PROCEEDINGS

THE THIRTY-THIRD SYMPOSIUM ON THE ART OF GLASSBLOWING

1988

THE
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THE AMERICAN SCIENTIFIC GLASSBLOWERS SOCIETY
Toledo, Ohio

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"GENTLEMEN LIGHT YOUR BURNERS"

Don Lillie
Don Lillie Inc.

The purpose of this paper is to focus on a very simple phase of glassblowing and to show that a paper can be given on a simple subject. The challenge is to make it interesting, informative, and educational. The ultimate object is to dispel the perennial excuse for not giving a paper because the technique, formation or approach is not complex enough to qualify.

The ignition of the flammable gases emanating from your burner is a prerequisite to lampworking. Centuries ago the lamp was possibly ignited by flints. Once lit the wide flame from the wick would probably burn all day. In France, around 1780, the "Ethereal Match" or "Phospheric Taper" was developed which consisted of phosphorous and a piece of wax paper sealed in a glass tube with the oxygen removed. When the glass tube was broken and the contents withdrawn, the exposure to air would result in ignition.

In the early 1800's, it was discovered that potassium chlorate and sugar on the end of a wood splint would ignite if dipped in sulfuric acid. So a Samuel Jones of London in 1828 patented the "Promethan Match", which consisted of a glass ball containing acid and the outside coated with a potassium chlorate-sugar solution. "When the glass was broken by means of a small pair of pliers or even the user's teeth, the paper in which it was wrapped was set on fire."

Around 1830, the friction match was developed and produced. Some of the early phospher matches would self-ignite or would be extremely difficult to light. In addition, the smell was particularly offensive and the warnings printed on some boxes stated, "Persons whose lungs are delicate should by no means use lucifers."

Besides the commonplace match, there are today an infinite number of devices to light your burner.

Slide III

Most notable is the butane lighter, which can last several years without fail. Perhaps the most used device is the striker.

Slide IV shows two styles — an old open style and the more modern type with a trapping cup designed to capture the flammable gas in the ignition zone. The material used in the striker is a ferro-cerium alloy. Another way is using a piezo-electric starter.

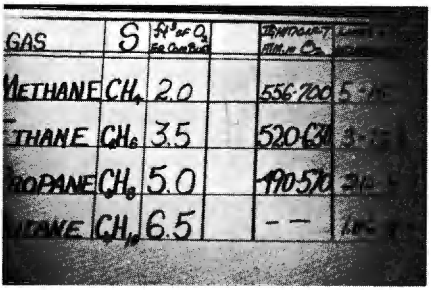
Slide IV

NOT
AVAILABLE

Slide V

The one on the right uses the energy dissipated in compressing a spring to create a spark at the tip. The device on the left is a battery operated lighter triggered by placing the torch tip on the switch.

I have long had in mind a quick ignition device which I thought I would develop for this paper.



Slide VI

This is a pilot tube with a 1-1/2 volt model motor glow plug. My theory was that simply pressing a switch would result in the pilot light being ignited. This did not occur, even though I increased the voltage as high as 3 volts. Puzzled, I looked up the ignition temperature of natural gas in *The Handbook Of Chemistry And Physics.*

Slide VII

The column on ignition temperature shows that methane ranges from 556° - 700° C. Evidently the range was too high, so noting that propane was much lower at 490° - 570° C, I tried a tank of bottled gas, but the low voltage was not causing ignition. I do not think it wise to utilize higher voltages in the burner area. When sealing pieces in the annealing oven, I have ignited a hand torch by simply placing the tip, with the gas valve on, next to the glowing nichrome wires. However, this is a 200 volt source.

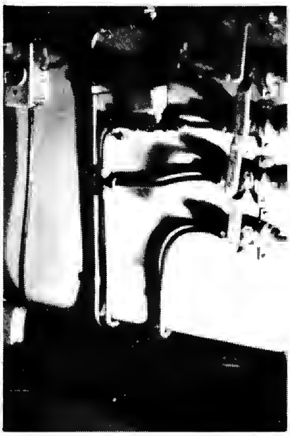
Before I leave this chart, I would like to point out an interesting quantity in column two marked "Ft.^{3} of O_2 For Combust." This means that two cubic feet of oxygen is needed for the combustion of one cubic foot of methane. Slide down to propane and you will see that five cubic feet of oxygen is required per cubic foot of the gas. A 244 cubic feet cylinder of oxygen will combust 122 cubic feet of methane but only 48.8 cubic feet of propane.

