners is a key element in the British Society of Scientific Glassblowers. The members can follow a written syllabus to study glassblowing from a technician to a Master Glassblower. A glassblower purchases the courses, practices the techniques

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[2] Ian Pearson, "Ed's Crack," *British Society of Scientific Glassblowers Journal*, 42.4 (October 2004): 141-142.

[3] Bill Rhodes, "Clearly James Mobile Glassblower," *British Society of Scientific Glassblowers Journal* 35.2 (April 1997): 95-96.

[4] Dr. Bernd Straube, "From A Grain Of Sand To Duran® Tubing," *British Society of Scientific Glassblowers Journal* 35.2 (April 1997): 73-83.

[5] Roger Waring, "International News-Zimbabwe," *British Society of Scientific Glassblowers Journal* 41.3 (July 2003): 119-123.

[6] Konstantine Kraft, "Fusion Of Graphite Rods With Glass," *British Society of Scientific Glassblowers Journal* 41.4 (October 2003): 152-155.

[7] Graham Reed, "Constructing A Jacketed Dropping Funnel," *British Society of Scientific Glassblowers Journal* 37.1 (January 1999): 37-40.

under the watch of an experienced glassblower and can take a test. The BSSG web-page has the following description:

> The Board of Examiners has, over the past 20 years, developed a series of Basic Training Courses. It is not intended that these courses should, in themselves, make up a craft apprenticeship but rather to provide a series of progressive basic training courses in bench lamp work (3 syllabi), hand lamp work (one syllabus) and lathe glass working (2 syllabi), in such a manner as to enable, by selection, the varied personal requirements to be met."[8]

The Elementary Syllabus, as the starting point for all scientific glassblowers, provides the first steps in bench work for the trainee glassblower and has equally proved to be an ideal course for the laboratory technician and scientist wishing to acquire a useful elementary skill in simple glass manipulation. There are several levels of difficulty and a certificate of competency establishes full membership in the Society. Companies and universities use it to assure the quality of job applicants; it can be used to judge merit pay as well. Ian Pearson wrote:

> Thought you would like to know that a student member of the BSSG has just passed his Elementary BSSG qualification. He is a Greek student from Athens University and took the exam at York University under the direction of Board of Examiners Competition Secretary Stephen Moehr. The test pieces were a liebeg condenser and a viscometer. The student had received basic training at Athens for about a year. We have also been approached by a Nigerian University to do similar testing.[9]

The title of Master Glassblower is the ultimate goal; currently 25 Master Glassblowers including Examiners Chair Graham Reed have attained this title. At the BSSG symposium, members can submit pieces for competition. BSSG competitions are judged by the Board of Examiners. There are seven competitions including one with a 100 pound prize. The A. D. Wood Cup is for candidates with up to three years' experience as a glassblower who make a standard piece chosen by the Board of Examiners. The Hampshire Trophy, for glassblowers with up to seven years' experience, requires two pieces, one project chosen by the examiners and one by the glassblower.

The annual BSSG symposium is usually held in mid-September and rotates among various areas of England and Scotland. Early arrival can begin Wednesday. Thursday and Friday have planned events all day and evening with a closing held mid-day on Saturday. The Symposium for 2005 which ran from September 15 through17 was in Liverpool, UK. The cost was 225 pounds and included hotel and meals; it was 130 pounds for spouses. Lectures are very informative and interesting. Topics covered in the past include determining the age of glass and ceramics, glass and the development of science, the history of Heraeus Corp. A lecture on glassware and its use of Carbon 14 to date objects was very interesting: Carbon 14 dating is not a linear decay but is affected by solar cycles. The diet of the subject also affects the original carbon content. This was shown by an

[8] www.bssg.co.uk

[9] Ian Pearson, private email, June 22, 2005.

arrow fashioned from a reindeer bone imbedded in a human thigh bone. The raw dating would indicate that the arrow was hundreds of years old when it hit the poor human.

The "Formal Banquet" on Friday evening is the social highlight. This is not a casual affair, men wear tuxedos or Scottish kilts, ladies wear formal attire. The Honorable Mayor and his spouse preside over this event. Part of the ceremony includes a "Toast to the Queen" and the announcement that men can remove their coats and light up a cigar. Entertainment is provided similar to that at the ASGS banquet.

The BSSG exhibitors are different from those at an ASGS symposium. Plowden & Thomson attend annually; they are a manufacturer of colored soft glass and specialty tubing and also sell glass working tools. Stopcock manufacturers J Young of England and Louwers Hapert of Holland both display their wares. Several other vendors offer everything from diamond wheels to general glassware.

The *BSSG Manual of Scientific Glassblowing* is 256 pages long and is available both in print or on a compact disc; it covers everything from ventilation through glass to metal seals.[10] It is quite a bargain at 20 pounds for members.

Paula Craib, the scientific glassblower at Aberdeen University, moderates the "International Glassblowers' Mailing List." You can request to be a member of this list by contacting her at p.m.craib@abdn.ac.uk.

The British Society claims to have the largest library of Scientific Glassblowing in the world. Members can contact the Society's librarian to borrow books or videos.

There are many reasons for you to join the British Society for the incredible rate of 19 pounds. It will help you learn new techniques and find sources of materials. It may inspire you to travel to a safe, friendly country which has a common language as a business or an educational expense; while there, you can explore history or family roots for personal fulfillment. The best reason is to make friends across the sea.

I wish to thank my daughter Emily Kenfield for helping to organize and edit this technical paper into an acceptable format.

[10] "British Society of Scientific Glassblowers Manual of Scientific Glassblowing," Editor M. Hart B.S.S.G et al, CD ROM Version 2002.

Christmas In July

by
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ABSTRACT:

A light exposé on the operation of a glassblowing lab and some constructive suggestions drawn from past experiences.

In my long association with the ASGS, I have presented quite a number of technical papers. The most difficult was the obtainment of a formula to help determine the number of revolutions required to hot crack a tube of X diameter and Y wall thickness. This has faded away into the *Proceedings*. I even, on a whim, gave a paper entitled "Lighting Your Burner." The most popular was an "Explanation and History of Crystal Palace in London." I have received more comments and questions on this than on any other paper.

As a passing comment to Jim Hodgson, I mentioned the fact that I thought more glassblowers should make a niche for themselves. Enthusiastically, he convinced me to do a presentation on that subject; so I accepted. Webster defines a niche as a hollow space for statues; a simple recess in a wall, but best of all, a condition of employment or position suitable for the capabilities and merits of a person, such as "his poetry fills a niche of its own." Another definition is a recess in a tunnel where workmen seek safety from passing trains, but since it implies avoidance, I would like to call that a "notch." Anytime you hide from challenges or responsibilities, I will refer to it as a "notch."

One of the most helpful items in my search for ideas and material was Harold Eberhard's article in the February 2005 *Fusion* about the decline in university glassblowers and a display of salary ranges. His excellent study revealed that the average salary was $53,000 per year. Now if you think that is all your employer expends, let me clarify-

Average U.S. Salary	$53,000
U.S. and state unemployment taxes	1%
Social Security	7.5%
Workman compensation	4-6%
Retirement contribution	6%
Health and Misc. Insurance	5%
A conservative estimate	23.5%

This amount adds up to over $65,000 per year. Add to this maintenance, materials, utilities and equipment, and the total expenditure could be over $100,000 per year. You as a professional who has accepted this position must totally realize the responsibility and commitment involved. There is also an intangible and personal contract with yourself. Albert Einstein wrote, "Many times a day I realize how much my own outer and inner life is built upon the labors of my fellow men, both living and dead, and how earnestly I must exert myself in order to give in return as much as I have received."[1] We all owe a passionate debt to our present and deceased professionals in the glassblowing field. When

[1] Albert Einstein, "Living Philosophies," 1936.

you return to your labs next week, stop a moment to realize the work of the people who preceded you in the development of lathes, ovens, burners and materials. This allows you to focus on today and to lay the framework for the future. Now how does one attempt to establish a niche? Here are some guidelines and suggestions:

1. Mount a bulletin board outside your lab to display recent articles, drawings, new products such as joints, valves, etc. There are tremendous possibilities if you apply your interest and ingenuity.

2. Keep your work place clean, organized and safe. The first impression of guests or clients is reflected in these qualities.

3. Strive continually for knowledge. Join various related groups, i.e., American Ceramic Society, in continual search for relevant information and articles.

4. Display interesting and curious items in your lab such as a water hammer, a hero's fountain, a thermoscope, a dipping duck, a falling hourglass—the list is endless. Rotate your display so only several are visible; they always stimulate conversation, especially in an educational environment.

5. Accept challenges within the limits of your ability and supporting equipment. This does not only apply to fabrication requests but many other facets. Do not impose limits and barriers.

6. Do demonstrations for selected groups even after hours. Investigate teaching a class in glassblowing to graduate students or a class to the public in glass appreciation.

7. Any glassblower who does not emotionally react when the rumblings of the holiday season approach, does not possess the traditional appreciation of a crystal Christmas. Do not use the jaded response that I have absolutely no artistic talent. Now scientific apparatus does have a tendency to make one structured and precise, but some ornaments are simple but attractive. For example, a 6" crystal icicle, a slice of contourex transformed into a wreath, a 1" medium wall tube created into a candle or a simple blown bulb poked into a memorable keepsake. You may contend that gifts would create some problem areas. One can focus on possible solutions. Select an art show for charity or a benefit program that is non-committal and terminal. Is there someone at work who did something memorable?

So ask yourself: if something happened to you, would your employer seek a prompt replacement? Have you created a niche? Have I made a niche in the glassblowing field? If I have not, then maybe it's one heck of a big NOTCH!

Cleaning Glass Vessels for Use in Electric Gas Discharge Tubes

by

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ABSTRACT

The cleansing of glass vessels is crucial to operating quality and longevity of all electronic discharge lamps. Impurities absorbed in the glass as well as deposited on the interior surface must be removed. It is also necessary to cleanse all inclusions. Electrodes need to be degassed and most electrodes require processing of the emission coatings. Filling the vessel is also important and is discussed at the close of this paper.

History

In the early days of electric discharge lighting, manufacturers had their own proprietary approach to processing lamps. This practice was kept secret, and without a forum, shops would not compare notes to improve the process.

Fortunately, just before the turn of this century people started talking. Along came the fourth edition of *Neon Techniques*, electrodes came packaged with instructions, and manufacturers demonstrated pumping at conventions. Technical representatives from manufacturers and sign associations assembled to carve out a universal pumping procedure.

Creating such a procedure was difficult. With so many variables affecting the required time to properly heat and cool the tubing, it became evident that the most important criteria was the temperature. The manufacturers and associations now agree that proper pumping is achieved by using temperature waypoints throughout the pumping process. The overall process is summarized in figure 1. The traditional approach of internal bombardment is detailed below, and an alternative method of external heating follows.

Preheat – Ambient Temperature to 100˚C

Examining different manufacturer's pumping instructions, you will find some manufacturers will include a preheat as part of their pumping procedure. Others merge preheating into the first step by starting with a very low current and very slowly heat the glass. In either case, the gentle heating of glass drives off "the big stuff," primarily water vapor. This will yield a more stable pressure in the tube and provide better control over the process.

Here is a basic preheat method. Attach the vessel to the manifold system and reduce the pressure to about 2 Torr. Begin bombarding at the electrode manufacturer's recommended starting current. The pressure will rise as the temperature rises. When the pressure climbs to 3 Torr, let off the bombarder, lower the pressure, and then continue bombarding. Maintain approximately 2-3 Torr of pressure. Continue in this manner until the temperature rises to about 100˚C to 125˚C. Do not worry about an exact temperature, anything in this range is good. Stop bombarding and open the main valve. The vast majority of the moisture in the tube will be removed in 15 to 30 seconds. Apply the thermo

crayon now while the glass is warm, if this is your temperature "gauge."

In clear tubes, the pressure rise during preheat stage is slight. Coated tubes usually have a higher moisture content, therefore the pressure will rise much faster. Excessively long tubes and tubes with high moisture content place an additional load on the bombarder.

There may be difficulty maintaining an arc stream. The arc might flash, fade, or possibly pop a hole in the tube by taking an electrical shortcut. In this case, pull the pressure down further. The tube may have so much moisture in it that when pulled down to "zero" Torr you may still see a pressure rise when the main is closed. If you pull it down repeatedly so that there is no rise at "zero" Torr, that is about as low as you can start. Any lower, you may find that there are so few molecules and therefore few collisions, that the arc stream will go straight out of the electrode shell, not turning at the double back, heat the glass and suck it in. Be alert! This can happen very quickly.

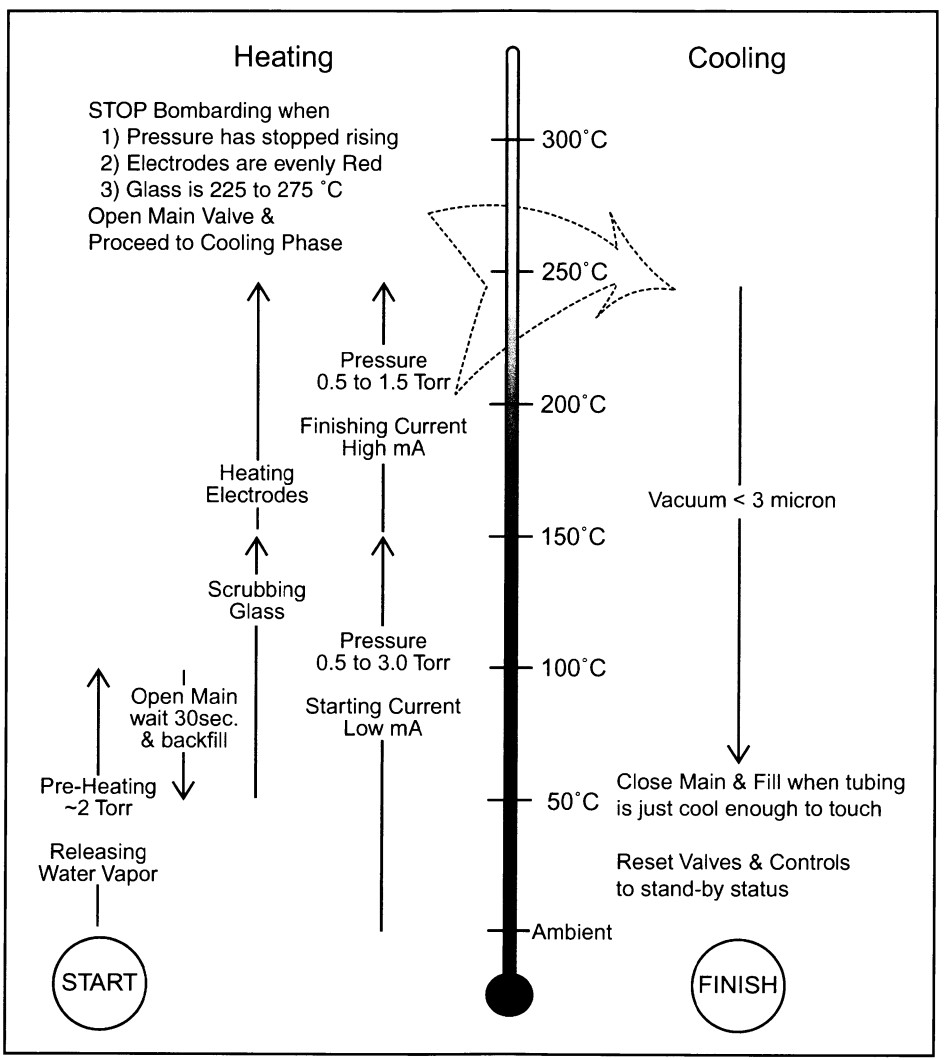

Figure 1

The tube pressure is not too critical during preheating. Just work in a range where control is maintained. BUT, if it is necessary to drop below 1/4 Torr or so for preheat, you may find that after backfilling and starting the bombarding process it will be difficult to maintain the arc stream at the pressures recommended by the manufacturer. And if you cannot maintain these pressures or if you must increase the amperage beyond the stated starting currents, you are obviously not following the pumping instructions. This can lead to decreased tube life.

Through trial and error, you will find the maximum length of tubing that your bombarder will drive at the specified currents and pressures; you should then make all your tubes to this length or shorter.

When the tube has cooled to 50°C, or a temperature that is comfortable enough to put your hand on it, you can zero the U-gauge, close the main, and carefully admit a couple of millimeters of air pressure to get to your starting pressure and proceed.

Heating the Glass – 50°C to 150°C

This point begins the actual bombarding process. Strike the arc at the recommended starting current for your electrodes. The pressure gauges should stay steady. This was the benefit of preheating. Complete control over the pressure of the tube while heating is achieved.

Most manufacturers suggest that during this stage the pressure should be maintained at between 2 to 3 Torr. As before, when the pressure climbs to 3 Torr, let off the bombarder, lower the pressure, and then continue bombarding. Bring the temperature up to approximately 150°C.

This range is intended to heat the glass. The beauty of electrical bombardment as opposed to oven pumping is the scrubbing effect. This scrubbing is achieved by a vast quantity of particles beating around inside the tube and cleaning out impurities from the glass wall. To take best advantage of this effect, lengthen the time that the tube moves through this temperature range. Lowering your mA and heating more slowly maximize the effect.

Heating the Electrodes – 150°C to 250°C

Now we let off the bombarder and lower the tube pressure to a range between 0.5 and 1.5 Torr. Begin bombarding again and raise the current to the specified finishing bombarder current. This value is specified for each size and brand of electrode.

As the tube continues to heat, there will be a little bit of color in the electrodes. Both electrodes should be heating evenly. When the upper pressure is attained, let off the bombarder and lower the pressure to maintain the range. Continue bombarding until the electrodes are completely red, cherry red, end to end.

The scrubbing effect works on electrodes as well. Do not rush through this. It is important however, to use full rated current in the final stage of bombarding to ensure complete emission coating conversion. This coating is on the inner wall of the electrodes. It is changed from a carbonate to an oxide, releasing carbon dioxide. This contributes in the rise in pressure.

Toward the end of the process, observe the temperature gauge, the Torr gauge, and the color of the electrodes. All three indicate something about conditions that must be ful-

filled in order to complete bombarding. The tube temperature needs to be above 225°C. This is hot enough for impurities to remain liberated from the tube while being removed by the pumps. Contaminates will start recondensing on the walls of the glass at about 175°C. The process requires this window of opportunity from at least 225°C to 175°C to remove these contaminates. By climbing to higher temperatures, this period of evacuation becomes longer, offering a better chance of pumping out more unwanted matter. Experience shows that above 300°C some phosphors can be damaged. This leads to a practical target range between 225°C and 275°C. The color of electrodes is important too: full cherry red from end to end and they should be hot enough to show some color for at least 10 seconds after letting off the bombarder. This does not mean that you should heat them for an unnecessarily long time. The ceramic collar should not have any darkening inside. This comes from bombarding too long or at too low a pressure. However, some darkening is better than not fully converting the emission coating.

The most important indicator: More important than tube temperature or electrode color is the pressure gauge. The Torr gauge MUST stop rising before you let off the bombarder and call the tube finished. If the gauge is still rising, it indicates that the glass or more likely the electrodes are still degassing. Continue to bombard until this pressure criteria is met. Remember that any impurity that is not removed during pumping will degas into your finished tube causing staining and a lack of longevity.

The Cooling Phase – From 250°C to 50°C

Open the main stopcock and evacuate the tube. Wait until the tube cools down to 50°C. A simple way to determine the temperature is 50°C is if you can comfortably hold the tube in your hand. Different gauges are going to read that temperature differently. At this point, one option is to use the vacuum gauge to check that there are no leaks in the tube. Now, as the tube is cooling, we can remove the bombarder leads, getting them safely out of the way. By the time the temperature is approximately 150°C, the pressure should be close to one micron.

Use this opportunity to heat and degas the tubulation. This procedure will release moisture and other contaminates back into the tube from the tubulation glass that has not been heated during bombardment. A simple way to avoid this problem is to run the tipping torch down just behind the pinch seal on the electrode, run it back and forth a couple of times where the final tip off will be. Then drive the torch up the tubulation toward the manifold fork arms stopping just before the seal to the manifold. Go back again to the area where you are going to be tipping off and heat that section a bit more. This procedure is known as "chasing" the tubulation. Rather than using a torch, this can also be done by using a hair dryer on the tubulation. In either case, do not heat the mercury trap. Remember to be careful: the electrode pinch seal and the seal to the manifold are both areas that can easily break from heat stress.

An Alternative Method: External Heating

An alternative method is to heat the tubing and electrodes externally. The tubing is heated by placing it in an oven and the electrodes are processed by induction. In some places, this method is business as usual (see Dutch Ovens; *Sign Business Magazine* or www.neonshop.com). There are also situations when internal bombardment just will not work.

Consider the case of a single electrode tube: with only one electrode, there is no way to create an electrical current path through the tube. Some may argue that you can pump a

normal, two electrode tube and then seal it in the middle. Sure, go ahead, but for those living in the real world, consider oven pumping. Oven pumping is also the only solution for tubes with no electrodes or special effect items like crackle tubes and plasma spheres. Oven pumping is also common in other industries such laser and x-ray tube manufacturing.

External heating ovens come in all sizes and styles. Electric annealing ovens used in scientific glass shops work well. Kilns intended for ceramics can also do the job. Many ovens are also custom built to suit space requirements or production parameters.

The Process

All remains the same. Go back and re-read the first half of this paper, but think "oven" instead of bombarder. The criterion is to get the glass and the electrodes hot enough to fully degas. It is also necessary to heat the electrodes with an induction heater so that the emission coating will fully convert.

There are too many variables to prescribe an exact formula, however you will become self-directed by understanding the physical requirements. The general method for oven pumping is to first let the tube pull down for at least 5 minutes. You should be close to the ultimate vacuum with a drift rate of 20 microns per minute or less, even for a large piece. Start heating on LOW. The glass can crack with too much localized heat if you start on high. The temperature will climb between 100°C and 150°C.

The main stopcock is open and you are pumping the piece down now. After the temperature stabilizes (about 15 minutes), switch the oven to high and the temperature will go to over 200°C. Let the glass soak at this temperature for 15 minutes or so, SWITCH OFF THE OVEN, and then carefully open the oven and heat the electrodes one at a time while the main stopcock is still open. During this time, the temperature rarely falls under 200°C.