Another idea I had was to crimp a platinum gauge over the end of the pilot tube. The theory being that the Pt. would glow from the ignited gases at the tip and, if blown out, the residual thermal energy stored in the Pt. would reignite the flame. Unfortunately, a 26G. Pt. screen did not have enough thermal mass and a thicker one did not absorb enough energy to glow for ignition.

Now, once your burner is ignited, what do you place it on and regulate on-off flames?

Slide VIII

This shows a work bench in our lab. The desk is a modified metal office desk fitted with a 3/4" thick custom colorlith top by Johns Manville Company and supplied by R. R. Horne of Stone Mountain, Georgia. Vee notches, 2-1/2" deep are located on 3 sides. Since we had twelve desks to install, a custom layout would have been too expensive and this design work bench has provided adequate service for over 16 years. On this work bench is a Carlisle CC burner with pilot. The gases are fed through the regular Tygon twin tubing which is quite common. However, on the pilot light feed we are using silicone tubing instead of amber rubber tubing. It remains flexible, cleaner, and does not deteriorate.

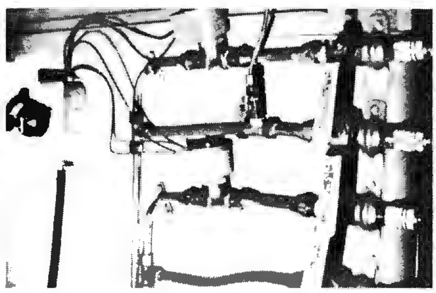


Slide IX

Shown here is the plumbing under the desk with an electric foot pedal arrangement.

The valves are 1/4" Apollo ball valves available from Will Process Equipment Corp. in Atlanta. These are maintenance free, economical at $7.00 each and display on and off modes at a glance. The handles can be easily removed and dipped in plasacote to color code if desired. The fittings and connections are all compression style because they can be easily installed and readily disassembled; if leak checked periodically, they are safe and reliable.

The foot switch is a Treadlite T-51S and can be obtained in either "On-Off" command or "Kickon-Kickoff" models. The open gas line contains the pilot valve since this must be separate from the solenoid line. This configuration with quick couplers allow the burner to be switched to a continuous mode if the foot switch is impractical or the electricity fails.

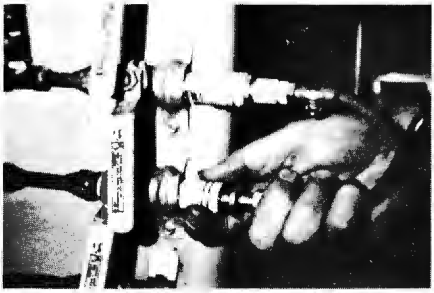


Slide X

The solenoids are ASCO 1/4" valves #8262C13. They are manufactured by the Automatic Switch Company in Florham Park, N.J. and are designed for gas, air, water, and light oil. Our gas lines are under 5 pounds pressure and the oxygen line pressure is normally 20 psi. Engaging the foot switch causes the plungers to raise; deactivation results in a closing mode. When energized for long periods, the solenoid closure becomes hot. "Any excessive heating will be indicated by smoke and odor of burning coil insulation", so states the instructions. Our valves have operated for over 15 years and have never failed. They can be obtained from Brownell Electric in Hapeville, GA and cost about $27.00 each.

Slide XI

All burners are connected with quick couplers obtainable at any compressor supply store. These are Amflow C-20 quick disconnects with 3/8" hose barbs for tubing connections. This facilitates rapid changing of burners and guarantees a safe leakproof connection.



Slide XII

I have seen various mechanical foot pedals with sliding valves and spring retracts. These are expensive, have a tendency to develop leaks, and require frequent maintenance. Several years ago, a foot pedal was sold which mechanically compressed the Tygon tubes for shut-off and released it for the on-position. This arrangement was, of course, terminal for the tubing.

The distinct advantages of the arrangement I have shown you is it's longevity and reliability. It can be installed by the glassblower and maintained "in shop".

Thanks are given to: Jerry Cloninger, Rick Smith, Thom Lillie

Suppliers:

Brownell Electric
3020 Commerce Way
Hapeville, Georgia

Will Process Equipment Corp.
3800 Wendell Drive, Suite 107
Atlanta,Georgia 30336

Automatic Switch Company
Florham Park, N.J.

R. R. Horne Company
1584 McCurdy Drive
Stone Mountain, Georgia 30083

CO_2 LASER WELDING OF AN INFRARED CATHODE RAY TUBE

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This paper presents the construction sequence for a fused silica infrared cathode ray tube which is assembled by means of CO_2 laser welding. The advantage of this technique over the more conventional methods of torch welding lie in the elimination of OH absorption by the fused quartz windows. The inclusion of OH would greatly impair the infrared performance of the device.

The phosphors employed for infrared (IR) cathode ray tubes (CRTs) typically are cooled to temperatures in the vicinity of liquid nitrogen. Thus, the phosphor supporting substrate must be both infrared transmitting and capable of cryogenic cooling. To satisfy these requirements, a design has evolved which employs Infrasil fused silica for components which must be transparent in the infrared. The balance of the cooled structure is then fabricated from commercial-grade fused silica. Assembly is by means of CO_2 laser welding. This allows the construction of a self-contained dewar assembly, having windows which are not impaired by the absorption of OH.

The Infrasil windows cannot be sealed with a hydrogen-oxygen flame, since the water of combustion would be absorbed; thus diminishing the IR transmission. The front part of the CRT, the funnel, the cryogenically cooled phosphor supporting box, and the faceplate are then sealed to the electron gun assembly, which is made of Kovar. This is a graded seal and is accomplished through the use of Kovar seal glass.

The completed instrument is show in Figure 1; a cross section, in Figure 2, shows the structure. The phosphor is deposited on the cooling box which is fabricated from two 5-cm Infrasil windows and a fused silica frame. The electron beam is directed at the phosphor. The resulting photons are transmitted through the cooling box and then the faceplate. The cold nitrogen gas, close to its boiling point, is fed through the side arms, which are vacuum jacketed and fitted with expansion bellows to relieve the stress. The funnel is evacuated separately through the port.

The instrument is assembled in the following sequence.

1. A 75-mm dia fused silica funnel is joined to a length of 50-mm tubing by means of a ring seal formed on a glass lathe (Fig. 3).
2. A section of the 75-mm funnel is removed by means of a diamond saw so as to allow installation of the internal cooling box (Fig. 4). This section will later be rejoined to the funnel by laser welding, and as such, the saw cut must be straight to prevent gaps in the interface surfaces.
3. The cooling box envelope is cut from 50-mm tubing, and short side arms are attached. These side arms must be short enough to allow eventual installation of the box within the 75-mm funnel. Infrasil windows of 50-mm diameter are then welded to each end of the envelope to form the cooling box as shown in Figure 4.
4. The cooling box is annealed at 1100° C. An electric furnace is used for the annealing operation to assure that the infrared transmission of the Infrasil windows is unaffected.
5. After annealing, the cooling box is laser welded to the 50-mm tubing previously joined to the funnel neck by the ring seal. This operation is illustrated in Figure 5.

6. The section of tubing removed from the 75-mm funnel during operation #2 is ultrasonically milled to create 25-mm access ports corresponding to the installed position of the arms of the cooling box. The funnel sections are then rejoined by means of laser welding (Fig. 6).
7. The assembly is installed on a glass lathe and the side arms of the box are extended beyond the walls of the funnel. This operation is performed through the access ports in the funnel using a micro-torch as shown in Figure 7. Care must be taken so that the silica soot is not deposited inside the instrument, which would contaminate the Infrasil windows of the cooling box.
8. The exposed side arms are covered with vacuum insulated jackets having bellows for stress relief. These are joined at the 25-mm access ports on the 75-mm funnel by means of a micro-torch, as shown in Figure 8.
9. The insulated jackets are then terminated and sealed around the side arms which serve as the inlet and outlet ports of the cooling box.
10. An Infrasil window, 75-mm x 10-mm thick, is then laser welded to the funnel to form the front faceplate of the CRT, as shown in Figure 9.
11. After a final annealing, the phosphor is deposited on the innermost Infrasil surface, and an electrical conductor is applied on the inside of the funnel from the phosphor to the neck where the electron gun is attached. This final attachment is accomplished through the use of a graded seal. The evacuation of the electron gun and CRT should be performed simultaneously to prevent unnecessary stresses.