Close the oven, reheat to 250°C—300°C and soak at this temperature for another 15 minutes. Check your vacuum gauge for best vacuum and drift; that is, by closing the main and noting how quickly the pressure rises, you can tell if you have baked all the bad stuff out of the glass; if the pressure rises any during one minute, you should continue baking and vacuuming the glass.

Filling the Tube

At this point the tube is ready to fill. The temperature on the gauge displays about 50°C to 60°C. The vacuum gauge shows that the pressure has fallen down to one micron or less. Close the main valve and back fill the tube with the selected gas.

Check the tube color with the Static tester or the spark tester at the far end of the tube. Any impurities left in the tube will have been forced to the far end of the tube by the gas rushing in. This is the best indication of the quality of the fill.

At this point, remove the temperature gauge and tip off the unit. The tubulation collapses and separates. This delicate procedure is described in full detail in chapter 15 entitled "Tipping Off Tips" in *The Neon Engineers Notebook.*[1] Now proceed to the ageing table to allow the tube to burn in. There should be no snaking, no flickering, and no funny colors. The tube should be 100% neon red or 100% argon deep purple. The burning in

[1] Jacob Fishmand and Morgan Cook, *The Neon Engineers Notebook* (Northbrook, IL: Lightwriters Neon, 2003).

process should be only for testing or letting the mercury vaporize and not for "fixing" the aforementioned problems. By following the manufacturer's pumping instructions and maintaining a good vacuum system, you will produce long-lasting, non-staining tubes.

Some Odds and Ends On Bombarding

Short tubes can be difficult to pump because the glass heats much faster than the electrodes. This can result in the electrode emission coating not being fully converted. The lack of full conversion can be a source of staining during the life of the tube. The same problem can occur when you are forced to use large 60 mA rated electrodes on a short section of glass. To overcome this problem, the pumping process is modified slightly. Normally we drop the pressure and raise the current at between 150°C and 175°C. We need to move that change point to a low end of the range. At 150°C, drop the pressure and increase the current. In extreme cases, consider moving the change point at 125°C.

Filling Short Tubes

Remember to adjust your filling pressure on short neon filled tubes. During the life of any tube, the gas is slowly absorbed into the electrodes. Short tubes have a lesser volume and therefore will clean up sooner. To avoid early lamp failure, fill to a higher pressure. The recommended pressure posted on most filling charts is for tube lengths around ten feet. As a rule of thumb, add 1 Torr of pressure for each foot short of ten feet.

Tweaks for Quality

Beyond good pumps and sensible manifold design, some benefits in throughput can be had by simply using 6 mm tubulation rather than 5 mm. As always, it should be as short as practical and rubber "vacuum hose" should never be used to hook up your units.

Another very good option is a helium flush. This is done after the tube has cooled and is at the point where it would normally be filling with gas. Backfill with 4 Torr of helium, set the bombarder to the "finishing" mA, and begin bombarding for one minute. During this time, the tube temperature hardly rises and the color remains constant. If there was a problem with the tube, the color would shift at the point of the problem. If there were still some contaminates in the electrodes, then the color of the discharge would change near the electrode. If there were remaining contaminates in the tube, the color of the discharge in the tube would change in the middle of the tube. This method not only gives us a "scrubbing flush" with an inert gas, but it also gives an excellent visual inspection of the tube. After the tube cools, it is filled normally.

Another option to increase tube cleanliness is a simple rinse. Here, rather than filling as normal, we fill to half pressure with the same gas and then open the main and re-evacuate the tube. Then fill normally. What this does is dilute any impurities that may be left in the tube and then pull them out.

Sizing Electrodes

When making tubes that will run on 60 mA transformers, electrodes rated for 60 mA must be used. In addition it is important to balance the mass of the electrode shell to the mass of the glass. If the tube and the electrode diameter are close, you should probably use short shell electrode for glass units up to six feet in length. Use long shell electrodes for glass units that exceed six feet. This rule of thumb will make it easier to get the glass and electrodes to the correct temperatures at the same time during processing.

Pointers on Dirty Mercury in the Tube:

Mercury will chemically react with almost anything with which it comes in contact. If mercury is in a dirty environment, it will pick up unwanted matter and carry it into the tube. The solution to this is to keep mercury clean. Do not store in or dispense it from containers that are not designed specifically for mercury. Glass and stainless steel make the best applicators. Keep your tubulation clean.

How Much Mercury is enough?

For indoor applications and short tubes, a ball that is just big enough to wet the inside of the tubulation is about right. For cold weather and longer tubes that need "excess" available mercury, three or four of these balls would be the right amount. Mercury by itself does not cause mercury staining. Staining is caused by mercury combining with impurities left in the tube. This is dependent on the amount of impurities, not the amount of mercury. Use this "number of balls" as a guideline.

Why Flash a Tube After Filling.

Tube quality can be examined while the tube is still attached to the manifold. This saves the time of tipping off, testing, reopening the tubulation, and rebombarding if something is wrong. Some people believe that flashing dramatically reduces burn in and snaking time. However, if you are using flashing as a "solution" to bad snaking or off color tubes, you need to spend some time and maybe some money evaluating your pumping system or pumping technique.

We prefer to get the bombarder leads unhooked and out of the way for safety considerations, which are always a high priority. It is also faster if you have the leads off, the mica out, and are ready to immediately get the next tube in place to begin bombarding.

Another disadvantage to flashing is that it is not exactly a subtle way to go about checking for contaminates. With so much amperage, small amounts of impurities are instantaneously cleaned up (remember the faster burn in part?) so you do not necessarily get an accurate picture of the purity of the tube.

A good alternative is to check the filled tubes with a spark tester instead of flashing them. This satisfies the safety issue and provides the speed and convenience of having the tube ready to get off the table as soon as it is tipped off.

A better solution is using a battery-powered tube tester. It has all the advantages of the spark tester and will illuminate a lower level of contamination in the tube.

Creating Glassware with a View to Its Destruction

by
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Abstract

This year, 2005, sees the United Kingdom Atomic Energy Authority's facility at Dounreay on the North coast of Scotland celebrate 50 years of existence. This paper provides an overview of a selection of glass apparatus created by the team of "in-house" glassblowers during that time. The plants have now commenced their decommissioning phase to be completed in 2036 and this paper addresses the change in approach of satisfying the customer's glass requirements, taking into account the need to reduce waste. In addition, an approach to dismantling and destroying certain items of glassware while preserving selected items is highlighted.

Introduction

The United Kingdom Atomic Energy Authority (UKAEA) was incorporated as a statutory corporation in 1954 and pioneered the development of nuclear energy in the UK. Today it is one of the world's leading nuclear decommissioning organizations, with more experience of managing nuclear cleanup than anyone in Europe. The UKAEA currently manages the restoration of sites used for the UK's nuclear research and development programme under contract to the Nuclear Decommissioning Authority. Its objective is to restore the sites for conventional use in a safe and environmentally sensitive manner.

Photo 1. *Aerial view of the UKAEA Dounreay Site - 2004.*

Dounreay pioneered the development of fast reactor technology. Now that this mission is complete, Dounreay is pioneering the decommissioning of the nuclear research site.

- The site was opened in 1955 and three reactors were built over the next 20 years – the Dounreay Fast Reactor (DFR), Prototype Fast Reactor (PFR) and the Dounreay Materials Test Reactor (DMTR). All are now closed and being decommissioned.
- Management at the site is now focused on decommissioning the reactors and the ancillary nuclear facilities, and the restoration of the environment. The cleanup programme will be completed by 2036 at a cost of £2.7 billion.
- Built on some 135 acres, the change from operations to decommissioning has led to a substantial increase in employment in recent years. Some £80 million is injected into the economy of the Scottish Highlands each year as a result of decommissioning.
- UKAEA manages and operates Dounreay under contract to the Nuclear Decommissioning Authority.
- The Dounreay Site Restoration Plan is probably the most comprehensive for the restoration of a major nuclear site in the world. It is a significant milestone in nuclear decommissioning. The plan integrates the many separate activities of decommissioning, fuel treatment, waste management and land remediation to allow the work to be done progressively, efficiently and according to an ambitious but achievable programme.

An important element in decommissioning nuclear facilities such as Dounreay is the categorisation of waste. The higher the radiation level of waste, the more expensive and labour intensive the sentencing and treatment is. The majority of glassware produced at Dounreay is used in either low radiation level environments or does not come into contact with any radioactive material. Very few items were designed for high level radiation work but a significant amount was used in areas with intermediate radiation levels. These areas include remote handling cells where specific designs of glassware were requested.

Photo 2. *Artist's impression of the Dounreay Site in 2035.*

This was an important aspect to consider when making glassware as the handling was carried out by mechanical manipulators and not human hands. In addition, surplus items such as glassware which was no longer needed was held in the cells, as at the time this was preferred to immediately processing the glass as waste. Over a period of time, cells could get quite cluttered with various glass items that were no longer in daily use. The cost of processing intermediate waste at 2005 prices is £40,000 to £50,000 per cubic metre compared to £25 per cubic metre for waste that has been proven to be free from radiological contamination hence the importance of maintaining the amount of materials such as glassware to a minimum.

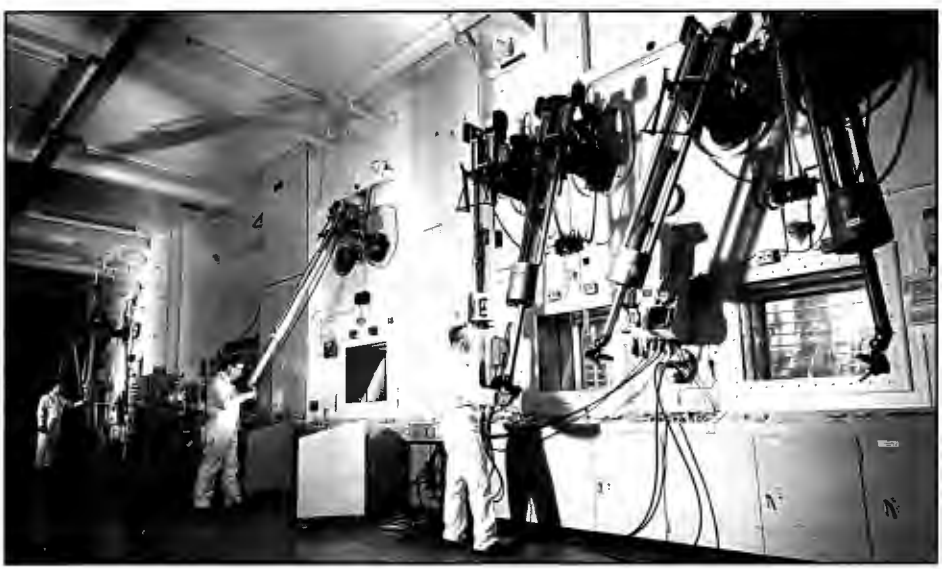

Photo 3. *Remote handling cells.*

Design of apparatus used in remote handling cells had to consider access to such cells through an "air-lock" which led to the optimum design always being of a modular nature. This seeming limitation on creativity actually benefited decommissioning through objects being easily dismantled at the end of their use.

Unlike a number of organizations that have a high demand for glass repair work, this does not happen at Dounreay. One main reason is the nature of the physical environment where the glassware was in use. Although glassware can be radiologically decontaminated, this is dependent on the complexity of design and may not be cost effective in many situations. In addition, there is a perception by the public and media of nuclear issues, meaning that regardless of the evidence of the "cleanliness" of an item, it will always be seen as "dirty."

Organizations such as "LabAid" which is a registered charity dedicated to aiding science education in developing countries will gladly accept redundant glass apparatus.

The Dounreay Glass Department

There has been a scientific glassblowing workshop at Dounreay in various locations and arrangements since the nuclear facility was first constructed. Originally situated outside the main perimeter fence, the Glass Department has now been established for the last

thirty years within the 'Fuel Cycle Area.' This location is close to the majority of customers who are based in the chemistry laboratories. At the height of research and development at Dounreay, which was in the 1960's and 1970's, up to six scientific glassblowers were employed in the Department. Overtime and shift working were common and work was contracted for other establishments in the region such as colleges and schools. In 1963, the volume of requests for work to the Glass Department accounted to just over one thousand. Over the years this has dramatically reduced to an average of ten.

Photo 4. *Dounreay Glass Department.*

I joined the UKAEA at Dounreay as the senior scientific glassblower in 1981, and was responsible for the management of the Glass Department which at that time employed one trainee glassblower. Coinciding with my arrival, the Department enjoyed an investment of new equipment including a 'Heathway' lathe replacing the older 'EXE' lathe. This machine proved to be vital in responding to requests from many chemical engineers. A large amount of glass process plantware was modified and created. In order to fulfill such requests, the lathe benefited from having a large enough bore such that six-inch glass process pipes could easily pass through. Complementing the lathe, other equipment includes two annealing ovens, various drilling tools, four other work stations with bench burners (turret pre-mix), a lapping wheel, two cutting machines with diamond wheels and a small bench lathe.

In 1993, it was noted that the workload of the Glass Department had fallen to a level where justification could not be made for the continuation of the Department as it was. To address this and to demonstrate a flexible and efficient use of staff resources, my role as a scientific glassblower was combined with the duties of being a record manager. This arrangement has worked extremely well, helped chiefly by the fact that the Glass Department is situated next to the Archiving and Records Office. The demand for archiving and record retrieval has grown hugely over the years to the point where the same number of people are employed in the Records Office that were employed in the Glass Department during the 1960's!

Glassware Produced Prior to Decommissioning Plans

This paper does not concern itself with the effects of radiation on the glassware discussed. A fully comprehensive article published in *Fusion*, in February 1962 by P. S. Rudolph entitled "The Irradiation of Glasses" fully addresses this. Of particular interest here is the approach to the design of the glassware.

There was a tendency in the early days of Dounreay for scientists to constantly challenge the Glassblowing Department with requests to manufacture complex apparatus without consideration of cost or need. Requests for single items were rare; normally five or ten spares were always demanded at the same time. These surplus items were never used and

ended their days in laboratory store rooms, drawers or cupboards. Size of glassware was never an issue; the bigger the better seemed to be the rule of the day. The main customers were developing techniques for reprocessing nuclear material and a lot of glassware was constructed from components of QVF ("Quick Visible Flow"). Some of these items were customized in the Dounreay Glass Department. A lot of this work was created by then Head of the Glass Department, Keith Goodchild, who developed valuable work on glass to ceramic sealing and on producing rectangular section tubing prior to his leaving in 1979. The following is a list of some glasswork typically handled at this time, essentially between 1960 and 1990.

Some examples of the glasswork carried out by the Dounreay Glass Department are listed here:

- Hand lamp work *in situ* focusing on confined space working and in "hostile" environments. No blowing by mouth was possible in these circumstances.
- Sealing metallic samples in silica capsules under vacuum. Use of vacuum rig in Glass Department with connections through the use of interchangeable joints and sealing wax. This was prior to the days of PTFE valves, etc.

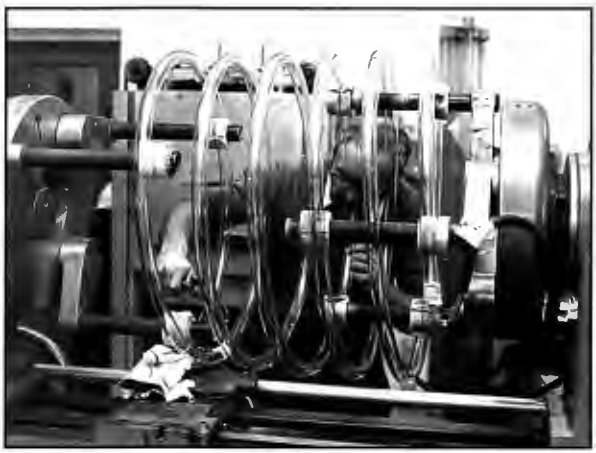

Photo 5. *Keith Goodchild working on a large diameter coil.*

- Cutting grinding and polishing lead glass windows used in radiation shielding positions. Occasionally the polishing of glass was on the interior of the window and involved remote handling of an air-driven polisher as no electrical power was permissible.
- Calibrating and marking vessels in such a way that identification was prominent enough to be observed through four foot thick windows by operators using binoculars.
- Pipettes using glass to metal seals using adhesive for connections to create a robust device to withstand handling by mechanical clamps.

Photo 6. *Constant Volume Feeder.*

- Large process plant adaptations, commonly six and eight inch diameter. Size dictated by size of annealing oven but extra capabilities were made available at other sites of UKEA

in the South of England. This involved flying to London with tools and some raw materials then flying back using UKAEA's own charter air service and runway at Dounreay. Photographs 5, 6 and 7 illustrate this type of work.

- Ceramic to borosilicate seals to create a safe handling device for bell jars.
- Distillation apparatus, some of which used soda joints.
- Vessels with electrical conductive coatings.

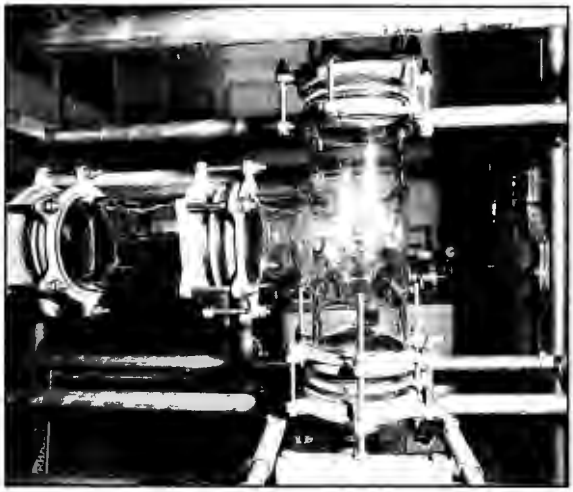

Photo 7. *Large tee joint in glass process plantware.*

A majority of work referenced in the list could have been adapted by forethought by the customer and by design from the glassblower. This would have resulted in using less glass and by eliminating surplus spares. As an example, a particular type of pipette used 10 mm diameter tubing with each item being 150 mm long. By reducing the diameter to 6 mm and the length to 100 mm, the savings in waste amounted to between £500 and £1000 per year. This does not take into account the saving to the environment in quality terms.

Glassware Produced Following Commencement of Decommissioning

Photographs 8 and 9 highlight the design adaptations incorporated in two typical items of glassware made at Dounreay in response to customer's wishes to ensure disassembly would be simple. The Toepler Pump uses screw thread connectors and conical joints instead of permanent glass seals. As this pump is part of a large vacuum system which was installed in a cell, ease of assembly and eventual removal was paramount. If the rig had been constructed using traditional hand lamp work, removal from cells would have created unnecessary work. By using jointed glassware, dismantling the rig became a straightforward task.

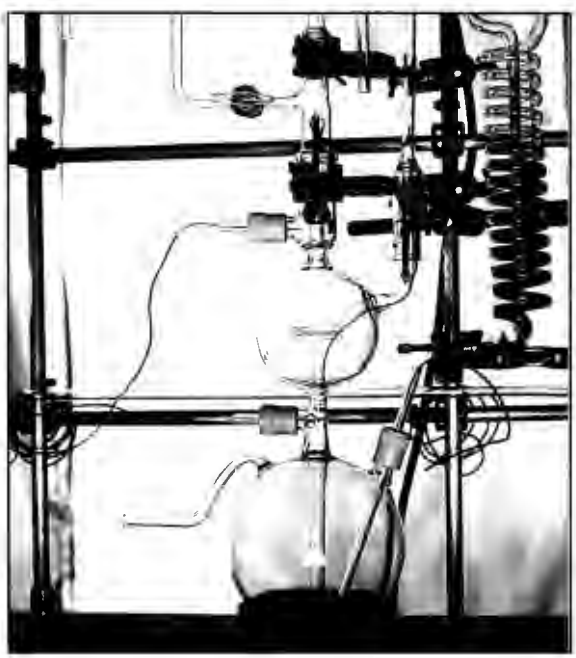

Photo 8. *Toepler Pump.*

In photograph 9, the arrangement uses spherical joints and clips to great advantage. The clips have been proven over years of operational use with mechanical manipulators to be trouble free, and again, at the appropriate time, disassembling the object was without any significant problems.

Other types of work which demonstrate the change in producing glassware following commencement of decommissioning are:

- Large flanged lids with inlets using screw threads.
- Vessels with internal seals replaced by joints with "dip legs."
- Micro glass apparatuses.
- Flat flanged glass connectors with quick release clamps.
- Simplified designs with minimal surface complexities.

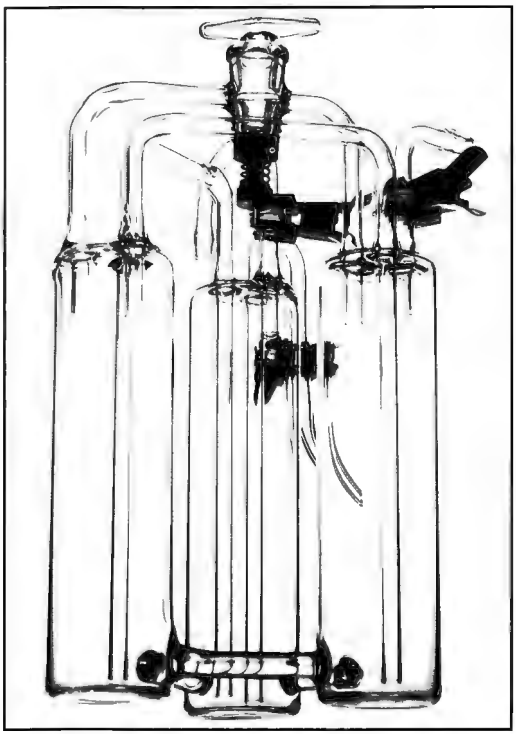

Photo 9. *Arrangement with spherical joints and clips for remote handling.*

Specific Examples Highlighting Different Approaches of Glassworking Pre- and Post-Decommissioning

Glassware known as mixer settlers were used extensively throughout the development phase of Dounreay's reprocessing activities up until the 1990's. Many designs considered took into account the purpose of the item which is to study solvent extraction. Mixer settlers form an important part of the Fast Reactor Reprocessing Plants at Dounreay and are constructed from stainless steel for active work. The glass mixer settlers were used under laboratory conditions, sometimes in fume cupboards or cells with remote handling devices. Early designs incorporated many seals both internal and external. Sizes varied, but twenty-four inches in length was not uncommon. Construction times were extensive and

Photo 10. *Ian Pearson working on a mixer settler.*

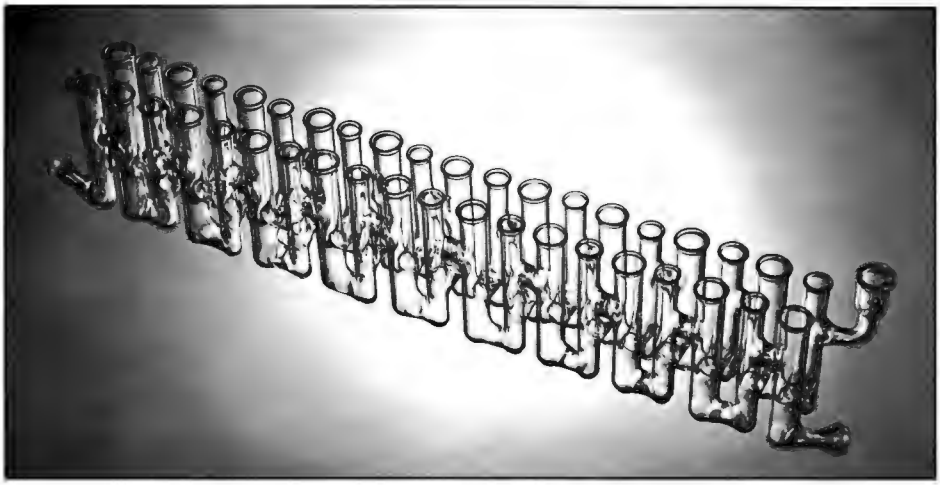

Photo 11. *Simplified mixer settler.*

required glassblowing skills of the highest order. A considerable amount of a glassblower's time was occupied producing these items as can be seen in photograph 10. Techniques used included, cutting and grinding, flaring, sealing and testing for leaks. Later designs omitted internal seals in favour of using PTFE tubing positioned in the open ends of the tubes. Results from this design change (shown in photograph 11) were unaffected. Manufacture time was considerably reduced but more importantly less glass was used, thus less glass waste produced.