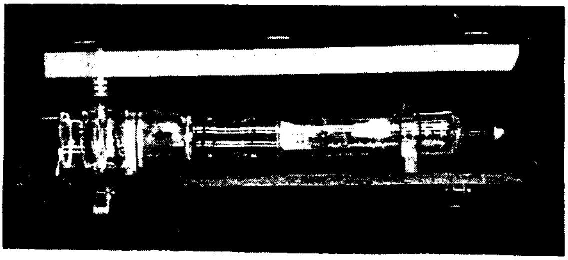

Figure 1

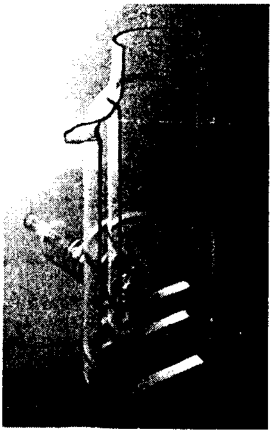

Figure 2

Figure 3

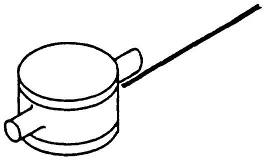

Figure 4

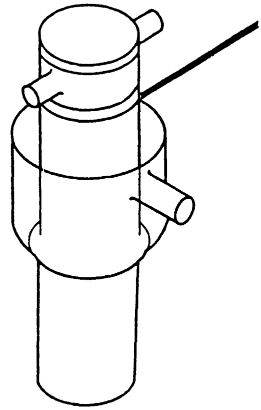

Figure 5

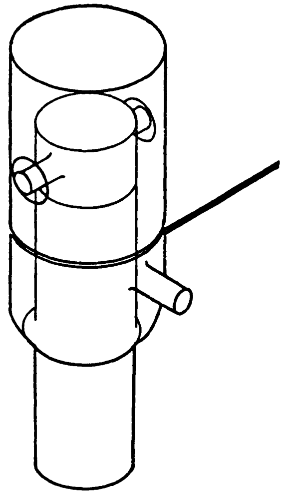

Figure 6

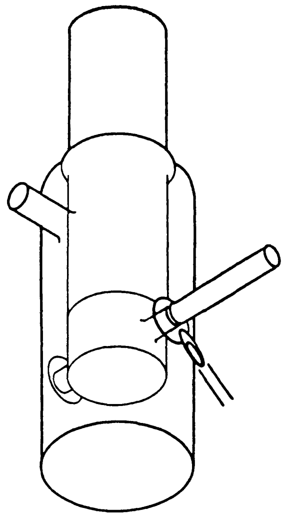

Figure 7

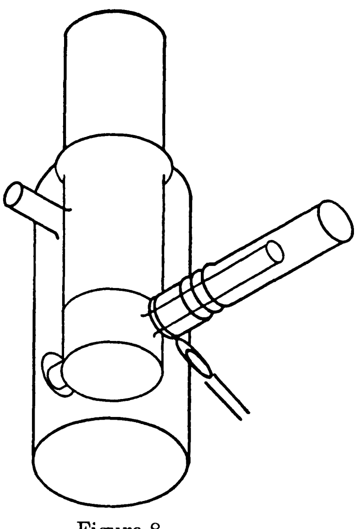

Figure 8

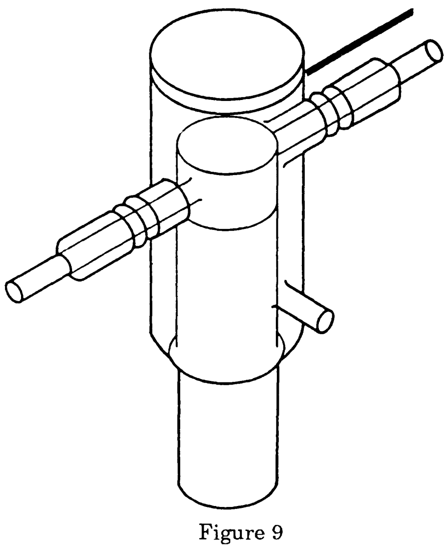

Figure 9

TEACHING GLASSBLOWING TO THE NON-GLASSBLOWER

Larry Williams
University of Massachusetts
Amherst, MA

I am very happy to speak today at the 1988 American Scientific Glassblowers Society Symposium. The University of Massachusetts has been offering a glassblowing course for graduate students and staff for over twenty years. It was initially developed by Gordon Good, Joe Walas and myself. More recently, Tim Landers and Sally Prasch have modified and taught the course. The results have been so rewarding that we would like to share them with you now. A course of this type can be taught in many different ways. This paper will concentrate on one method we use in teaching glassblowing to the non-glassblower.

Our glass course is not meant to produce glassblowers but to give scientists a better understanding of how glass apparatus is made and repaired, as well as the ability to make simple repairs and apparatus on their own. Communication between ourselves and the scientists, and consequently the final product, will be improved as a result.

There are a few considerations that must be taken into account before embarking on teaching such a class: The lab area in which the class will be held, the type and number of students, the number of classes, their length, grading scales, instructor/student interaction, and the expectations of the student. The class must be structured, but still flexible.

When choosing an area in which to hold class, there are a few things to keep in mind. We put safety at the top of our list. Safety equipment must be readily available in case of emergency. A fire blanket, extinguishers, first aid kit, and a phone must be easily accessible to anyone in the lab. An explanation of how to use the safety equipment in case of emergency should be given the first day of class. The classroom must be large enough to adequately contain the equipment. As you see in the slide, each bench has its own regulator, gas valves, torches, and a variety of glassblowing tools. There is storage space in the drawers to the side and underneath each bench. On the first day of class the student picks a bench, and from that day on each student is solely responsible for keeping that area clean.