A need for a higher through-put of material than could be handled by mixer settlers was identified in the late 1970's. The result was the use of pulsed columns and an appropriate facility was built containing six columns: one of 4 cms diameter, two of 5 cms diameter and three of 2.5 cms diameter. The columns were contained in a glove box 11.5 metres high by 6.5 metres wide and 1.2 metres deep. The material used was borosilicate process plantware supplied and installed by Schott. In total there are four cubic metres of glass to remove; photograph 12 illustrates this. The plant is now in a decommissioning phase with the major challenge being the safe removal of the glassware. To ensure that this is carried out with minimal risk, a special machine for crushing the glass has been built. Photograph 13 shows the machine before it commenced work.

Photo 12. *Pulsed Columns.*

It was made by an engineering company a few miles from the Dounreay site in conjunction with development ideas from Dounreay's own staff. This type of business arrangement typifies the cultural shift in work patterns from a time when only Dounreay staff wished to be responsible for activities on site to a state where delegation under Dounreay's specific control is now a favoured option in selected situations.

Photograph 14 shows a simplified version of an item of glassware that is illustrated in photograph 6. The Constant Volume Feeder was first constructed from glass in the 1960's to study how a stainless steel version of the same design operated under certain conditions. Thirty years later, a request to the Glass Department for the same item arrived but was met with a different response. The original item was nearly a metre high and involved complicated assembly techniques. The later version was a quarter of the size, used far less glass, and took a fraction of the time to make when compared to the first one. The end result as far as the customer was concerned is that both versions achieved the desired results. The latter one, however, is the preferred type in regards to reducing waste glass.

Photo 13. *Machine used for crushing glass columns.*

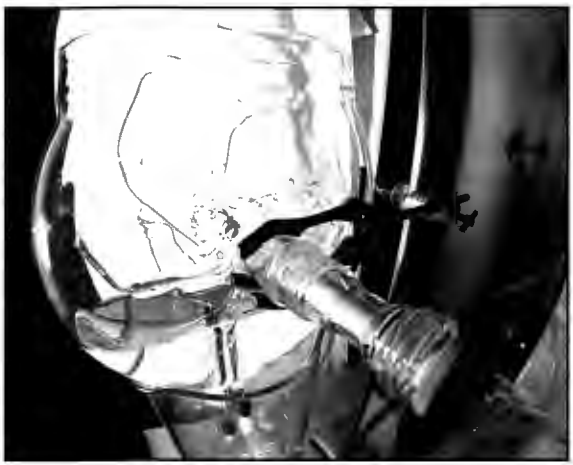

Photo 14. *Small Constant Volume Feeder.*

As is familiar with most people working in glass departments of large organizations, the one aspect of the job that does not appear to be subjected to economising is producing presentation pieces. Photograph 15 shows a retirement gift for a member of the management who was in charge of nuclear re-processing at Dounreay; it seemed appropriate in this case to create a small nuclear reprocessing plant in glass. The completed object was a metre in length by 50 cms wide and 30 cms high. It took approximately four weeks to complete and will not end up as waste!

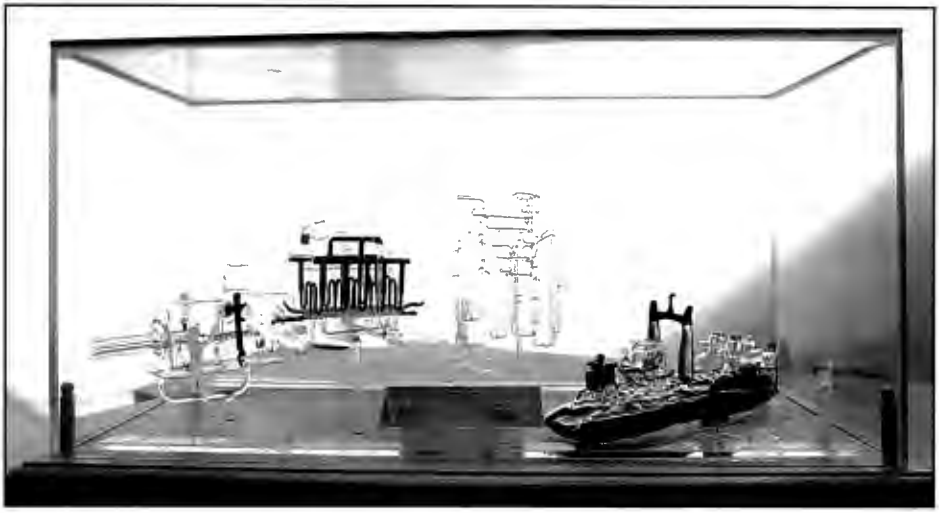

Photo 15. *Glass model of nuclear reprocessing facility.*

Conclusion

The focus of this Paper has been to highlight the changes in working practices and culture experienced through a period of transition in the Dounreay Glass Department. By thinking the "big picture" and seriously considering the outcome of glassware once it has ceased to be useful, design approaches can be adapted to satisfy environmental concerns:

- Think different.
- Think the bigger picture.
- Think about the end life of a product.
- Think about change as being good.

References

The following two websites give further information about the United Kingdom Atomic Energy Authority and in particular Dounreay.
www.ukaea.org.uk/
www.ukaea.org.uk/dounreay/index.htm

More details on the British Society of Scientific Glassblowers can be found on www.bssg.co.uk/

Details of Labaid on www.labaid.org.uk

Credits

I wish to acknowledge the support given to me for this project from my employers the UKAEA and the ASGS for inviting me to present this paper at their 50th Annual Symposium. In addition, special thanks go to "Johnson Controls" Graphic Services-Photographic Department at Dounreay for providing the photographs used in this paper.

A Day in the Life of a Scientific Glassblower

by
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Abstract

In the last 35 years as a research scientific glassblower, I have received quite a few very unusual requests. I would like to share some of the most interesting ones and use them to illustrate the life of a scientific glassblower. At the same time, these cases will serve to illustrate the conception and the creation of those pieces and some glassblowing techniques that were used to solve those special problems.

Going beyond the obvious

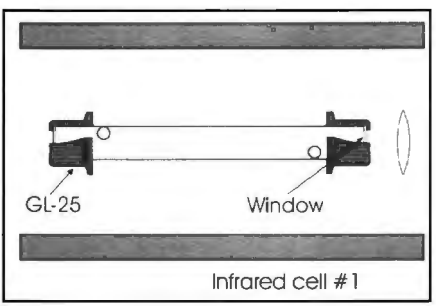
Construction of the largest possible infrared cell that will have to fit in a limited space.

For a specific research project, an infrared cell was needed; it had to be built quickly, with easily replaceable windows and had to contain **as much solution as possible**.

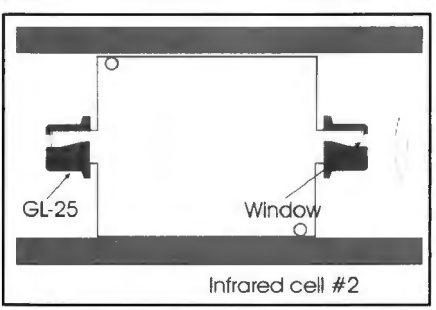
I decided to use 2 GL-25 since they were just about the right size and their design matched the requirements very well. (Cell #1)

In order to increase the volume of the cell, an obvious solution was to increase the diameter up to the maximum available space; the volume it contained was many times larger than the original cell, but I thought that one could make it larger still... (Cell #2)

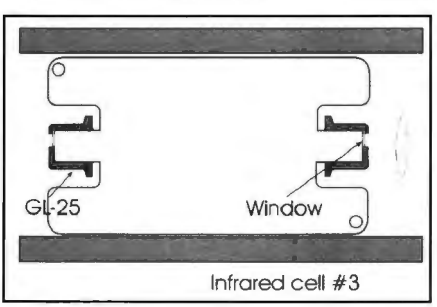
A better solution was to go beyond simply enlarging the tube as in the previous picture, but **rather to extend the increase all along its length**. (Cell #3)



Infrared cell #1



Infrared cell #2



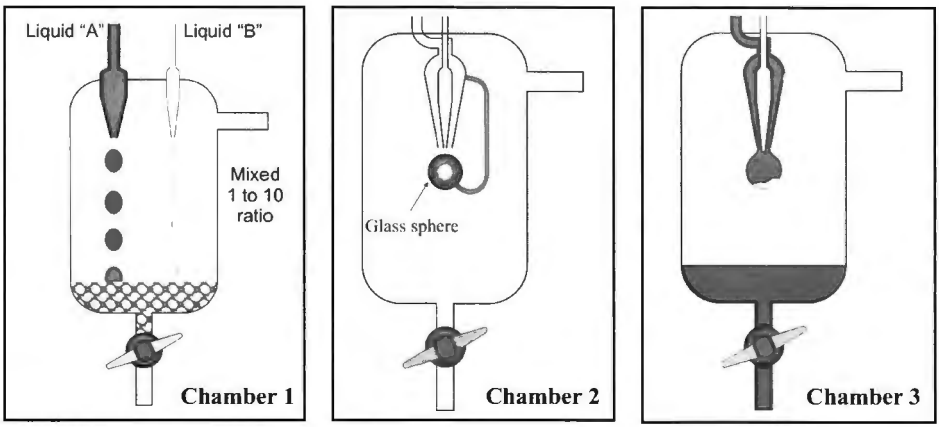
Infrared cell #3

Innovative Design

Construction of a new mixing chamber for the preparation of a polymer initiator.

A MIXING CHAMBER. For a research project, it was necessary to mix very quickly two polymers in a precise ratio: 1 to 10. A chamber was built with two injectors calibrated in the proper ratio and then the liquids injected. Unfortunately, despite fast agitation with a stirring bar, the two materials did not mix well and formed lumps. (Chamber 1)

I figured that if the two polymers came very fast as a very thin layer over a glass sphere, they would have more surface area to stay in contact and therefore a better chance to mix properly. (Chamber 2)

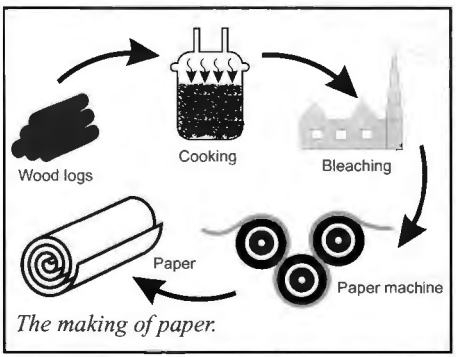


An injector with the proper ratio diameters was welded over a glass sphere into the chamber that was furthermore evacuated to decrease the surface tension. The two stopcocks were opened simultaneously and the two liquids became thoroughly mixed. (Chamber 3)

One Complete Project

Designing a new apparatus to measure the absorption level of "Kraft liquor" into a wood sample.

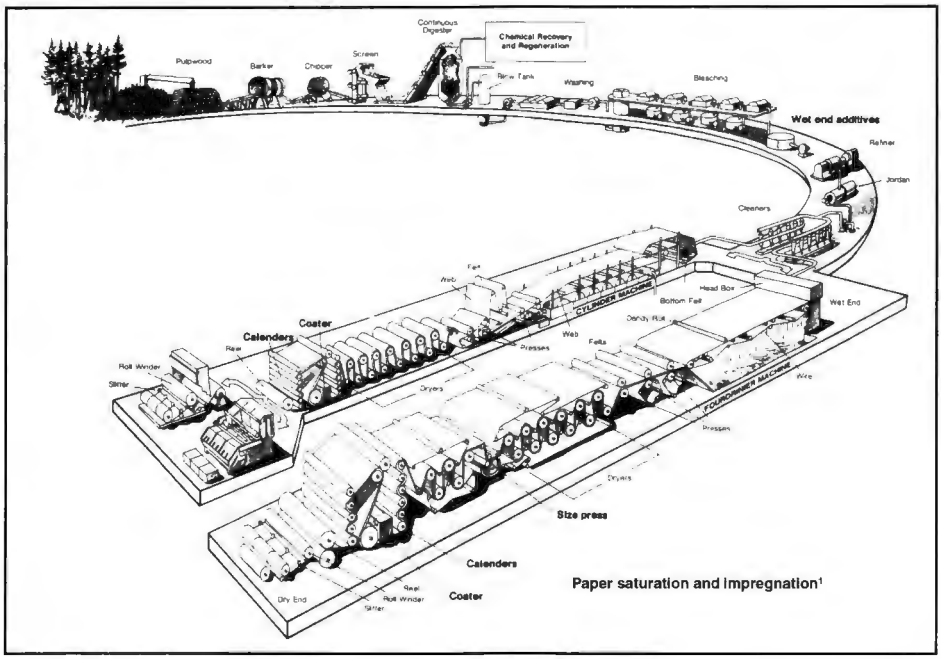
"The making of paper is a long and complex process involving many steps. Probably one of the most important steps is the possibility to analyse rapidly the potential yield of a given batch of wood pulp. To understand the project, it is necessary to know what is involved in the preparation of the pulp that will become the paper. The following two schematics will attempt to simplify the many steps involved in the manufacturing of paper.



The making of paper.

PULPING. In a chemical pulping process, heat and chemicals are added to wood chips in a pressure cooker called the digester. In the Kraft process, an aqueous solution of sodium hydroxide and sodium sulfide, known as white liquor, selectively dissolves the lignin and makes it soluble in the cooking liquid. After two to four hours, the mixture of pulp, spent pulping chemicals and wood waste is discharged from the digester.

For this project we are interested in the pulping process part of the making of the paper. When paper mills receive a new batch of wood they have to determine the optimal concentration of the liquor and how much surfactants they have to use according to the type of wood: each type, like heartwood, sapwood, soft and hard wood requires different formulas. Hence the need to determine quickly the optimal ration of surfactant and liquor that will yield the best result.



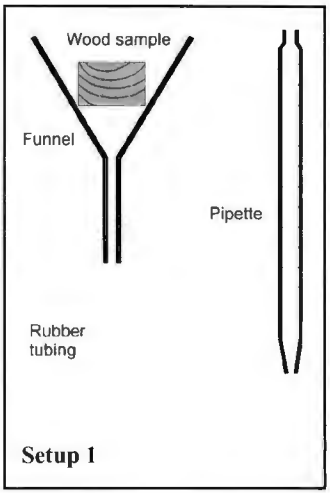
For each type of wood, an optimum formula has to be determined by a series of experiments. To find that optimum formula, the technicians will have to chip the wood into small particles, then cook them in the Kraft liquor in a digester for four hours. Several analysis of the pulp will need to be conducted over the course of one week. Four or five formulas will be tried and verified for the best yield. The entire process takes four or five weeks. For **each** experiment, large quantities of wood (1 kg) and 3 liters of liquor are needed."[1]

THE RESEARCH PROJECT. Dr. Julan Zhao of the Pulp and Paper Research Center at McGill University wanted to devise a new simpler method to achieve the same results while using much less material and giving the requested results quickly. Furthermore, that research would provide interesting results on the liquor penetration theory and the effect of the surfactants in the penetration. For this purpose, Dr. Zhao asked me to build a special glass apparatus to measure the amount of absorbed liquor into the wood over a period of time at a controlled temperature.

This is what the scientist came up with to test if it could be possible to see if the "Kraft" liquor would penetrate into the wood by capillarity and whether it could be measured. I realized how cumbersome it would be to zero the level and fill both sides at the same time. After several drawings I came up with the following idea. (Setup 1)

[1] http://www.energysolutionscenter.org/GasIRPaper/Learn%0About/Paper_Manufacture.htm#TheKraftLiquorCycle

MY SUGGESTION. It became apparent to me that an O-ring joint would make a good seal between the wood and the liquor. Then a double wall tube would maintain the liquor at the required 80°C. Direct reading at regular intervals of a 5 ml pipette would show how much liquid had been absorbed by the wood then a graph could be plotted. A reservoir would permit filling both sides at the same time and the use of a GL-14 would permit vertical adjustment for "zero-ing" the pipette. (Setup 2)



Setup 1

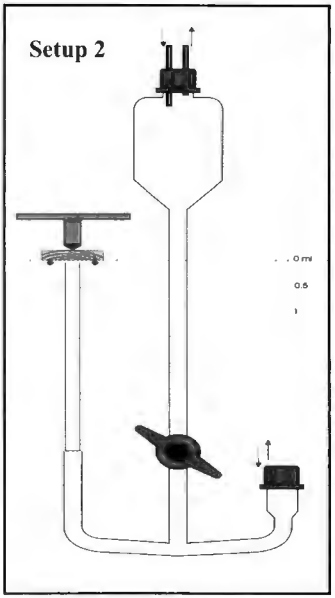

Setup 2

Photo 1 shows the first apparatus built according to the drawing. The wood sample will be held over the O-ring with a Teflon piece, the bottom chamber will be heated to 80°C. After some time, the liquor will penetrate the wood sample and the quantity absorbed will be measured from the graduated pipette on the right.

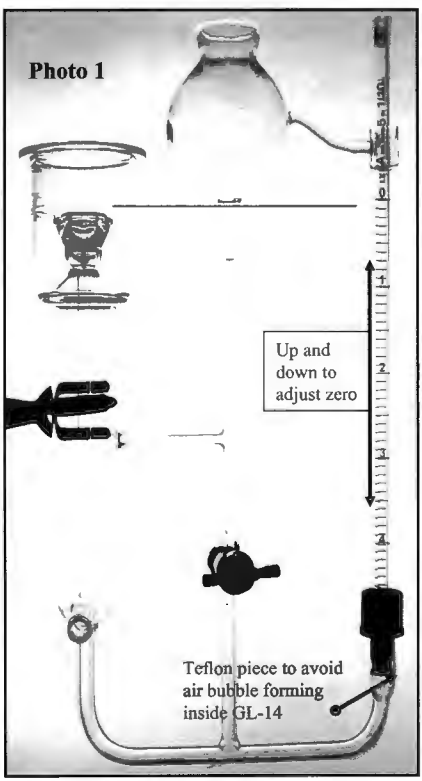


Photo 1

Photo 2 is of the assembled setup: the wood sample in place over O-ring and held with Teflon piece. After several experiments it became apparent that there was a large gradient in temperature between the liquor inside the O-ring area and the thermostated chamber. It would be more efficient if the O-ring joint was welded inside the chamber.

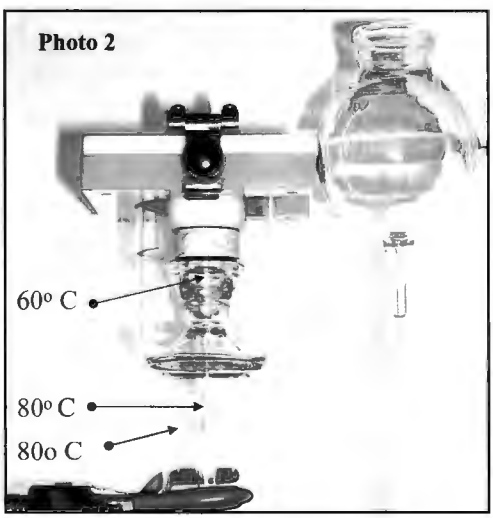
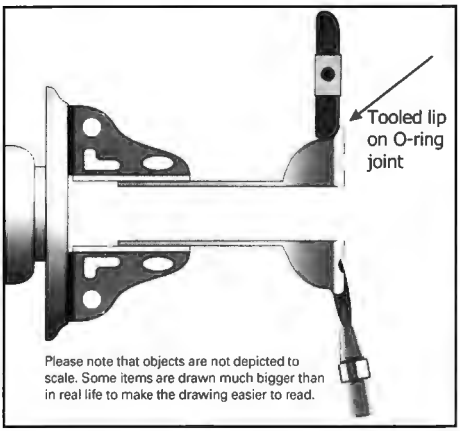
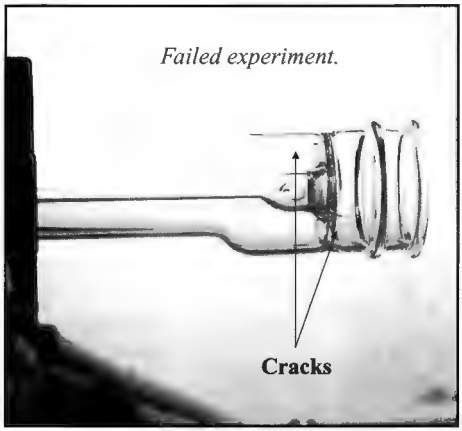


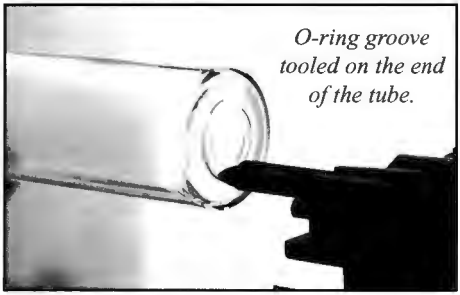
Photo 2

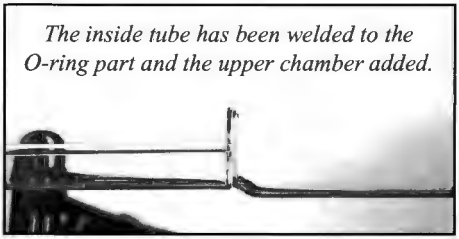




Knowing that it would be very difficult to weld directly an O-ring joint inside a flat bottom, I tooled a "lip" on it that I thought would give a smooth transition to the flat bottom. I attempted to weld it inside the double wall thermostated chamber but without success despite several attempts.

Since I was not successful at attaching an O-ring joint directly inside the double wall, I figured that it may work better if I tooled the O-ring groove directly on the end of the inside piece. In order to make it the exact size I copied the shape with my regular up and down tool.





Detail of O-ring groove.

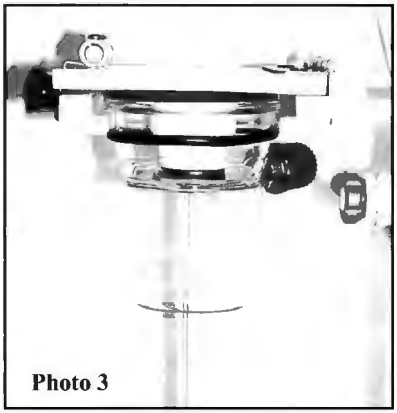


Photo 3

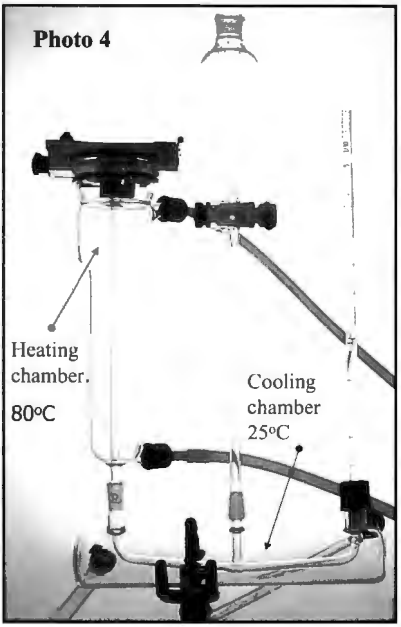


Photo 6

In Photo 3, one can see the wood sample in place over the O-ring and kept in place by a Teflon cover.

Photo 4 shows the completed apparatus. This time the liquor was kept at the same temperature as in the heating chamber. An extra chamber to cool down the liquor was added in between the heating chamber and the pipette measuring the absorbed liquor.

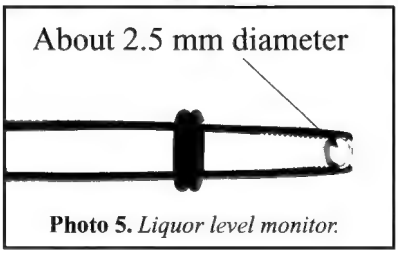
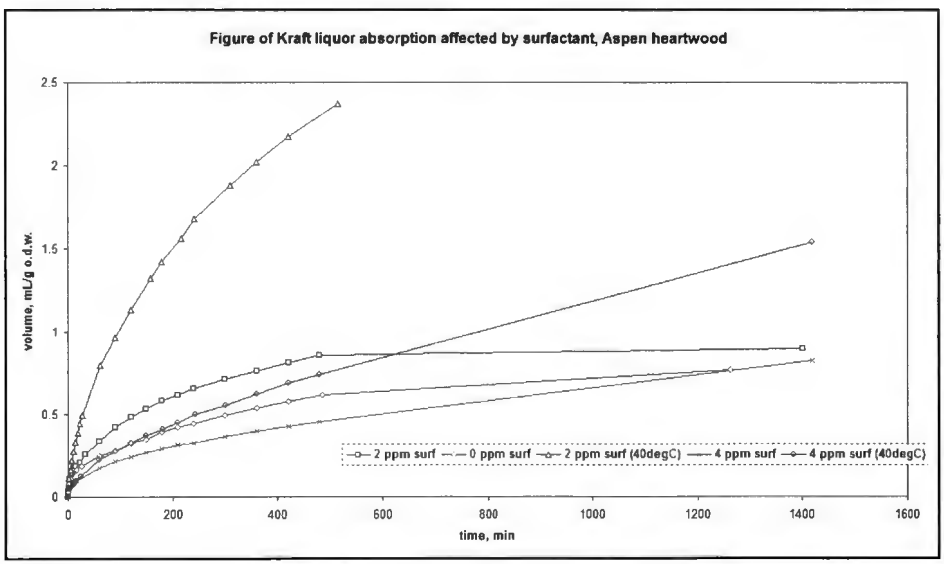


Photo 5. *Liquor level monitor.*

In order to automate the process, I thought to insert into the pipette a small glass sphere with a colored liquid that would follow the level of the liquor as it is absorbed into the wood.



One experiment's results.

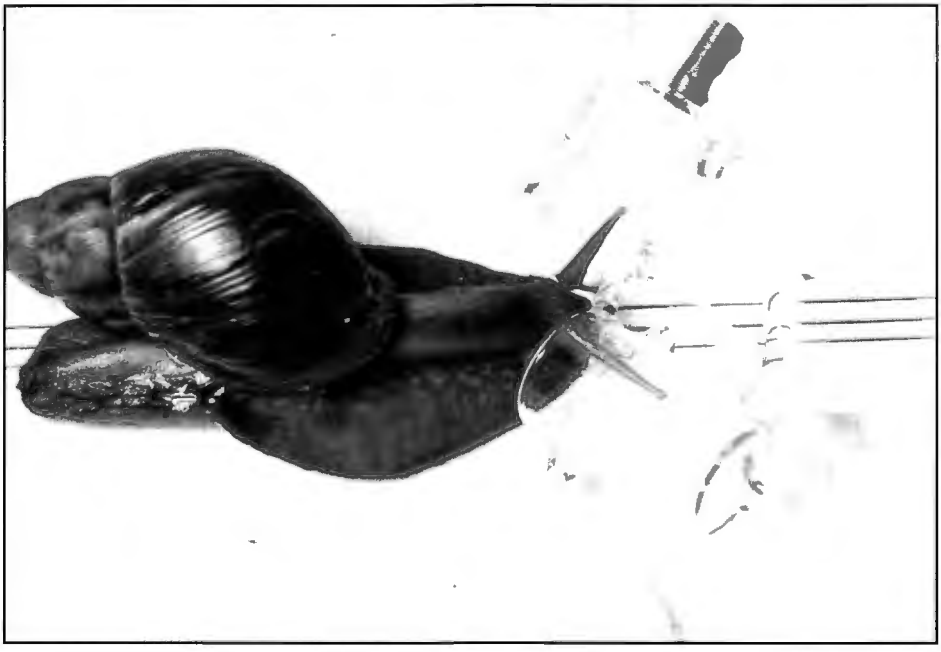
Sensors will be positioned along the graduated pipette every 1/2 ml and the signal sent to a computer at regular intervals to plot the curve giving the amount of liquor absorbed over time.

In order to make such a small glass sphere, I used a Pasteur pipette made of soft glass (easier to blow out fast) then evacuated the small bulb and sucked the reference liquid into it. (Photos 5 and 6)

This new apparatus requires only 30 ml of liquor and 4 g of wood sample versus kilos of wood and liters of toxic liquor and, even better, instead of the conventional five weeks of work, the experiment is completed in about only one week. So it is a substantial gain of time, resources and less pollution into the environment.

The funniest project in my life as a research glassblower.

One professor wanted to measure the sensitivity of snails to pheromones, the sexual hormones released in the air by creatures to attract potential mates. He came up with the idea that if one would inject male and female pheromones in the proper ratio around the tentacles he could "make" the snail "walk" straight on graph paper. So I built a kind of hat for the snails with four ports for introducing pheromones and two exhaust tubes to pump out the pheromones.



A glass hat to measure the sensitivity of a snail to pheromones.

Conclusion

Despite being sometimes frustrating, the life of a scientific research glassblower offers many challenging and rewarding experiences, if not hilarious at times.

Quick and Easy Graphite Form Building

by
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Abstract

This paper will cover an easy method to duplicate shapes by creating graphite forms using only a draftsmen's Flex-Curve, sabre saw and a sanding drum mounted to a drill press. I will discuss layout, cutting and finishing of forms and touch briefly on graphite grades and what we have found the best to use. To finish, I will cover tips and methods of using these forms.

The objective of this paper is to show a method of how to manufacture and duplicate glass shapes easily, quickly and accurately by using graphite forms.

When a customer of ours came to us and asked if we could precisely reproduce small quantities of multiple shapes of wax forms that they had made of some prototype pieces, we had to come up with a quick and easy way. First we knew that the form would have to be made of Graphite to withstand the multiple heatings and direct fire contact it would receive. Secondly, we knew that for ease of use it must be adjustable. Lastly, with the size of the pieces we were duplicating, we had to adapt this to one of our lathes.

After contacting one of the lathe suppliers, we were supplied with an adjustable rack and pinion unit that would mount onto the fire carriage of our Woodland lathe. We modified

Adjustable rack assembly mounted to lathe fire carriage.

Modified arm holding graphite form on tube centerline.

the rack assembly with an arm that would allow us to hold up to a 5/8" thick graphite sheet (form) on the centerline of the glass tube and raise and lower it to the glass. (Photos 1 and 2)

We discovered that laying out and making the forms was rather easy and quick to do by using only the following materials and tools: 1/2" to 5/8" thick graphite plate, draftsman's flex curve, grease pencil, saber saw, drill press or drill, sanding drum with medium sand paper and fine wet sand paper.

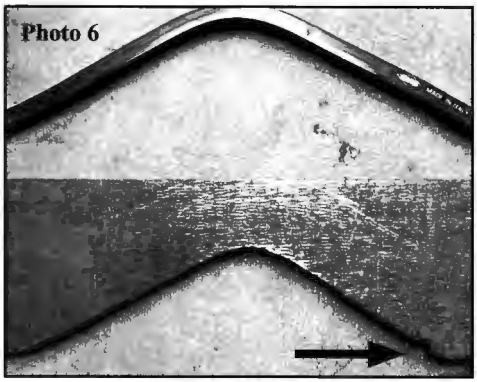
To start laying out the form, the first thing that you must do is decide which size tubing best works for the shape you are trying to form. The key is to use a tube that will allow a portion of the tube on each end of the form to be used as a bearing surface onto which your form will ride, therefore, allowing your shape to come out consistently the same. Some more intricate shapes require a larger tube; part of the form must be then lowered into the tube and part of the tube blown into the form. However, I have found that most shapes can be made from a tube smaller than the smallest diameter of the shape you are reproducing and blown out into the form. This includes the sample globe shown in Photo 3. After selecting the tube which you are going to use, draw a line (with a grease pencil) horizontal to the bottom of your graphite sheet that indicates the edge of your tube. The sample globe shown requires that one side of the finished shape is larger than the other so another line is drawn indicating the diameter of the larger top opening. Next, the draftsman's flex curve is shaped to the sample, and with the grease pencil, marks are placed on the flex curve corresponding with the diameters laid out on the graphite plate. (Photo 4) Carefully remove the flex curve from the sample and lay it on the graphite plate matching the marks you placed on the curve with the corresponding lines drawn on the plate. Use the grease pencil and draw the shape onto the graphite plate. (Photo 5)

Sample Chandelier Globe.

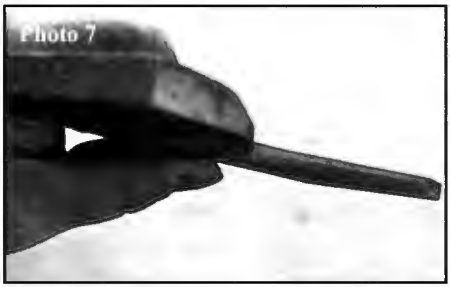
Forming Flex Curve to sample.

The form is now ready to be cut out. In doing this, cut to the inside of the line so that the form can be sanded for the final fit to

Scribing shape to graphite plate.

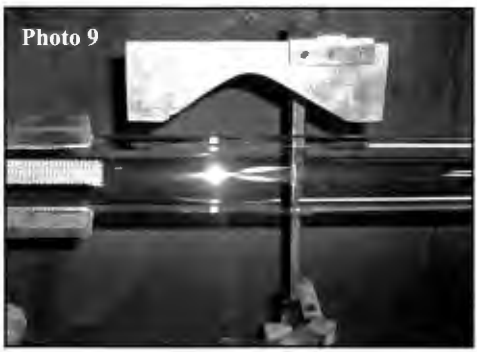


Cut out form.



Beveled edge on form.

Final test fit.

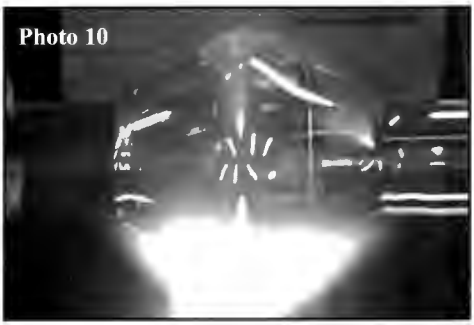


Mounted and adjusted form.

the sample. A notch is also cut in the form (see Arrow) corresponding with the larger top opening. This will place a mark on the glass when blowing up the glass into the form and indicate where the top of the shape will later be scratch cut. (Photo 6) Now that the form is rough cut, use the sanding drum mounted in a drill press or drill and sand the form to the lines on the plate, test fitting it often to the sample. On the back side of the form, sand a bevel approximately half the thickness of the plate and 3/8" high on the back of the plate along the edge of the shape. (Photo 7) This allows the glass to flow to the form and not catch on the edge of the form. To finish off the form, use wet sand paper and slightly round the edges and smooth out all the glass contact surfaces of the graphite form. Do a final test fit against your sample and you are ready to proceed. (Photo 8)

With the form finished, it can now be mounted into the adjustable rack assembly and adjusted to ride directly on the top center of the glass tube and making contact with the tube on both ends of the form. (Photo 9)

With the form mounted, the glass can now be heated and blown into the form. Below are several key things that help in this process. Use a soft bushy flame getting only a light color in the glass and slowly enlarge tube while feeding in lathe tailstock to maintain tube wall thickness. Blow glass softly against form. (Photos 10 & 11) With the main shape re-



Gathering and forming shape.

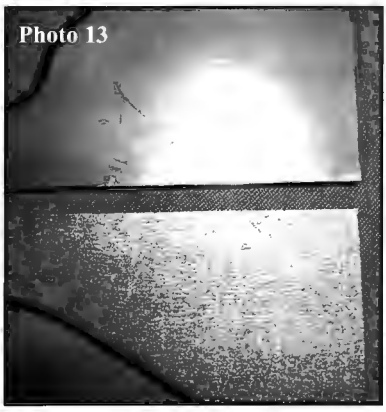
Finished main shape.

produced, a straight carbon is now installed into the adjustable form holder and set to the angle to form the bottom of the shape. (Photo 12)

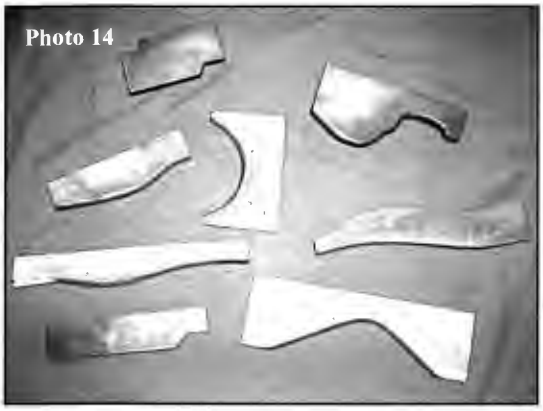
Finished shape.

NOTE: There are several different graphite grades available for use when creating forms, and they all have pros and cons. Coarse and medium grades are good for rough forming and small runs but the material burns away quickly. These are the least expensive to purchase. Fine grade high density graphites provide a finer finish, are more durable and last much longer but they can be costly. (Photos 13 & 14)

In conclusion, this setup has allowed us to broaden our abilities and to quickly and easily duplicate shapes individually or in large quantities with minimal time and effort.



Fine grade (top)
medium grade (bottom).



Miscellaneous forms.

Glasses at the Edge of the Envelope

by
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Evanston, IL 60202

Abstract

In the quest for improved performance, glass makers have developed formulations that span a very wide range of properties and workability. Levitation melting further expands the envelope of glass formation by eliminating crucible-based nucleation and allowing very fast cooling of liquid drops less than a millimeter in diameter. This paper reviews levitation melting techniques, preparation of some silica-free oxide glasses, and describes development of "REAl™ Glass," a family of glasses based on rare earth and aluminum oxides that have useful optical properties for applications in infrared and laser equipment.*

Introduction

Almost all commercial glasses are made from molten materials that are processed in a furnace and cooled to make glass products.[1] Subsequent glass working such as molding, fusing and fiberizing is performed at temperatures slightly above the glass transition. In the working range, the glass becomes a viscous, supercooled liquid. As long as crystallization does not occur, the glass reforms when the article is cooled.

Liquids that easily form glass are sometimes classified as "strong" liquids.[2] As shown in Figure 1, strong liquids have a nearly linear relationship between logarithm of viscosity and reciprocal temperature. The result is that the glass has a relatively long working range and can be processed easily. Strong liquids usually contain a large amount of network forming components – typically oxides of silicon, boron, phosphorus, germanium or tellurium. Most liquids are "fragile" and show a discontinuous change in logarithm viscosity with reciprocal temperature. Fragile liquids are usually difficult to vitrify and, if glasses can be made, they have a small working range. Fragile liquids, however, can lead to interesting new glasses that have useful properties such as infrared transmission, high strength, or high refractive index. Development of new glasses based on fragile liquids presents both a challenge and an opportunity to the glass scientist.

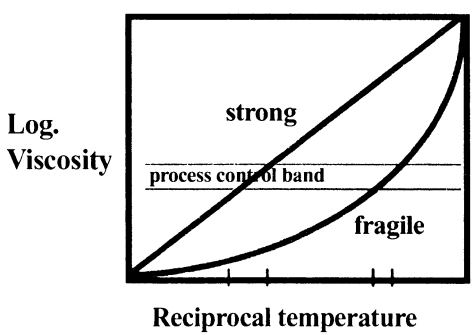


Figure 1. *Schematic plot of logarithm viscosity vs. reciprocal temperature for a liquid. Liquids can be classified as "strong" and "fragile." Strong liquids are often good glass formers. They have a relatively long working range or process control band where their viscosity is suitable for forming operations. Fragile liquids are usually poor glass formers and have a relatively small working range. The marks on the bottom axis indicate the relative working ranges for strong and fragile liquids.*

*** REAl™ Glass is a trademark used by Containerless Research, Inc.**

Levitation Melting

We have used "levitation melting" or "containerless processing" to control liquid phase processing and to study glasses made from extremely fragile liquids. Some of the reasons why levitation melting helps in studying glass are illustrated in Figure 2.

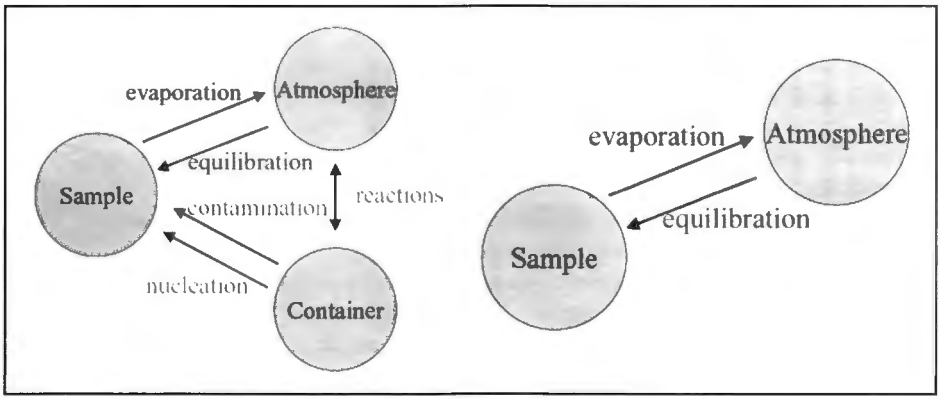


Figure 2. *Left – normal processing in a container introduces sources of contamination due to reactions with the crucible and sources of nucleation that can prevent glass formation. Right – levitation eliminates the container (containerless processing) to allow the synthesis of new glasses and studies of high temperature liquids without contamination.*

The methods for levitation melting require that a force equal and opposite to the weight of the levitated material is supplied by the levitator. Formally, the balance of forces required for levitation can be described by the equation: $\boldsymbol{F = -mg}$.

Where $\boldsymbol{F}$ is the levitation force, $\boldsymbol{m}$ is the mass of the object being levitated and $\boldsymbol{g}$ is the force of gravity. Much of the development of levitation equipment was done in work with NASA. In space, gravity forces can be much smaller than on earth making levitation easier to achieve with small forces. Also, much of the matter in the universe is in effect "levitated" in outer space. Levitation experiments on earth provide a way to study the kinds of processes that occur in formation of planets and evolution of natural glasses.[3]

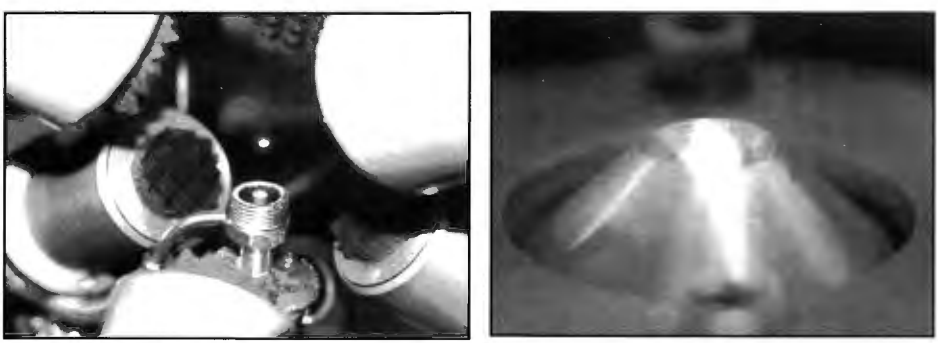


Figure 3. *Left – photograph of an Aero-Acoustic Levitator (AAL). The white dot near the center of the image is a ~0.3 cm diameter drop of molten aluminum oxide heated by a laser beam. The tube-shaped pieces are the six acoustic transducers and the gas jet that provides lift is vertically below the sample. Right – close up view of an aerodynamic levitator with a ~0.3 cm diameter drop of molten aluminosilicate material.*

In order to make a practical laboratory levitator, a source of the controlled levitation forces are needed. For good electrical conductors such as metals and alloys, electromagnetic forces can be generated with a high frequency power supply. For poorly conducting oxides, like most glasses, aerodynamic, acoustic, electrostatic and magnetic forces have been used separately or in various combinations to levitate 2-5 mm drops of liquid. In our high temperature experiments, we use a 500 Watt carbon dioxide laser beam to heat the levitated sample to temperatures up to 3000°C in some cases. Pictures of molten oxides levitated in an aero-acoustic and an aerodynamic levitator at CRI are shown in Figure 3.