The glassblowing course at the University of Massachusetts is offered to graduate students and staff at any of the schools in the Five College system (i.e., University of Massachusetts, Amherst College, Mt. Holyoke College, Smith College, and Hampshire College). Before enrollment we talk individually to people interested in our course, and we inform them of the time requirements and our expectations. We require students to be on time to all classes, have a positive attitude towards learning glassblowing, and be capable of learning a few basic glass skills. Graduate students in their final year have top priority when signing up, then other graduates, faculty and staff, and lastly undergraduates. We are limited to ten benches, so we always have to turn some away. Those denied are then put on a waiting list for the next semester.

Each class is unique; some learn fast, others are slower. Keeping this in mind, we try to stay flexible to meet the needs of the students. We follow a class outline that we use for lessons covered during the semester. Some of the skills taught are points, rings, constrictions, bulbs, straight seals, "T" seals, hooks and possibly ring seals. There is enough flexibility in the outline to give added information if time allows. If you would like to look at our outline, you can find one on our poster board. Our outline is arranged as a guide for instructors of this course. Those of you who are currently teaching or would like to teach such a class may find our outline helpful.

We offer twenty-seven classes, each one hour long. Although our students are very busy with their graduate work, they are encouraged to come into the teaching lab any time the glass lab is open to work at their benches. After a semester's work, the students may not have mastered glassblowing, but they have a better understanding of glass fundamentals.

We are not trying to make glassblowers out of the students, but to increase their understanding of the capabilities of glass, giving them invaluable knowledge for their careers in laboratory science. Their grades are based on three factors: attitude, knowledge and skill. The student is graded on a point system. To obtain points the student must be timely, have good self composure, be safe, be able to do simple glass skills and be considerate to others. We give four examinations to test the student on knowledge and skill. Three of these exams cover recent material. The fourth is a final exam that covers all the information taught throughout the semester.

We team teach the glassblowing course. Team teaching enables us to give each student more personal attention. Like glassblowers, students will try to find the most comfortable way in which to perform a skill. Keeping this in mind, we teach a skill in one particular way. If we see that a student is having difficulty, we often suggest an alternative method. This way the student is exposed to a few different techniques to choose from when learning a skill. Learning the art of glassblowing can, as we all know, be very frustrating at times. When we see a student becoming frustrated, we usually recommend that he/she set the piece of glass down and attempt a different glass skill for awhile. Sometimes we suggest taking a short walk and trying again later.