Glass Development

CRI scientists have been using levitation melting to study molten oxides for about 15 years. A major part of the work has been investigating how liquids change their properties and structure to form a glass. The work has been mainly on fragile liquids and oxide materials. Examples of some early glasses based on rare earth aluminates are shown in Figure 4.[4] The rare earth aluminate glasses are useful because they can "host" large amounts of laser active ions and make good laser materials with properties similar to the crystalline yttrium aluminum garnet (YAG).

Containerless processing enables the formation of supercooled liquids that cannot be made by other means. A few years ago, CRI scientists demonstrated that glass fibers can be pulled from supercooled fragile liquids by using a small tungsten "stinger" inserted into the liquid to draw out a fiber.[5] The glass fibers were used to "benchmark" the properties of a material at the limits of the glass forming range.

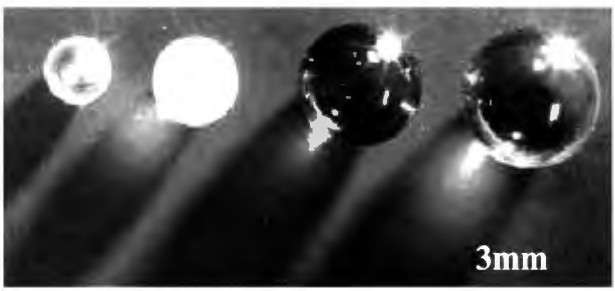
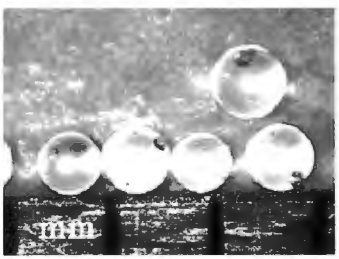


Figure 4. *Rare earth aluminate (REAl Glass) glasses made by levitation melting. The sample on the right is about 0.3 cm in diameter and it is transparent clear glass. The smaller samples on the left of the figure are two phase glasses that scatter light.*



To develop compositions that provide many of the properties of pure rare earth aluminates and that are readily vitrified, over a hundred glass formulations were tested. Figure 5 shows a sequence of glasses. The small beads, shown at the top of Figure 5, required

Figure 5. *Top – aluminosilicate beads made by containerless processing. Even though this glass contains 33 mole % silica, it requires cooling at ~1000°C/second in containerless conditions to prevent crystallization. Bottom – a wedge test of an advanced glass formulation containing 20 mole % silica that can be cast in sections up to 3 cm thick. The glasses that have been developed are called "REAl Glass" because they are based mainly on **Ra**re **E**arth oxide and **Al**uminum oxide.*

cooling at ~1000°C/second in a levitator to form glass. Slower cooling resulted in crystallization. These glasses have a working range of only a few degrees. The glass wedge in the lower part of the figure was formed by melting the glass components in a platinum crucible. The crucible-melted glasses can be cast in sections up to 3 cm thick and they have a working range of about 200°C.

Development of REAl Glass has been pursued using formulations that can be melted in platinum crucibles and cast to form blanks for lenses and infrared windows. The glasses also work well as a host for laser active ions. Doped glass compositions that can potentially be used for laser devices and optical amplifiers are being developed.

Conclusions

1. Levitation melting (containerless melting) expands the range of glasses that can be formed. It enables the glass maker to "push the glass forming envelope".

2. Glasses made by levitation are valuable as a means to "benchmark" the properties of new glasses.

3. Containerless melting provides the glass scientist with a powerful tool to help in understanding the properties and structure of liquids and glasses.

Endnotes

[1] H. Pfaender, *Schott Guide to Glass*, 2nd Ed., (London: Chapman and Hall, 1996).

[2] C. A. Angell, "Formation of Glasses from Liquids and Biopolymers," *Science* 247 (1995): 1924-1935.

[3] S. Kohara, K. Suzuya, K. Takeuchi, C-K. Loong, M. Grimsditch, J. K. R. Weber, J. A. Tangeman and T. S. Key, "Glass Formation at the Limits of Insufficient Network Formers," *Science* 303 (2004): 1649-1652.

[4] J. K. R. Weber, A. D. Hixson, J. G. Abadie, P. C. Nordine and G. A. Jerman, "Liquid-liquid Phase Transition and Polyamorphism in Undercooled Rare Earth-Alumina Compositions," *J. Am. Ceram. Society* 83 (2000): 1868-1872.

[5] J. K. R. Weber, J. J. Felten, B. Cho and P. C. Nordine, "Glass Fibers of Pure and Erbium or Neodymium-doped Yttria-alumina Compositions," *Nature* 393 (1998): 769-771.

Acknowledgements

We acknowledge research support from NASA Physical Sciences Division, National Science Foundation and the Air Force Office of Scientific Research. Work to develop the REAl Glass was done by a team of researchers and students including: Mr. Ben Cho, Mr. John Felten, Ms. April Hixson, Mr. Johan Abadie, Mr. Thomas Key, Mr. Richard Scheunemann, Ms. Kirsten Hiera, Mr. Jim Rix, Dr. Jean Tangeman and Dr. Paul Nordine.

The History of Charles V. Litton and Litton Engineering Laboratories as they Relate to the Field of Glassworking

by
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Abstract

This paper will chronicle the education and early work history of Charlie Litton prior to the formation of Litton Engineering Laboratories in 1932. How Litton Engineering Laboratories began and its 73-year history of development and use of glassworking equipment will also be presented.

Charles Litton was born in San Francisco, California in 1904. The son of a dentist who wanted to be an engineer, he spent many hours with his father working on projects in their garage. At age 15, he was 15th in line when the government began issuing ham radio operator licenses; he was W6AO, a license he held for the rest of his life. Vin, as he was known, attended Lick Wilmerding High School in San Francisco and later attended Stanford University where he received degrees in Electrical and Mechanical Engineering in 1925.

Upon graduation, Charlie went to work at Bell Labs in Murry Hill, NJ as a Research Engineer. After two years, he had to return to the west coast where he took a position with Federal Telephone and Radio as a Vacuum Tube Development Engineer. It was at Federal that Charlie engineered his way around the patent held by RCA on the manufacture of the triodes used for long-range world-wide communication. This allowed Federal Telegraph to enter the tube manufacturing business and enter the long-range communication business.

In 1932, Federal moved their west coat plant to the east coast and because Charlie's contract with Federal specifically stated they had to provide employment for him on the San Francisco peninsula, they were forced to buy him out of his contract. In payment, Charlie took machinery which he then used as the founding assets of Litton Engineering Laboratories.

As a vacuum tube engineer, Charlie was involved not only in the design of the tubes but also in their fabrication. If machines were not available to do a job, he would invent and build what he needed. Charlie held 66 patents in vacuum tube technology.

Charlie built his first glassworking lathe in 1924 in his father's garage from bicycle chain, pipe, sleeve bearings and angle iron. During his time at Federal, he built lathes that used precision ground bar stock for ways. These machines, however, could not provide the precision required to make tubes to the necessary precision. His next design included ground box ways that had been used in precision metalworking machinery for decades.

During the 1930's and 1940's, Litton Engineering Laboratories designed and built a plethora of machinery for building vacuum tubes: the G-Mill, Q-Lathe, AQ-Lathe and AF-Polishing Head for making metal tube parts accurately and rapidly. Vertical Hydrogen Furnaces and Bell Jars for making high yield vacuum tight joints in brazing operations. Spotwelding Machines, Ion Gauges and Vacuum Pumps were also produced. This was also the time in which the glassworking machinery was designed.

The first production models produced were the models F (1-5/16 gear driven), H (1-5/8 bore), E and K glassblowing lathes and the Vertical Sealing Machine. The Litton Planetary Chucks and the Litton articulating burner systems (Single Jet and 7-Jet) were designed at this time also.

During the war, Charlie was asked to work on government projects at Federal on the East Coast instead of joining the armed services. Federal sent someone west to manage Litton Engineering in his absence. Litton Engineering expanded rapidly during the war. Many machines were sent to England and many a machine ended up on the bottom of the Atlantic in ships sunk by the German U-Boats.

In 1945, Litton Engineering burned to the ground. Charlie flew back from the east coast, surveyed the damage and decided that most of the machinery could be rebuilt rather than scrapped. Production had to continue, so friends of Charlie's, Bill Hewlett and Dave Packard, allowed Litton to use their machine shop in the evenings.

After the war, Litton built a new plant in San Carlos, CA. In 1947, he started a new company called Litton Industries. In addition to manufacturing the machinery, Litton Industries became a major manufacturer of Magnetrons for use in radar. Soon Litton Industries became synonymous with high quality, long lasting and reasonable cost in both its vacuum tube and machinery manufacturing.

Over the years, customer needs have dictated new models. The beginning of the 1950's saw the rise in television manufacturing so the models M and ME were born to provide larger radial clearance. The 4600 and 4601 four jaw chucks were created to hold the four sided TV tubes. In the late 1950's, larger bore diameter machines were required for apparatus manufacturers which led to the HSD, ESA and KA models.

The 1950's also saw a major change in the Company as a whole. In 1953, Charlie sold Litton Industries to Roy Ash and Tex Thorton who proceeded to build the conglomerate you may be familiar with. The purchase, however, was only for the vacuum tube manufacturing, not for the machinery manufacturing. So in 1954, Litton Engineering Laboratories was resurrected and moved to Grass Valley, CA where an incomplete hospital building was purchased to house the manufacturing facility.

The early 1960's saw Litton's reentry into the vacuum tube manufacturing business. This venture ended in failure when the government decided not to purchase the tubes that had been designed.

In the mid to late 1960's, Charlie put a huge personal effort into creating new glassworking products. During this period, Charlie would work until 2 or 3 in the morning. This is when he designed the model U Lathe. Charlie did everything in bringing this lathe into production. He conceived it, he drew the pattern drawings and the part fabrication drawings. He built the patterns, he cast the castings, he machined the castings, he built all the associated parts and assembled it. He also designed and built the motor that was used on the U Lathe. He designed the UC Planetary Chuck. It was a one-man effort. This lathe was called the Model U for Universal and University. For Charlie, it was the lathe that embodied everything he thought a lathe needed.

1964 saw the introduction of two models of the 6-Jaw Interdigital Universal Chuck. This was two independent planetary chucks in one body allowing a glassblower to hold two pieces of glass concentrically.

Also in 1964, Charlie wrote several monographs:

"What is Important in the Glass Working Lathe?"

"Plumbing for the Glass Working Lathe"

"The 'Spit Tube' in Glass Working"

"The Use of the Collet in the Glass Working Lathe"

"Picking the Hole"

"Chucking with Planetary Bar Chucks – An Application Note"

In 1968, Charlie decided to start his move out of the state of California. At that time California had an inventory tax which Charlie found oppressive. The state of Nevada next door was much more business friendly. It had no inventory tax or even a state income tax. The first thing to move was the inventory and the assembly and shipping departments of the company. Manufacturing was to follow soon. At first Litton rented space at Stead Airforce base north of Reno. Later Charlie bought property outside of Carson City, Nevada from Bill Eitel, one of the founders of Eitel-McCullough, another early Silicon Valley company. Charlie then built a building and moved everything down from Stead. In 1972, Charlie unexpectedly passed away and the move to Nevada was put on hold.

The family held a meeting and soon decided that we preferred living in California so by mid 1973, everything was moved back to Grass Valley where Litton Engineering remains today.

In the late 1960's, Corning was perfecting a process that would revolutionize the communications business and provide a boom to the glassworking lathe manufacturers around the world. They had discovered a way to produce low-loss optical fiber that could be used to send information long distances using light. Since Corning had been a user of Litton Lathes since the early forties, they developed the MCVD process using the Model EE lathe as the base for their machine. By the late 1970's, several companies were making optical fiber using the MCVD process and the demand for EEL lathes skyrocketed. Delivery for any Litton lathe went to 18 months in the early 1980's. The first MCVD boom lasted through 1986. This was followed by short-lived booms in 1995-1997 and 2000-2001.

It was also during the early 1970's that the microprocessor became available. Charlie Litton, Jr. had taken over as president after Charlie's death. Larry Litton had left the Navy and was attending Cal Poly in San Louis Obispo. Charlie and Larry and long-time employee Jack Marshall took a class on programming microprocessors and soon after that the idea of an automated glassblowing lathe took root. By 1975, Larry had created the 9665 controller that could operate two stepping motors and interface with the outside world through I/O ports. It was up to the glassblower to make the mechanical interface. Well that did not work. The next task then was to do the interface ourselves. In 1984, we introduced the first automated lathe which consisted of an HSJ Lathe with programmable firecarriage motion, tailstock motion, spindle speed, tooling motion, burner flame control and air pressure control.

Over the years Litton has also produced many specialty machines to meet specific customer requirements such as welding and grinding machines.

In recent years, with the efforts of Victor Mathews, Litton has added supply and glass products to its manufactured machinery to offer a complete line of glassworking products.

A Multi-Purpose Glass Vacuum Assembly for the Extraction of Gas Samples for Stable Isotope Analyses

by
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Abstract

Stable isotopes of carbon, oxygen, hydrogen and nitrogen have become a powerful tool in several branches of science, namely geosciences, environmental sciences, biology, chemistry, nutritional studies, drug delivery studies and even in forensics. However, in order to analyze samples for their various isotope ratios, it is necessary to prepare all the samples in the form of a suitable gas for injection into a mass spectrometer. Moreover, all the extractions must be carried out under vacuum conditions. An extraction assembly that is capable of preparing these various gasses from a wide variety of samples such as soils, carbonates, natural gasses and water has been built for the Department of Geosciences at Western Michigan University. Additionally, a "sample tube cracker" that enables the introduction of gas samples directly into the mass spectrometer has been designed and constructed. This has the advantage that the gas samples can be kept sealed for long periods of time until the mass spectrometer is available for use. The design, construction, and use of this system will be discussed.

Introduction

Vacuum lines are a very important tool for scientists to conduct research and development. I would like to describe a vacuum line used for teaching and research at Western Michigan University, Kalamazoo, Michigan. The vacuum line system is unique because it is designed for multiple uses and allows scientists to process solids, liquids, and gases for isotope analyses. The vacuum system described in this paper was designed and developed by Dr. R. V. Krishnamurthy of the Department of Geosciences; it has been in use for more that 10 years and serves its purpose well. The vacuum line system was originally built by my mentor, Mr. William DeWolf, a charter member of the ASGS. It has been modified somewhat over the years but its usage remains the same.

The purpose of this paper is to describe the design of this apparatus and to provide examples of how the vacuum system is used in select scientific experiments. Also, continuing a theme of "how does it work?" may help glassblowers in design and construction of glass apparatus for scientific and other purposes.

Construction of a Multi-purpose Vacuum Line

The glassblowing required for this multi-purpose vacuum system is basic and consists of joining mostly T seals and straight glass seals while avoiding pin holes in order to maintain high vacuum conditions. However, repairs and modifications can be challenging because the unit ends up as essentially a single piece in a vertical position. As shown in Figure 1, this system is rack mounted on a table so as to be accessible from both sides of the table. This feature allows for easier servicing and repairs. With the improved O-ring seals available today, this unit could be designed in a modular fashion in the shop and installed at the site. Vacuum in the system is provided by rotary vane and diffusion vacuum pumps located on the floor below the table.

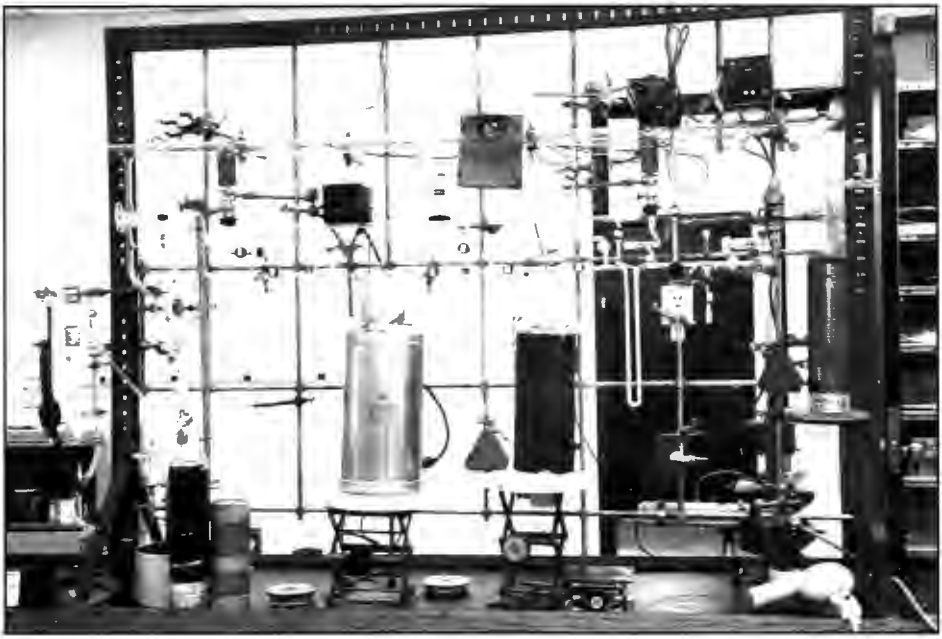


Figure 1. *Vacuum Apparatus.*

The glass tubing used to build the system is all borosilicate except for some quartz U-tubes. At the top, the vacuum line consists of a main manifold tube 51 mm in diameter by approximately 6 feet in length connected to the vacuum pumps via a trap (Figure 2). Below the main manifold are sections of 10 mm special wall tubing lines fitted with 0-4 mm stopcocks that are used to control vacuum conditions in the lower portions of the apparatus. The lower section of the apparatus consists of glass U-tubes and coils separated by stopcocks. On the left side of the apparatus is a Toepler pump with its own dedicated controller and vacuum pump. Vacuum conditions in the system are monitored by one or more Pirani gauges located at strategic locations depending on system design. Once the

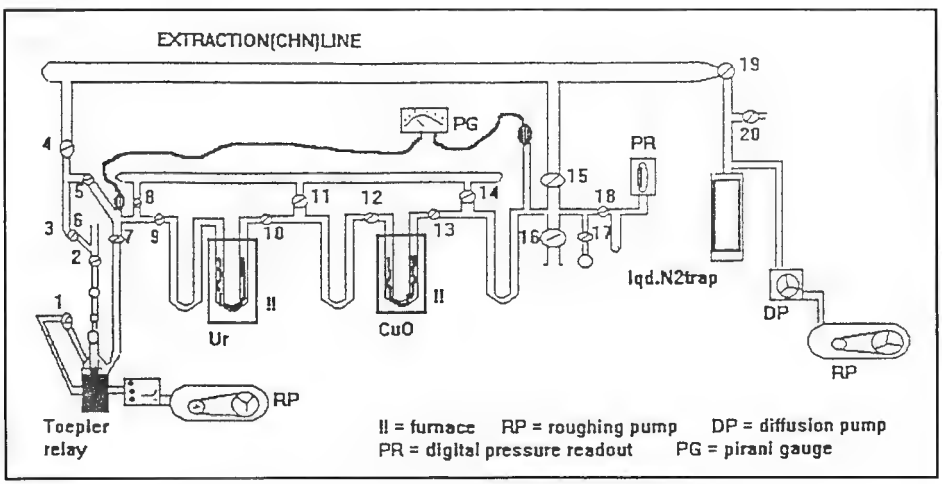
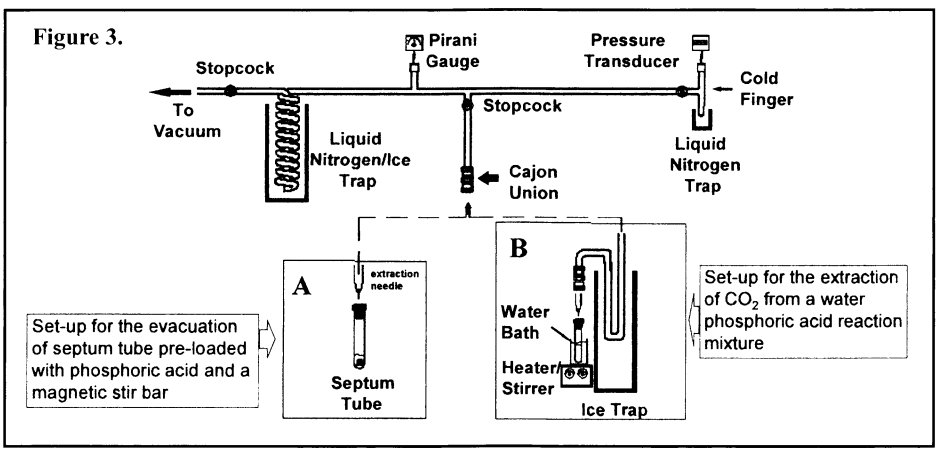


Figure 2. *Vacuum Extraction Line for the Preparation of Hydrogen Gas. The numbers refer to specific location mentioned in the text.*

gases are purified, they are measured using a pressure gauge fitted to a calibrated cold finger on the right side of the apparatus. Pressure gauges can also be installed at strategic locations within the system for different applications. For most applications, a vacuum of 10^{-3} torr is sufficient. Three examples of how this apparatus is used to prepare samples for isotope ratio determinations are described as follows.

Preparation and extraction of carbon dioxide in water samples

Most people are aware that carbon dioxide is essential for plant growth and is an important chemical constituent of natural waters. One application of the multi-purpose vacuum line is to determine the amount of carbon dioxide in a water sample by using the gas evolution technique developed by E. A. Atekwana and R. V. Krishnamurthy. See Figure 3 for diagram of section of the vacuum system used. A water sample is collected and reacted with acid under vacuum conditions in a prepared vial with a septum plug (blood serum vials). The carbon dioxide released in the reaction and trapped in the vial is extracted and purified in the vacuum line. The amount of gas in the sample is determined and the gas is collected for isotope ratio measurement using an isotope ratio mass spectrometer (IRMS).



The details of determining and collecting the amounts of gas are as follows: the vial (A) with carbon dioxide from the water-acid reaction is connected to the line via a needle fitting. After purging laboratory air between the tip of the needle and the vacuum line stopcock, the sample (water and carbon dioxide) is introduced into the vacuum line (by puncturing the septum) through a trap immersed in a -68°C ice slush (B) composed of an organic solvent and frozen carbon dioxide (dry ice). The purpose of the trap is to prevent large amounts of water from being introduced into the vacuum line which might require extensive cleaning. As the sample gets into the vacuum system, the carbon dioxide in the sample along with other impurities are trapped in a coil trap immersed in liquid nitrogen and frozen at ~180°C. Any non-condensable gases (gases not trapped by liquid nitrogen such as nitrogen and oxygen) are evacuated via the manifold. This section of line is then isolated from the vacuum source and the liquid nitrogen used to cool the coil trap is replaced by the -68°C ice slush. This allows the frozen carbon dioxide to thaw (boiling point of carbon dioxide is -120°C), warm up, and turn into a gas, while any water + impurities in the trap remain frozen. The expanding carbon dioxide gas is transferred to the calibrated cold finger area (right side of the vacuum line) using liquid nitrogen to cool the cold finger. After complete transfer, the liquid nitrogen is removed and the gas is

allowed to thaw and builds up pressure that is read on the pressure transducer. This pressure reading is used to calculate the amount of carbon dioxide in the sample. Note that the cold finger was previously calibrated with known amounts of carbon dioxide which has a linear relationship as to temperature and volume.

The gas sample is now transferred from the vacuum line into a sample tube for mass spectrometric analyses. The sample tubes consist of 6 mm or 9 mm sealed on one end. The tubes are attached to the vacuum line via a Cajon coupling and evacuated of air. The sample is then transferred into the tube by freezing with liquid nitrogen after which the tube is flame sealed. The sample can now be introduced into the mass spectrometer for further analyses (see section on development of a tube cracker later in this paper).

Preparation and extraction of deuterium (H_2) and oxygen (O) in water samples

Water consists of two parts hydrogen and one part oxygen (H_2O). We all know the importance of water in our lives. Without water life will cease to exist as we know it. On the other hand, scientists are interested in analyzing hydrogen and oxygen isotopes in water and use this information to determine the source of the water, the history of the water, the quality of the water and other important chemical reactions that occur in water.

Preparation and extraction of deuterium (H_2) in water samples.

The vacuum line can also be used for the preparation of gas samples for deuterium (H_2) analysis. To do this, water must be reduced to hydrogen gas (See Figure 2 for the section of the vacuum line used). The water sample to be analyzed is sealed in glass and is inserted into a 7/8 heavy wall tube and attached to the line at 16. The tube is evacuated via the manifold by opening the appropriate stopcocks. The heavy wall tube is isolated by closing the stopcock and the vial is broken using the steel ball and magnet method. By opening and closing stopcocks in proper sequence, the water is transferred into the U-tube next to the uranium furnace and frozen by liquid nitrogen, while non-condensable gases are pumped away. The sample is then allowed to warm up and the water vapor is transferred into the uranium furnace. In the uranium furnace, the water vapor reacts with spent uranium shavings at 750°C to form hydrogen gas, hence the need for a quartz U-tube. In constructing the uranium furnace, the quartz tube in which the shavings are placed is joined to the borosilicate line using a graded seal. The hydrogen gas from the uranium furnace travels to the Toepler pump. The Toepler pump consists of an upper and lower chamber with electrical connections and a controller. For safety purposes, the Toepler pump sits in a containment vessel in case of a mercury spill. Driven by its own vacuum pump, the Toepler pump receives the hydrogen gas into its upper chamber through a small vent. Feed through electrical contacts control the level of the mercury. As mercury fills the upper chamber, the hydrogen gas is compressed into a calibrated extension (6). A check valve prevents the back flow of gas. After several cycles of the pump operation, 99.9% of the hydrogen gas is pushed into the extension. The number of cycles needed varies by sample size and is determined by monitoring the pressure reduction between 7 and 8. The extension was previously calibrated using known amounts of gas and thus allows for the amount of gas in the sample to be determined. The gas is collected into a small reservoir attached at 6 and later analyzed for hydrogen isotopes using a mass spectrometer.

Preparation and extraction of oxygen in water samples.

The oxygen in water samples is equilibrated with carbon dioxide and the carbon dioxide extracted and analyzed in the mass spectrometer. For this, the portion of the vacuum line

used is called the equilibration line (Figure 4). The equilibration line is used to transfer known amounts of CO_2 into sample vials for use in determining the oxygen isotope ratio in water. The vials used are the same blood serum vials with a septum stopper previously described. The section of the vacuum line used for this procedure consists of needle sample ports and U-tube traps fitted with a pressure transducer. Pure CO_2 delivered from a tank enters at point 1 and is trapped by liquid nitrogen placed on the U-tube trap between 15 and 16. Any non-condensable gasses are evacuated and the CO_2 is frozen in the trap. Next, the liquid nitrogen dewar is removed from the trap to allow a known amount of CO_2 to warm up into a gas and flow into the vials attached at 4 to 8. The amount of CO_2 released by thawing is monitored by the pressure transducer. This method provides an equal and known amount of purified gas in each vial. The vials are removed from the vacuum line and the water samples are injected into the vials and allowed to equilibrate with CO_2 in the vials at 25°C in a temperature controlled bath. The vials are introduced into the vacuum line near the cold finger as in Figure 2. The CO_2 in the vial is extracted in the vacuum line in a similar manner as described in the first example on extraction of CO_2 from water samples. After measuring the CO_2 amount in the cold finger, the sample is refrozen in 6 mm or 9 mm sample tubes as previously described and fed into the mass spectrometer for further analysis.

Only a general description of how this vacuum system works is provided. Some extraction steps and the chemistry involved have been omitted. For additional information, see the bibliography. Some other uses of the vacuum line include the preparation and extractions from soil samples, carbonates and natural gasses.

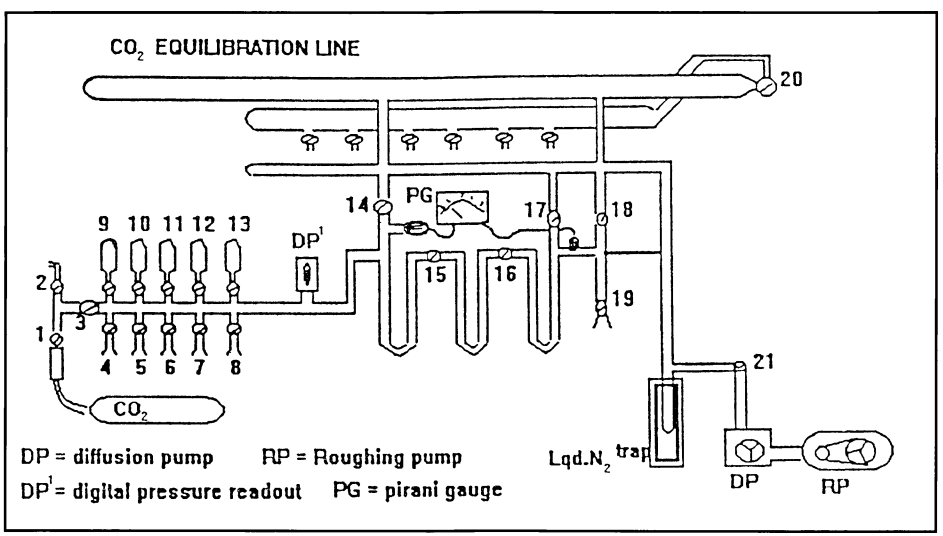


Figure 4. *Vacuum Extraction Line for the Preparation of CO_2-H_2O. The numbers refer to specific locations mentioned in the text.*

Development of a new style tube cracker

A common procedure used in vacuum line sample preparation is the capturing of samples in 6 and 9 mm borosilicate tubes and then sealing them closed using a torch. To release their contents into an instrument like a mass spectrometer, the tubes need to be in an evacuated chamber before the tube is cracked and the gas released into the instrument without contact with air. Thus breaking these tubes containing gas samples in a vacuum

environment required for machine analyses can be challenging. Sample contact with air will result in contamination. Also, air introduced into the mass spectrometer which operates under high vacuum conditions will destroy the machine requiring machine down time and costly and needless repairs.

A sample tube cracker was developed by Professor Eliot Atekwana and myself that has proved to fill the need (See Figure 5). The sample tube is held in place by a threaded nylon plug with O-ring seal (A). The sample tubes are pre-scored and there is a slight indent at E used as a fulcrum. The cracker device is attached to the vacuum manifold on the mass spectrometer using a Cajon union. After attachment, the cracker is evacuated of air creating vacuum conditions required to introduce the sample into the machine. The modified 0-4 stopcock plug (B) is advanced, applying pressure until the tube breaks. The stopcock (C) can be used to isolate the sample until ready for injection into the machine. A coarse frit (D) prevents any glass shards entering the vacuum line. Various connectors are used to attach these tube crackers to the vacuum line that goes into the mass spectrometer. The threaded O-ring style connector seems to work best because it has some flexibility. These have held up rather well through student use which is the ultimate test.

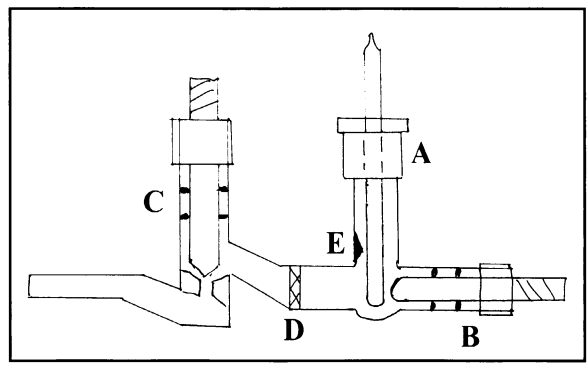


Figure 5. *Drawing of the tube cracker.*

Conclusions

Vacuum lines provide an important teaching and research tool. The units described in this paper are used to analyze water for water resources problems, water quality for human consumption, food production, and for environmental concerns. The information presented in this paper will be helpful to glassblowers in understanding how vacuum lines are designed, constructed and used.

Acknowledgements

Contributions to this paper and helpful comments by Dr. R.V. Krishnamurthy, Dr. Eliot Atekwana, and Tsigabu A. Gebrehiwet are acknowledged. Dr. R. V. Krishnamurthy and the Department of Geological Sciences at Western Michigan University, Kalamazoo MI, are open to any inquiry or additional information.

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Older Apparatus and the People Who Built It

by
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Abstract

This paper will attempt to cover some historical apparatus such as Sprengle pumps and the glassblowers who built them. As they are part of our past, where did they come from and where did they go? It will also be a plea to those of you who may know of the history of a glassblower from 80-100 years ago to get that information to me so we can record it in the history of our Society.

When I first envisioned this paper, I wanted to do something on older apparatus since this is our 50th Symposium. Through an e-mail conversation with Gordy Smith, he said "It would be interesting to know if the Glassblower prospered in any way from these things." Most of us have made apparatus for years without knowing where their names came from. Here is a small list of what I found.

Felix Richard Allihn – The Allihn Condensor – German scientist.

Pierre Vernier – Vernier Calipers – French scientist. This is a non-glass item but something no glassblower can do without. Vernier was born in France in 1584. His father was a lawyer and engineer and taught him math and science. Pierre first conceived the caliper in 1611 and finally perfected it in 1634.

Henri Vigreaux – Vigreaux Condensor – French scientist.

Ernest Buchner – Buchner Funnel – German scientist.

Johann Gustov Christian Kjeldahl – Kjeldahl Apparatus – Danish scientist. Kjeldahl's name is associated with the apparatus and flasks that are the international standard for the analysis of protein.

Franz von Soxhlet – Soxhlet Extractor – German chemist. Von Soxhlet developed a method for the analysis of fat.[1]

Here is a good one:

Joe Gregar – The Gregar Extractor for the extraction of solids. This is interesting because the only other glassblower that I found that had something named for him was Geissler. I am sure there may be a few others and I was only looking at older apparatus.

Heinrich Geissler – Geissler Tubes. Geissler was a second generation Glassblower who invented the tubes just for the fun of it. He mostly used the tubes as entertainment

[1] Kjeldahl and Von Soxhlet, Unity Scientific web site.

at dinner parties. These tubes later were the basis for the x-ray tube, neon and incandescent lamps, and, of course, the TV tube. I could not find any evidence of Geissler making anything but a living from his work.[2]

Sir James Dewar – Dewar Flask. Dewar was a chemist and physicist and was the co-inventor of cordite, smokeless gun powder. After his invention of the Dewar Flask in 1892, he became the first person to liquefy hydrogen. He had a German company owned by glassblower Reinhold Berger produce the flasks for him.[3] Berger told him he saw potential for home use. Dewar wanted nothing to do with this and told them to do what they wanted with it. He did. He made a sturdier version with a metal exterior for home use and gained a patent in 1903. Flask production began in 1904. He than ran a contest to rename the flask. A resident of Munich won with the name "thermos" which came from the Greek word "therme" meaning heat. I assume there must have been some kind of prize but could not find what it was. In 1907 Berger sold the trademark rights to three companies: The American Thermos Bottle Company, Thermos Limited of England, and the Canadian Thermos Bottle Company Limited. The first machine-made "thermos" bottles were made in 1911.[4] It looks like the Glassblowers may have prospered here.

Hermann Sprengel – Down Draft Mercury Pump. Hermann Sprengel invented a Down Draft Mercury Pump where the mercury was recycled by hand. This was in 1855-1865. It was quite primitive. Thomas Edison obtained his first Sprengel pump in 1879 and quickly realized that if he was going to be able to maintain these pumps, he was going to need his own in-house Glassblower. This is one of the better stories I found. He first hired William Baetz of Reinmann & Baetz to work part-time for him in the evening. This may be the first documented case of a glassblower moonlighting. This, however, turned out to be unsatisfactory and Edison advertised for a full-time glassblower. Along came Ludwig Bohn, an 18 year old, who had been trained by Geissler. Edison was desperate at this point and when Bohn asked for $20 per week, he gave it to him. This was 1879 and Edison was paying his college-educated chemists $12 per week. Bohn worked for Edison for about 14 months, working 15-20 hour days. Some sources say he built about 480 pumping stations in that time. Bohn left Edison to work for a competitor. He sued Edison over patent rights, won some of them and later he obtained several other patents in his own name. He went back to Germany and several years later, he wrote to Edison and asked if he would hire his cousin.[5] I do not know how that ended.

In 1998, I presented a paper on the Lindbergh Perfusion Apparatus. In researching the paper, I found that the apparatus was built by a Glassblower named Otto Hopf who was the glassblower for the Rockefeller Institute at Princeton. I remarked that since this had been more than 60 years ago, there was probably no one who had known or worked with Otto.[6] When the *Proceedings* were published, I was contacted by the late

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[2] The Believer-Light: Geissler Tubewww.belivermag.com.

[3] Dewar, Sir James, Fact Monster web site

[4] Thermos, web site.

[5] Waits, Robert K., "Edison Vacuum Technology Patent," *J.Vac. Technol* A 21.4 (July/Aug 2003): 881-890.

[6] Merritt, James, "Lindbergh Perfusion Apparatus," *Proceedings of the Forty-Third Symposium on the Art of Glassblowing* (Bloomington, MN, 1998) 38-42.

Karl Walther. It seems Karl knew Otto and when he decided on a glassblowing career, he almost apprenticed himself to Otto but passed on the opportunity when he found out Otto's daughter was part of the equation.[7]

In conclusion, I would like to encourage all of you to put together a brief history of your shop, whether business, research lab or university shop. In my own case, the University of Southern California, I know that I am the third glassblower since the shop was started in the 1940's. The first being Bob Griener, the second, J. H. Old, longtime member of the Society and Director of our Section, and for the past 25 years, myself. Likewise, if you have a short biography from any long-time member of your Section, or humorous anecdotes about your life as a Glassblower, please send them to me and I will put them together and see that they are included in some future issue of *Fusion*.

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Andraos, Dr. John, Named Laboratory Apparatus web site.

[7] Walther, Karl, e-mail conversation, January 1999.

The PC in the Glass Shop
Technical Glass Drawings and Archiving

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Abstract
Discussion concerning the use of the PC in conjunction with inexpensive drawing programs for the time-sensitive creation of technical glass drawings and the compilation of data for the purpose of archiving.

The Problem
Currently, the PC is an underused yet essential tool of the modern glass shop. With the reduction of staff at most institutions through attrition or closure, the wealth of concrete knowledge regarding glass apparatus design and its manufacture is largely being lost. Ten years ago at the University of Alberta, there were two independent glass shops with six combined employees dedicated to scientific glassblowing. The glass shop has now been reduced to two glassblowers in one shop, and the need for efficiency is ever increasing. When previous employees retired, there was an increase in production requirements on the remaining workers, with a corresponding gap of resource information and administrative help; this gap put additional strain on the department as clients were forced to present new drawings each time a piece was requested, and inform a new glassblower of the technical requirements and operational limitations of the glassware required. Technical drawings supplied by the average client in a University setting were rarely highly detailed, most often consisting of simple sketches and requiring one on one verbal communication for deciphering the hieroglyphics. Consequently, when orders for replacement pieces were placed after long periods of time, the client was most often told that records had not been kept and that a physical model would have to be brought in for duplication or a direct meeting with the client would have to be arranged. The creating of detailed drawings by hand as well as the maintaining of physical paper records would be a huge space- and time-requiring endeavor, and searching through non-cross-referenced documents would test the capabilities of any administrative department, let alone any humble and somewhat disorganized glassblower. For this reason, I set out to find a solution to this problem for both my employer's and my benefit.

The Solution
The perfect solution would meet certain necessary requirements:

- be inexpensive to implement.
- be highly adaptable to different design scenarios.
- be easily searchable.
- produce diagrams/schematics that can be easily reproduced.
- have a reasonable learning curve.

The Search

I decided that the computer, having been useful in other departments, could be of better use within the glass shop than just as an e-mail/communications tool. After researching the issue on the Web, I found that in computer graphics there are three main categories of digital images:

1. Raster Images

Also known as bitmaps, these images are created by assigning colors to small square dots (pixels) and arranging them linearly within a defined rectangular area. These images are generally used for web graphics, digital photography and print media. These images are best suited for color rendition and depth through blending. One major disadvantage is the large file sizes which are generated given that image quality is regulated by the size and number of pixels in this defined area. Known as D.P.I. (dots per inch), this number allows greater detail in an image if it is large, but is easier to store and transfer if small. If a viewer increases the object's printable size or "zooms in" on the displayed image, these small dots of blended color become large square blocks that destroy detail. This effect is known as pixilization.

2. Vector Images

These images are created by mathematical trajectories originating from control points (nodes) used in succession to form lines, curves, and closed shapes such as circles, squares, etc. These shapes can be left empty, or filled with colors and stretched, moved, resized, or reshaped easily and independently to form detailed images. The file size created with each of these style drawings is typically 1/3 or less the size of a corresponding bitmap file.

3 CAD/VRML

Computer Aided Design or Virtual Reality Modeling Language is a predominantly vector-based graphic format, but true depth is achieved by the additional depth coordinates added to the standard height and width. These X, Y, and Z control point coordinates create a fully interactive digital object that can be handled, rotated and viewed just as a material object would be.

While initially intrigued by the CAD programs such as Autodesk's AutoCAD, I found that the product's initial costs and difficulties in learning far outweighed exceptional accuracy and 3D modeling capabilities. Raster image programs were ruled out immediately as they lack interactive measuring and are not easily modified. The field of 2D vector programs contains a wide variety, ranging from simple free programs available on the Web to more specialized commercial products that lean either to illustration or precision drafting. Since the primary goal was to facilitate the creation and continuance of design information received from a variety of sources, I decided that speed and ease of operation were more important than exactitude in position.

In the accompanying chart you will see a direct comparison of features for some of the best drawing programs available.

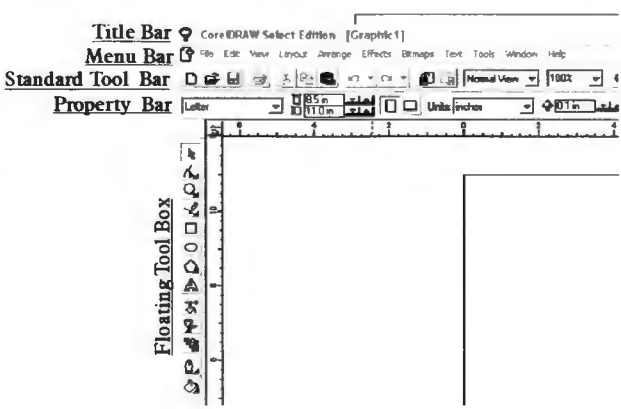
After examining the capabilities of the various graphics programs, I have decided to work almost exclusively with CorelDRAW 7 Select. It maintains the properties of ease of use and accuracy in depiction that define CorelDRAW products, and is also quite inexpensive. Therefore, the remainder of the discussion will be CorelDRAW specific, regarding its layout, various capabilities, and methods of use.

				
Autodesk AutoCAD LT $899.00	Adobe Illustrator CS $593.45	CorelDRAW Graphics Suite 12 $343.64	CorelDRAW Essentials 2 $79.00	CorelDRAW 7 Select $19.00
AutoCAD LT is perfect for drafts people, engineers, and technical illustrators who do not have to work in 3D. For 3D work, AutoCAD 2006 is available for $3750.00. PROS: Contains most of the 2D drawing features of AutoCAD 2006; costs significantly less than AutoCAD; 100% compatible with AutoCAD files CONS: Steepest learning curve; does not support 3D files; lacks a Bitmap editor	Illustrator CS makes 2D vector drawings with simulated 3D effects, in which creative tools (such as the Bezier pen), object attributes (such as color), and management functions (such as layers) reside in a floating palette. Anyone who has worked with PhotoShop or InDesign will be immediately comfortable with Illustrator. PROS: Most widely used by design industry; great for illustration and PDF creation CONS: Non-intuitive interface; additional courses or educational books required; limited internal bitmap support; companion software PhotoShop must be purchased separately	Graphics Suite 12 offers three integrated graphics applications, plus a collection of other useful tools and utilities in one box. The new Suite includes CorelDRAW 12 for illustration, Photo-Paint 12 for professional digital imaging, and R.A.V.E. 3 for motion graphics creation. PROS: Vector illustration with sophisticated bitmap and image editing; good Web animation features; ample clip art and font; terrific configurable interface CONS: The Visual Basic Script Recording seldom works properly	Essentials 2 contains all of the illustration and design power of Corel's vector graphics and page layout software. Photobook and PhotoAlbum make photo retouching, organizing, and editing easy. The Big Box of Art provides 100,000 clipart images. A free "Getting Started with CorelDRAW Essentials 2" CD from Lynda.com contains helpful design tips, tricks, and techniques. PROS: Same CorelDRAW vector program CONS: Older version of the software; oversimplifies bitmap editor	CorelDRAW 7 Select includes the full versions of Corel Photo-Paint and CorelDRAW. The Select edition also contains over 450 ready-made templates that aid in creating professional looking graphics with ease. It also includes Spell-check and a Thesaurus. PROS: Dirt cheap much older program yet still highly effective CONS: Most of the add-on programs and features have been removed

The Program: CorelDRAW

Before being able to produce any drawings, one has to become familiar with the way an operator should control the GUI or Graphical User Interface. Upon starting CorelDRAW, a representation or the page size and orientation is displayed in the center of the screen, surrounded by command and control bars, as well as a color option bar at the far right of the screen. Most of the bars are customizable and some will automatically change to present more options that are subsets of current commands.

At the very top of the screen is the Title bar, under which the program name and graphic name are shown. Under this is the Menu bar, which lists the primary operation choices as well as the ever useful Help button. These two bars are stationary and remain unchanged regardless of what operation is being done. When one of these options is selected, a drop down list will appear, offering a detailed list of all the corresponding commands available. For example, the File option lists commands related to opening an exist-



ing file, creating a new one, or importing information from another program or file, etc.

The standard Tool Bar is located just underneath the Menu bar, and is comprised largely of shortcut buttons that control zoom levels and viewing options, provide saving and copying commands, and facilitate quick shortcuts to opening related Corel project software.

The fourth bar from the top is known as the Property bar. The settings and options available on this bar change depending on the tool or object selected. When no drawn object is selected, the page setting default is shown allowing page size, orientation, and unit measurement, etc. to be modified.

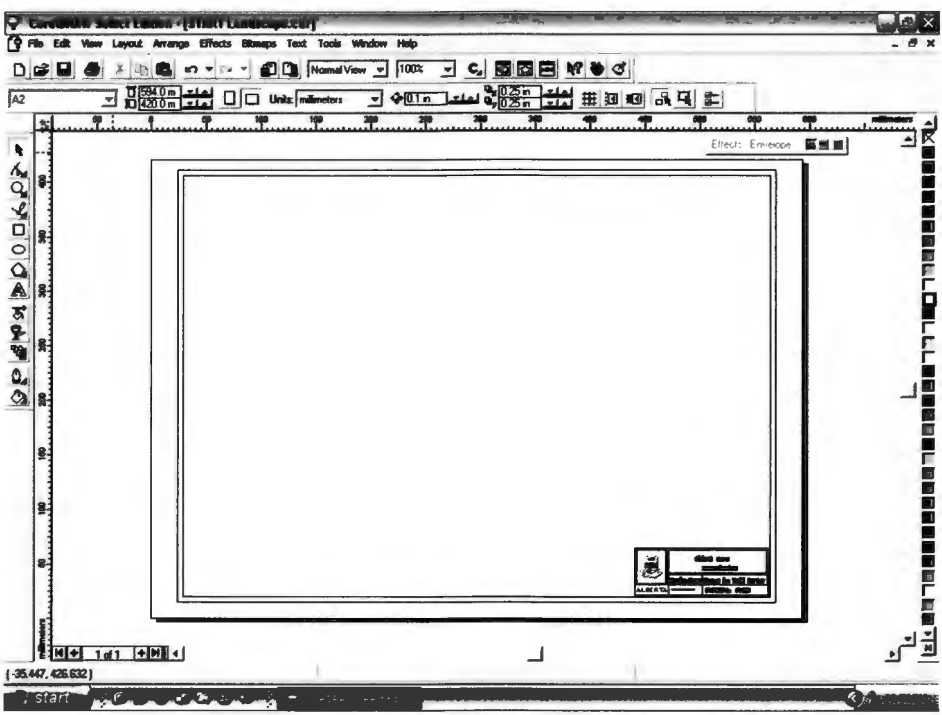
Pick Tool

On the left of the screen is the default position of the floating Tool Box. This box consists of thirteen call-out buttons which offer specific command options like the Pick tool (arrowhead), which selects individual objects on screen, or the rectangle box, which creates perfect squares or various rectangles. This Tool Box is somewhat unique in that it can 'detach' from its default location and be placed anywhere on the screen to make the buttons easier to access since it is the most common command list used. The appearance of the Tool Box will also change since the call-out button symbol will reflect the last operation performed. This change may cause the novice user to temporarily 'lose' a function they know they have used before.

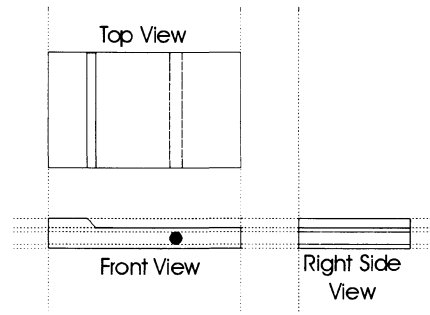
Rectangle Tool

The Creation Process

Using predominantly the rectangle tool and text tool, I have first created a stylized page template showing the borders of the page as well as a description box showing the Uni-



versity of Alberta logo, name of the apparatus, etc. This should be customized to best reflect the origin and particulars of the drawing. This template is placed on Layer one and saved as the Start Page, so whenever a new drawing is to be made, the start file is opened; the date, name, and other elements are modified, and the file is saved under a new name by pressing File on the menu bar and then Save As (providing that Layer one is locked so that the page template is not accidentally distorted while drawing). Using the Layers Manager available through the Layout selection on the menu bar, a new layer is created for the actual drawing. Most of my drawings are actually done in 1:1 scale with the page size adjusted according to need. The scale in the descriptive text box is set to none, however, because the scale is specific to the size of paper printed upon. If the project is printed out on 8 x 11 paper and it was drawn to fit on A4 size paper, the scale will be radically altered.



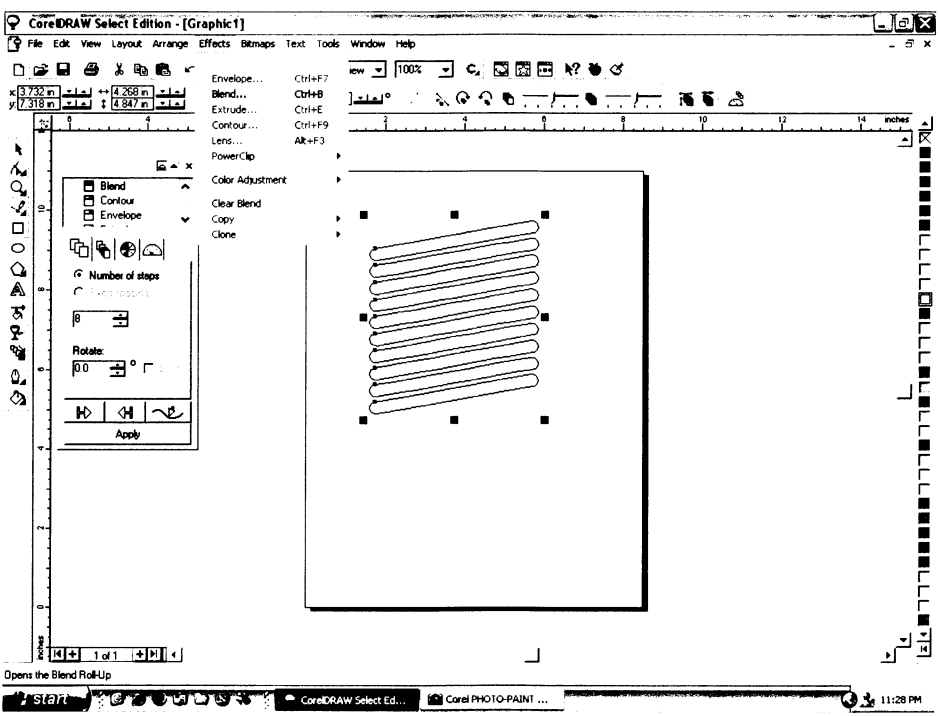
Before beginning a drawing, there are certain design rules or conventions that must be observed in order to help the observer read the information correctly. These conventions are called orthographic projections. The finished drawing must contain all the dimensions and details needed to manufacture a product. All dimensions should also be in millimeters as this is the standard in glass tube manufacture. If the project is very simple, a drawing must consist of one view or face elevation. However, more elaborate glassware will require an orthographic depiction of three views: a PLAN or TOP view, END elevation, or R.SIDE, L.SIDE, and a FRONT or FACE elevation. When drawing theses views, it is important to arrange them in a fashion that will allow the construction of guidelines from one view into the next (see graphic). Hidden details or inner details are represented by dotted lines of various styles, and center lines are shown by dashed lines.

Node Tool

The easiest way to create a drawing of laboratory glassware is actually quite similar to producing it out of glass. The creation of simple component parts are drawn using the rectangle form to represent cylindrical shapes. Once these shapes are drawn, they can easily be changed to precise dimensions by numerical input into the shape, width, and height box on the menu bar when the rectangle tool is selected from the tool box. Or by using the Sizing and Stretching handles (the eight black squares surrounding an object while it is selected), one can modify a shape's size by clicking and dragging on one of the corner Sizing handles to the approximate size required, then releasing the mouse button. By double clicking on an object, the sizing handles will transform into rotation handles to allow the free rotation of the object. For more complicated shapes, the use of the Node tool (arrow pointing to dot) is required. After converting the object to curves (so that the object is no longer 'locked' in a rectangle, circle, or other primary form), nodes can be individually moved, modified, added or subtracted. By selecting a point on a line then double clicking with the mouse button, a menu box will appear, allowing all available options on modifying control nodes. Select the line to curve option and the originally straight line can now be changed to any curved shape by manipulating the trajectory points emanating from the node, or by simply dragging the line from the

center section with the mouse into the desired shape. Familiarizing yourself with the command options and the creation and manipulation of basic shapes will take some time, but it is essential to any drawing software program.

Once shape creation has been mastered, the use of advanced effect options such as the Blend command can be used to decrease drawing times. For example, the drawing of a coil can be made simple with the use of the Blend tool. Create a long and narrow rectangle, rounding the ends using the corner rounding options (set to 100%); convert to curves and rotate to the proper pitch, either by free rotating or by inputting the desired rotation angle. Copy and paste the new object where the other end of the coil will be, and select both objects at once, and click the Blend command. The number of steps box will represent the number of objects to be created by the blend operation between the first two objects that have already been created. Click Apply and the coil will be created immediately with equally spaced loops.



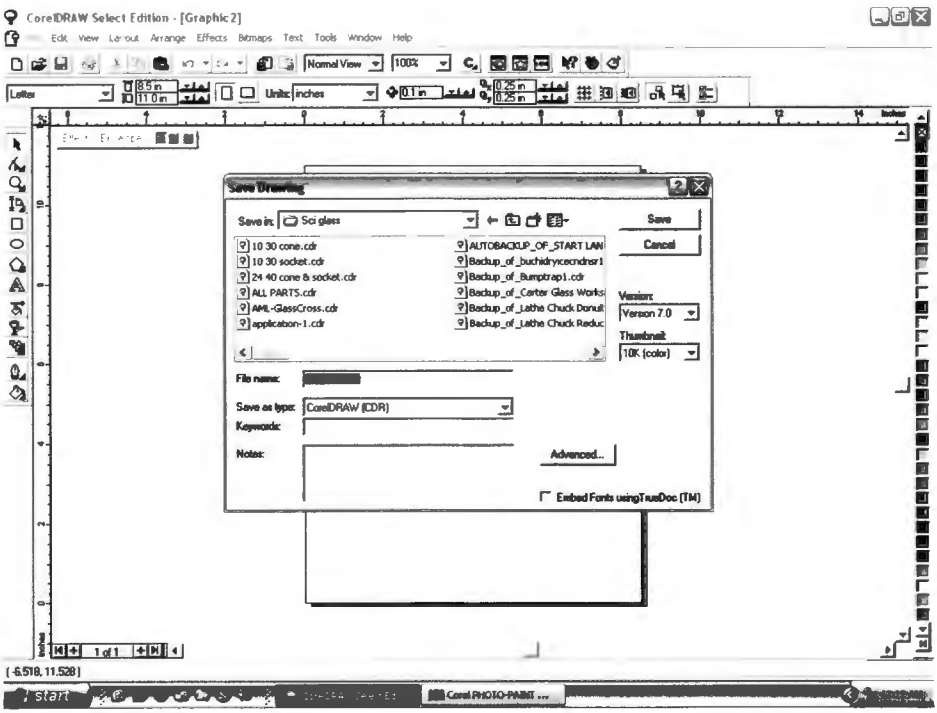
The use and reuse of previously drawn joints, hose connections, or other common shapes can be facilitated by storing them in a file called Parts list which can be opened concurrently with the drawing being created, and copying and pasting the item from one file to the other. The Contour, Lens, and Power Clip are also very useful commands for achieving complex results easily and quickly. The Dimensions tool is perhaps the most valuable tool of all as objects which are drawn at full scale are quickly measured and graphically displayed with only three clicks of the mouse.

More expensive technical drawing programs use a variation of these techniques to speed the creation process. These programs are shipped with extensive technical symbol libraries which contain shapes and symbols widely used in many electrical, architectural, and engi-

neering drawings. Unfortunately, these libraries do not exist for the field of scientific glass-blowing. However, CorelDraw offers the advanced user the ability to create these symbol libraries for use not only in Corel programs, but in all programs that support text.

Archiving

Archiving is the simpler of the two tasks outlined here. Corel offers a detailed options box from the SAVE or SAVE AS command. Besides the object name, keywords can be used signifying the process it is used for, client or lab group name or other alternative common names. A note box is also available to act as a reminder of pricing information, recurrent sales information, etc. All this information is searchable through the common Windows search engine. Additional information on creation techniques can be added directly to the file by adding a second information page. Additionally, the use of vector file formats in Corel allows a greater number of files to be stored on a single hard drive.

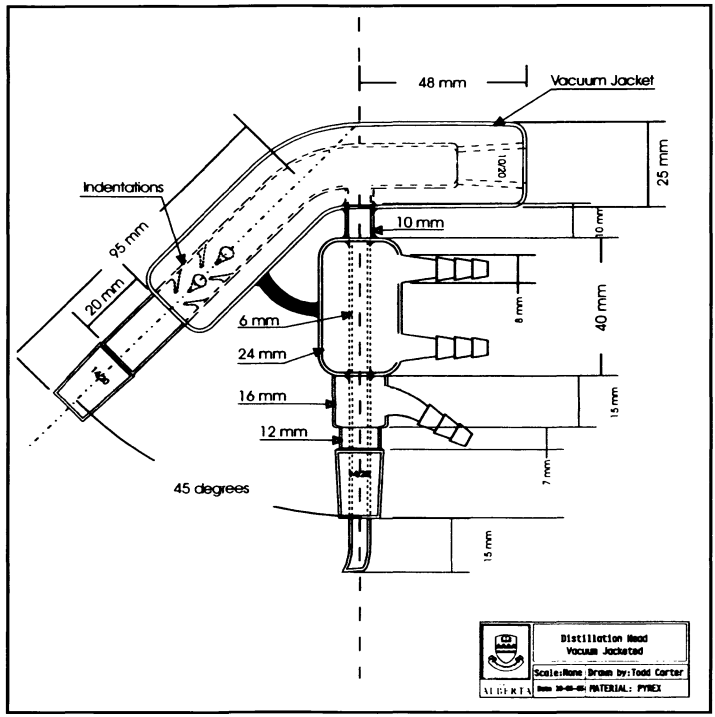


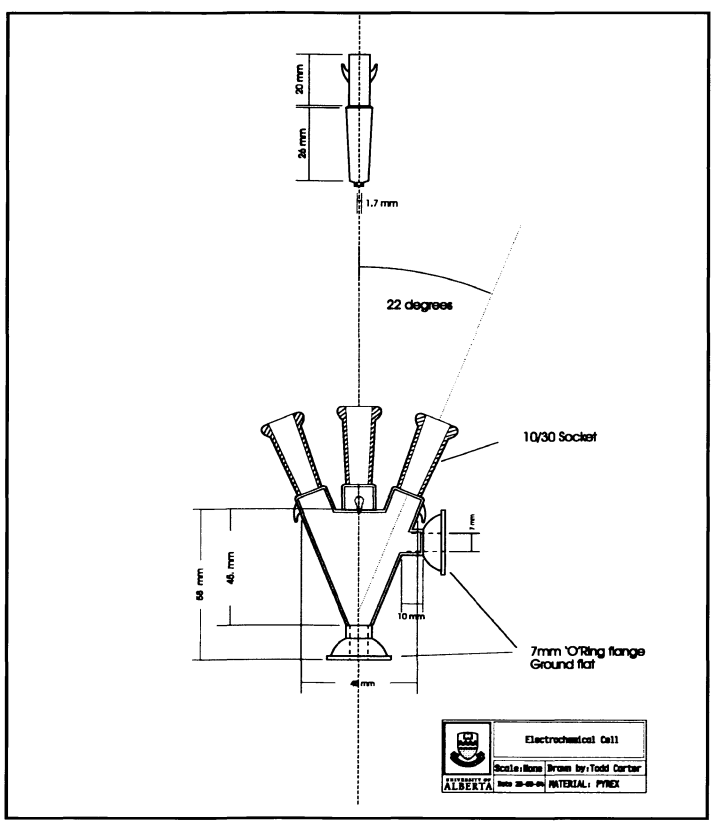
Conclusion

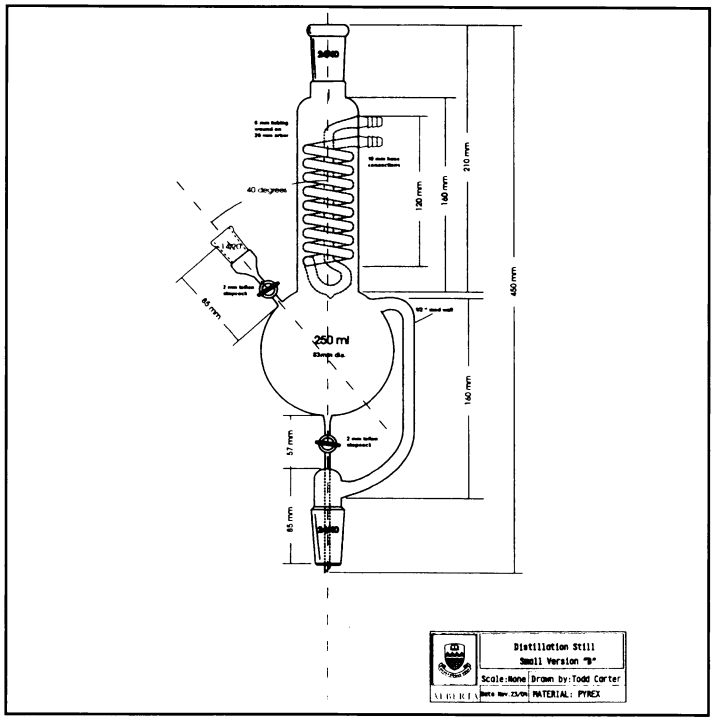
While there is a wide range of products available for implementation within the context of technical glass drawing and archiving, the keys to efficiency are

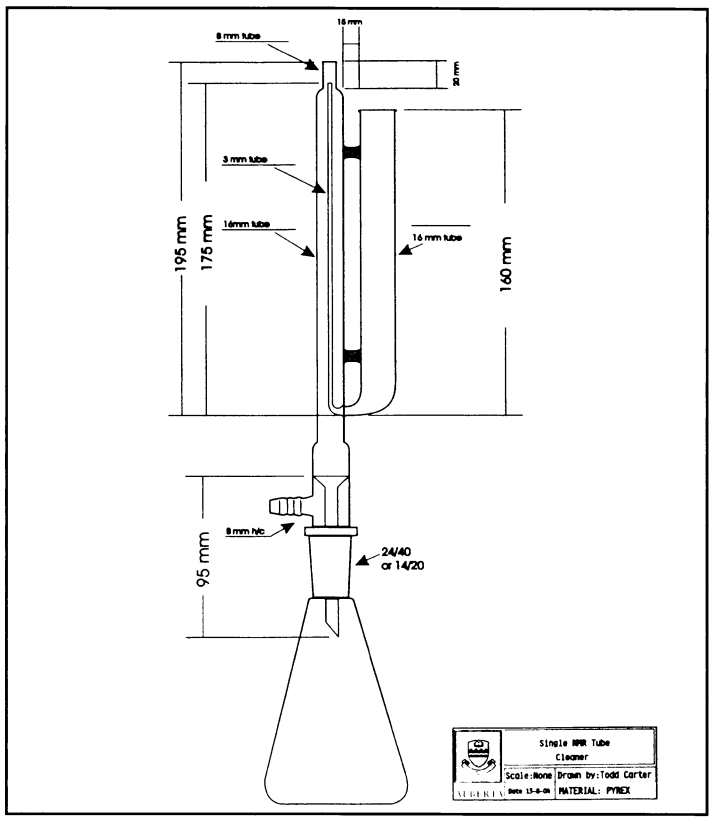
1. Become well familiarized with the program's capabilities.
2. Identify the basic building shapes.
3. Reuse previously made shapes.
4. Input specific how to and what for data.

Appendix
Sample Drawings






40 degrees
120 mm
160 mm
210 mm
450 mm
250 ml
140 mm
57 mm
65 mm
Distillation Still
Small Version "B"
Scale:None
Drawn by:Todd Carter
MATERIAL: PYREX


8 mm tube
18 mm
20 mm
3 mm tube
16mm tube
16 mm tube
195 mm
175 mm
160 mm
8 mm hdc
24/40
or 14/20
95 mm
Single NMR Tube
Cleaner
Scale:None
Drawn by:Todd Carter
MATERIAL: PYREX

The Wisconsin Firewagon: Construction of a Portable Glassblowing Podium

by

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Abstract

Outreach is one of the many elements of a scientific glassblower's job description. A grant was obtained for the construction of a portable glassblowing podium and necessary equipment. It is a self-contained unit that is easily maneuvered and can be loaded/unloaded by one person. It has been named the Wisconsin Firewagon. Construction process details will be highlighted, and various glassblowing demonstrations will be outlined. There will also be a discussion of possible funding sources, and the costs associated with building and outfitting a portable glassblowing podium.

Introduction

For over 100 years, the tradition of service at the University of Wisconsin has been embodied in a concept known as the Wisconsin Idea. This idea is based on the principle that the knowledge and resources of the University be available to everyone in the State of Wisconsin and beyond. The University's promotion and support of this philosophy allows me the chance to take the Chemistry Department Glass Shop research and craft out to the public. To effectively do this required a self-contained portable glassblowing station. Funding was applied for and was provided by the Institute of Chemical Education (ICE).

Our intention, as with all aspects of glassblowing, is to highlight what has worked for us. It is our hope that with this information and photographs you will be able to construct your own podium.

The Wisconsin Firewagon

This Wisconsin Firewagon is shown in Figures 1 and 2. It is a self-contained unit that is easily maneuvered, is professional looking and can be loaded into a vehicle by one person. The Firewagon design is based on a 1998 prototype made by Tim Drier (1) which is shown in Figures 3 and 4.

Prominent features of this prototype design include:

Figure 1.

Figure 2.


Figure 3.


Figure 4.

- Wheels mounted off the front of the podium. This configuration allows the podium to be easily maneuvered with the top lip acting as a handle. In motion, the angle of the podium keeps its contents intact. When stationary, the wheels are off the ground for stability.
- The top surface overhangs the main body. The overhanging top provides a handle to wheel the podium around and to maneuver into positions.
- Scalloped molding along the front top to prevent your glass and tools from rolling.
- Tool and equipment storage area.
- Angled front reduces friction and damage during loading and offers a professional appearance.
- Metal (aluminum) protective angle plates for the front angled edges. Figures 5, 6, 7, 8 and 9 illustrate how the podium is loaded/unloaded. The metal edge along the front length protects the wood from damage. Note the top drawer has been removed for loading. The podium is transported in a horizontal position as shown in Figure 9. The metal nose cone for the overhanging top prevents damage to the top. During transportation, a stable 3-point stance is assured with the overhanging nose at the top and wheels at the bottom.
- Internal tank saddles to secure oxygen and propane tanks. The saddle carriage is designed to distribute tank forces along the box frame when it is positioned horizontally for travel.


Figure 5.


Figure 6.


Figure 7.


Figure 8.


Figure 9.

Additions to this prototype:

- Enclose the rear of the podium to include two doors for the tank storage area and a top sliding drawer to hold tools and equipment.
- A small cut-out of the frame allows the torch hoses to pass through to the tanks with the doors closed.
- Rails underneath the main body which allows you to comfortably stand behind the torch while working.
- The top fireproof surface is screwed onto the top for ease of replacement.
- T-bolts on the top surface secure your torch during your presentation.

Construction

One of the key design considerations before you begin construction is that the standard width for doors in public buildings is 36". With the push handles on most institutional doors, 30" or 31" is more realistic. Another consideration is the working height of the podium and whether you want to sit or stand.

The Firewagon is a box construction from ¾" maple veneer sanded plywood. This includes the bottom rails and the rear doors. The framing around the rear opening, the front scallop molding, and the drawer front are solid maple. The drawer itself is made from pine with a thin plywood inset bottom.

The following figures illustrate the construction process of the main body. A parts list is found in Appendix I.

Figure 10: Runner construction. A "shelf" is glued and nailed to the runner so you can fasten the bottom onto it.

Figure 11: Cross brace fastened between the runners and the bottom fastened to runners.

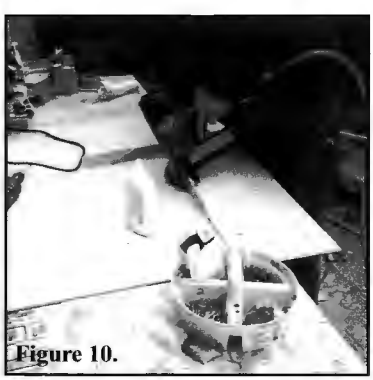


Figure 10.


Figure 11.

Figure 12: Mitered front panels glued and fastened along the bottom and up the front. A 1"x 1" furring strip is used for support on the inside corner. The furring strip height is the height of the main tank area.

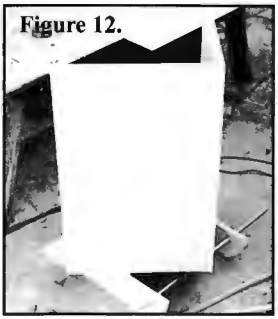


Figure 13: The side panels are added. Three corner supports are added to the top edge. These supports also give you something into which you can fasten the top plywood base. Note the furring strip on the inside front.

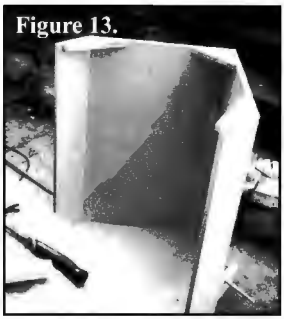


Figure 14: A cross brace is glued and fastened flush at the top between the side panels. The top is screwed into the corner supports and cross brace. The top is set flush with the rear of the podium.

Figure 15: Front view. Note top overhang (3/4") on sides and front.

Figure 16: Rear view.

Figure 17: ¾" x 1½" solid maple molding across the front of the top – flush with the bottom of the plywood top. An Elmer's glue bottle is used for the scallop pattern.

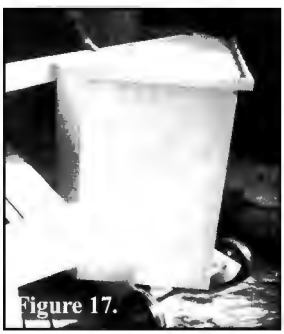


Figure 18: Solid maple framing is added around the rear opening. The top edge of the framing has rounded edges and is slightly above the fireproof top.

Not pictured:

- The rear hinged doors are fastened with non-mortise hinges, 2 per door.
- For the drawer supports, two rails are fastened between the rear of the frame and the front panels. Center mount drawer slides connect the drawer to the support rails.
- The ¼" cement board top is screwed down onto the top plywood base. Do not glue. The side and rear edges are banded with aluminum vanity mirror molding.
- The exposed sides of the top plywood are banded with ¼" x ¾" strip molding.
- Putty nail holes and stain.
- A dedication plaque in appreciation of the sponsor.

Figure 19: Tank saddles. The oxygen tank is as close towards the front as possible. It is supported with both metal tank saddles and wood. When in the horizontal position, the cylinder weight is distributed against both sides of the podium. The wooden curved tank saddle is to provide this force distribution for both cylinders over as wide an area of the front panel as possible. Necessary tank tie downs secure both cylinders.


Figure 19.

Figure 20: Tanks and fire extinguishers installed


Figure 20.

Figure 21: Finished podium – rear view

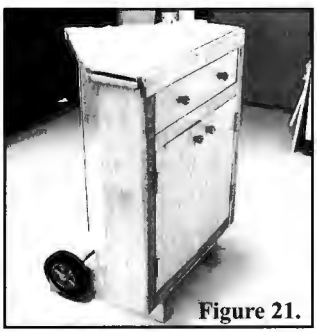


Figure 21.

Figure 22: Finished podium – front view. Note protective aluminum angle iron along front edge and top nose.

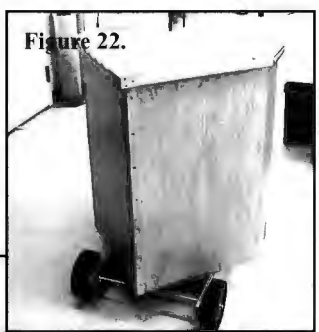
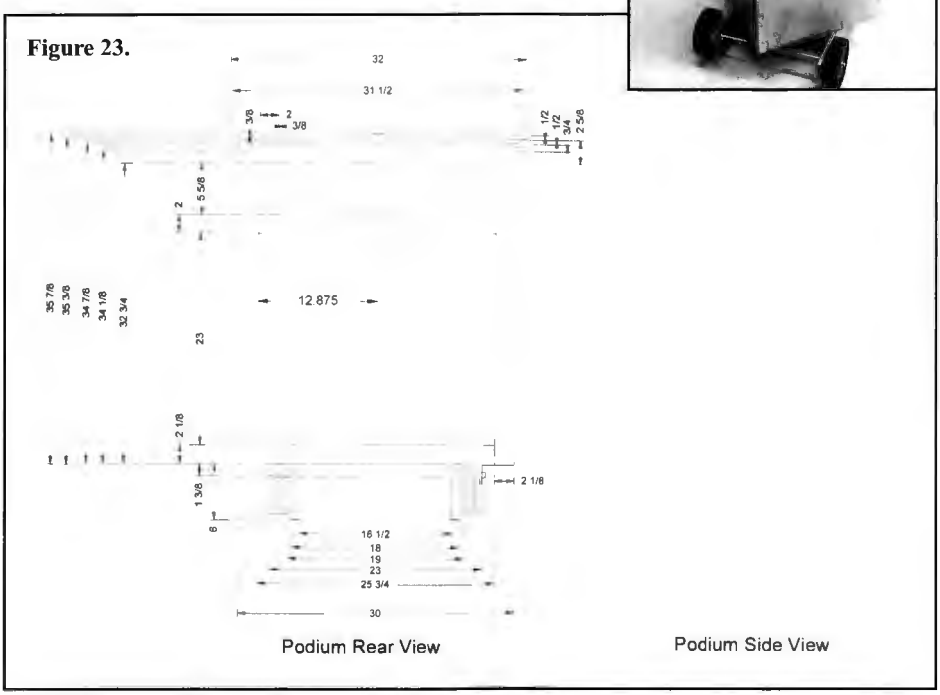


Figure 22.

Figure 23: Dimensioned drawing taken from the finished Firewagon. This should be used for reference only.

A list of glassworking tools is found in Appendix II.

Figure 23.



Presentations

Presentations are an opportunity to highlight the role of the scientific glassblower in scientific research as well as to discuss topics related to glass, glass science, chemistry, and physics. They usually last from 45 minutes to an hour with time for questions. It has been noticed that with grade K-12 demonstrations, the fire generates interest for the visual learners, and by pausing your demonstration, you can easily slip in science talk.

Appendix III contains a typical presentation outline. Additional topics are found in the funding proposal outline in Appendix IV.

The reference section contains a list of papers that highlight many varieties of presentations and possible topics for discussion (3 thru 14). Additionally, our notebooks are filled with ideas that have been presented at national and regional section meetings.

A couple of noteworthy visual aids were presented by Scott Bankroff at the 2004 spring Midwest Section meeting at Northern Illinois University in DeKalb. Figure 24 illustrates a variety of different glass types. The samples are approx 6" to 8" long (unless they are expensive or rare) and UV glued into a bundle. The tubes are engraved with their name/code number. It shows that just because they look the same does not mean they behave the same way. It also highlights the chemistry and science of the glassmaking process itself, and how researchers can use the specific chemical properties of glass to aid in their research and investigations. Figure 25 is an illustration of the variety of tubing and rods that are the raw materials of the scientific glassblower. The samples are 8" long and UV glued into a bundle. The tubing diameter range is 4 mm to 125 mm with an assortment of rod diameters that fit. Three evenly spaced feet around the 125 mm tube prevent it from rolling off your bench.

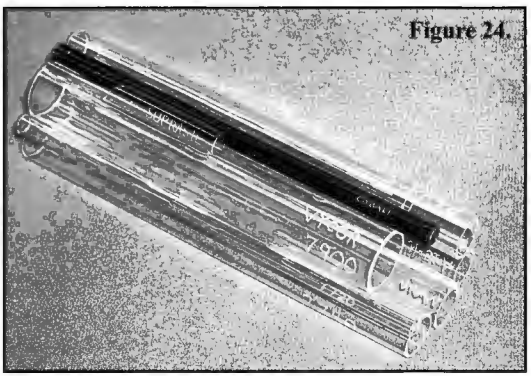


Figure 24.

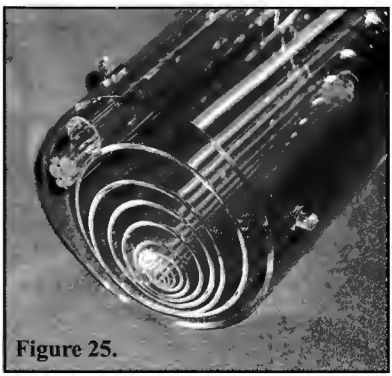


Figure 25.


Figure 26.

Figure 26 shows the Wisconsin Firewagon in action for the 5th grade classes at Cambridge Elementary School in Cambridge Wisconsin.

Funding

Community science outreach is a positive driving force for companies to contribute funding for a podium project. Their support and contribu-

tions are acknowledged during every presentation.

There are four funding options:

- Personal money.
- Departmental or company budget.
- Create a proposal for full or partial funding.
- Any combination of the above.

Local sections of the American Chemical Society, local welding and gas supply companies, local chemical or chemical-related companies are all potential sources for funding. Additionally, a small engraved plaque is fastened to the Wisconsin Firewagon to acknowledge the Institute of Chemical Education for their support with this project.

The prototype was built with partial funding from the local ACS section for the main components such as tanks, regulators, flashback arrestors and hoses (1). Free oxygen refills are courtesy of the local welding supply company. The building materials, torch and many of the glassblowing tools were personal.

The proposal request for funding of the Firewagon was made to the Institute of Chemical Education (ICE). See Appendix IV for the proposal. $3,000.00 was received for this project. Once the project began, we determined that there was a miscalculation on the engineering requirements for using structural aluminum. As a result, wood was substituted.

Conclusion

An efficient portable glassblowing podium design has been outlined and discussed. The intention is to provide the scientific glassblower with ideas and resources for building their own podium. Because of the unique aspect of our profession, we have an exciting opportunity through outreach to further our dialog with the public regarding our value and contributions to science and scientific research.

Acknowledgements

Many thanks to the following:

- Jerry Franzen, master carpenter, for his work on the construction of the Firewagon.
- Glenny Whitcomb. The winner of the (Wisconsin Firewagon) podium naming contest.
- Jim Hodgson, Erich Morraine, Ken Owens, Bob Ponton, Scott Bankroff, and Mike Souza for their presentation assistance.
- Randy Hansen for providing the catalyst to begin this podium project.
- The Institute of Chemical Education for their support of the Wisconsin Firewagon project.
- Dow Chemical, Midland, Michigan for their support of the glass Fabrication Department.
- The University of Wisconsin-Madison Chemistry Department for their continued support and promotion of the Glass Shop and the Wisconsin Idea.

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APPENDIX I. PARTS LIST

1 ea.	Maple veneer, sanded plywood	¾" x 4'x 8'
1 ea.	Maple Board	1" x 2" x 4'
1 ea.	Maple Board	1" x 4" x 4'
1 ea.	Maple Board	1" x 6" x 4'
1 ea.	Maple Board	1" x 6" x 6'
2 ea.	Furring strip	2" x 2" x 8'
4 ea.	Non-mortise hinge	3"
1 ea.	Aluminum angle iron	1 ½" x 34"
1 ea.	Aluminum corner Brace	1 ½"w x 2"
2 ea.	Center mount drawer slides, 12-7/8 slide length (Lee Valley Tools)	
2 ea.	Magnetic door catch (Lee Valley Tools)	
1 ea.	Fiber-cement board	14" x 3' x 5'
1 ea.	Silver vanity J molding	48"
2 ea.	T- nuts (plus bolts)	¼-20 (x 1.5")

2 ea.	Solid rubber tired wheels (Granger #2G356)	8" x 2 ½"
1 ea.	Aluminum rod	5/8"dia. x 26"
1 ea.	Aluminum angle iron	¾" x 36"
1 ea.	Oxygen cylinder	40 cu. ft. (dia.173 mm)
1 ea.	Oxygen regulator	
1 ea.	Propane cylinder	11 lb. (dia.230 mm)
1 ea.	Propane regulator	
1 ea.	Oxygen and propane quick connects and flashback arrestors	
1 ea.	Twin hose, grade T	¼" x 12'
1 ea.	Dry chemical fire extinguisher, Proplus-2.5MP (Granger #4XP87)	

APPENDIX II. TOOLS

Torch: Redmax. Premix top fire.
Plural Stopper
Swivel
Corks, assorted sizes
Tweezers
Carbon rods, assorted diameters
Small octagon reamer
Carbon plate, 6"x6"
Carbon Paddles: small, standard, and long handle
Scoring knife
Calipers
Protractor
150 mm steel ruler
Striker
Pick
Flat mashers
Marble mold
Support Roller

APPENDIX III. PRESENTATION OUTLINE

Layout glassware – assemble basic distillation set-up for display – lay out tools

Scientific glassblower for the UW – Madison Chemistry Department.
Look at the SCIENCE of: 1. the glass itself, and 2. the glassware.

Explain difference between scientific and artistic glassblowing.

Scientific glassblowing: shaping glass by melting tubing and rod with a fire (oxygen and gas) and blowing, bending, sealing, etc., to create a functional piece of scientific apparatus used by chemists, engineers and others in research and development.

Fire temperature: gas and oxygen: 2260 C / 4100F.

Glass working temps:
Qtz: 1600 C
Boro: 1250 C
Soft: 995 C

Learned at school: Salem Community College. Can also apprentice.
I belong to a community of scientific glassblowers.
There are national and international Societies of glassblowers.
Conferences and meetings to exchange ideas.
I am a member of the American Scientific Glassblowers Society.

Glass: a state of matter, no crystal structure, no defined melting point. Behaves like honey. Different from metal which has a distinct melting point.

Natural glasses (samples): Obsidian/Pumice (Volcano), Fulgurite (lightning striking sand), Tektites (meteoric/comet impact on earth/moon – no one is sure).

Earliest man-made glass is pottery glaze (sample).

Glass Composition (samples).

1. FORMERS: sand, SiO2. Melts at 1600 C. A lot of energy to melt: $$.

2. MODIFIERS (flux): Soda Ash. to lower the melting point. Problem: very unstable glass, e.g., will dissolve in humidity. Therefore, add

3. STABILIZERS (intermediates): CaO (limestone).

This basic composition: soda lime glass – typical for containers and bottles.

For Scientific purposes we want a high chemical resistance and good thermal stability. Add BORON as a stabilizer to the glass melt and we get these properties. It is called BOROSILICATE glass. One brand name you might recognize is Pyrex.

Adjust glass properties and color by changing the chemical composition (show tubing bundle sample composed of various types of glass). Entire science just devoted to glass-making (i.e., Alfred University, NY).

Another example of science of glassmaking - Didymium glasses.
Made from two rare earth elements: PRASEODYMIUM and NEODYMIUM.
Filter out orange flare caused by the presence of sodium in the glass (wavelength 589 nanometers).

My raw materials come in tubing and rod form – various diameters (show tubing/rod bundle of various diameters).

Build almost anything out of glass – takes time (and money).
Buy building blocks – standard tapers, valves.
Can be expensive – repair broken glassware.
Relative to metal, glass can be easily modified and repaired.

Glass is one tool available to the researcher. Also, machine, electronics and instrumentation shops.

Glass is integral to function of research laboratory.
In many instances of research, glassware does not exist.
Could not do synthetic chemistry without glassware.

Creative problem solving.
Figure things out. Experience helps, so does contact with other glassblowers.

Pose question – someone comes to you and says (dropping funnel drip tip joint).
People have been working on this problem for years.
Here is one method that works.
Holders – construction – build 24/40 drip tip joint.

It is not always about making stuff.
There are the physics and chemistry of the glass itself.

Hand mix some color. (Chemistry and physics)
Marble (Lens - physics)
Striking red (clear to red) (chemistry)

Colored Glass created from metal oxides:

Blue – cobalt oxide, copper oxide
Green – Iron oxide, chromium oxide
Violet – Manganese oxide
Amber – Sulfur and carbon
Red – Selenium and cadmium sulfide, cupric oxide

APPENDIX IV. SAMPLE LETTER

Proposal for funding of a portable glassblowing station

I am requesting funding for a portable glassblowing station for the UW Chemistry Glass Shop. It will be used for community outreach and education. My request is for $ 3,090.00 with cost details shown below. In order to be lightweight, portable and flame proof, this glassblowing station is to be constructed of aluminum structural framing components with a glassfiber reinforced cement working surface. This will be a one-time investment for this equipment.
My intention is to highlight the role of glass and the scientific glassblower as it relates to chemistry and science. This will be accomplished through practical demonstrations and discussions.

My primary obligation is glassblowing support of the Chemistry Department. Community outreach will be an on-going secondary obligation that I am dedicated to pursuing throughout my career at UW-Madison. Given my existing departmental workload, I believe it will be possible to make from three to five presentations during any given year.

The projected cost breakdown for this glassblowing station is as follows:

- Glassblowing station and construction: $ 1,770.00
- Tanks, torch and related equipment: $ 765.00
- Glass working tools: $ 480.00
- Safety equipment: $ 75.00

This self-contained unit will be easily moved into a classroom or auditorium space. I will have full glassblowing/benchworking capabilities. (See the attached sketch.)

I am currently in the process of putting together my presentation material. Topics of discussion include:

- History of glass and glassblowing.
- Glass in nature and our world.
- Glass composition and uses of soft, borosilicate, and quartz glass.
- Mechanical properties of glass: thermal (co-efficient of expansion).
- Stress (tension/compression) and its visualization with a polariscope.
- Scientific glassware examples.
- Connecting glassware/standard connections.
- Flameworking tools.
- Scientific flameworking techniques.
- Glassware construction techniques. Problem solving.
- Glass chemistry of techniques such as mirroring and coloring.
- Fiber optics.
- Flame chemistry and characteristics.
- Fire safety.

I will be happy to provide further details or clarification.

Best regards,
Tracy Drier

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