We have always found the students to be enthusiastic and responsive learners, particularly those from foreign countries whose universities lack extensive facilities. There are times when language can be a barrier. Repetition and feedback can help clarify instructions. Asking specific questions or repeating back what you think you have heard benefits both student and instructors. A little extra time spent in communicating will result in a motivated learner achieving a goal. And remember, students themselves may have special insights to share as well.

It is a good practice to remind the students that glassblowing is a skill that takes years to develop and they must accept their current level of ability, whatever it is. This advice will help them to have patience when a skill doesn't come as readily as they want it to.

Conversely, we as instructors must keep patience and tolerance in the forefront of our teacher/student relationships. We recognize that taking the course will enhance their understanding of the issues in glassblowing and apparatus design, but these students are not going to become full-time glassblowers. Our example as professionals is important in helping them to act professionally as students. The instructor is obligated to maintain a good relationship with each student so as to provide continual evaluation and encouragement.

This paper has concentrated on one approach to teaching a glassblowing course to graduate students in the sciences. We hope that others with similar facilities will offer a course of this type. The more scientists are able to understand the mechanics and techniques of glassblowing, the more easily they can communicate their needs and wishes to glassblowers. We will all be more satisfied with the final results.

It has been my pleasure to address the society this morning. I would especially like to thank my two co-workers, Sally Prasch and Tim Landers, for the time and effort they have put forth in helping me prepare this paper. Thank you all for your time and attention.

ADAPTING A CANOPY OVEN TO FACILITATE VERTICAL ANNEALING

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It is the lot of most scientific glassblowers throughout the world to have to make do with less equipment than their hearts desire, in order to cope with the multiplicity of tasks they must tackle during their daily toil. Sometimes a job comes along which seems to defy the ingenuity of the best of us. One might even postulate that our old demoniacal mentor, Murphy, probably figured out his law after discreetly observing some of our primordial colleagues doing their thing in the cellar of some Mesolithic glassworks.

By fair means or foul an object can be made, but, how to anneal out the strain when it's too long for the oven. In most cases, it's about an inch or so too long. Flame annealing is the only solution. The procedure works well enough for simple jobs but becomes questionable when applied to precision ware, especially without the back-up of a strain viewer to guide the procedure. This is not to say that flame annealing does not have its place in the scheme of things. Indeed, we frequently rely on flame annealing as an intermediate step to placing the object in the oven.

In the vast majority of cases, the removal of stress is directed towards the extremities of the object and thus becomes a question of annealing one end at a time. This simple fact provides the key to the solution to the problem. The only thing which remains to be done is to decide the best way to locate the stressed portion of the object within the body of the oven while the major portion of it remains outside. Trying to do this in a horizontal mode is impractical for several reasons. First and foremost, there is very little likelihood that sufficient free space is available along the work bench to cope with several feet of glass. The second drawback lies in the fact that the heating elements cross the four walls of the oven canopy, and rerouting the wires will be a major problem when trying to create a temporary access port through the side wall of the canopy. Furthermore, even assembling a tampion to cover the access port so that the unit can be used as a regular oven, is rather difficult to do. Fortunately, the solution to all these problems lies in providing access through the roof of the canopy. There are no elements to get in the way of the modification and gravity holds a simple tampion in place without fastenings of any kind. And, of course, no bench space is required all.

The procedure outlined in the following paragraphs is the one used at MPB Technologies. It is simple and requires a minimum of workshop facilities, but that is not to say that it is the only way to tackle the project. The first step is the most difficult, consisting as it does of removing the roof cover sheet prior to making a rectangular hole in it. The sheet is fixed to the canopy case by several pop rivets. Drill out as many of the rivets as is necessary to slide the sheet out from the retaining edge straps, (i.e. the rivets on the top of the canopy at the sides and rear, and the top and side of the front). Bear in mind the less that are removed the less there are to replace. Beneath the sheet there are some layers of asbestos paper which should be removed from whichever end of the canopy which has been selected as the access site. The firebricks are now exposed and it will be seen that they are the full width of the canopy in length and nine inches wide. The material is quite soft, and moderately fragile. Proceed to mark the center point of the second brick from the end. The second brick is preferred so that glass placed in through the top of the canopy will not have one side positioned too close to the end elements,thus receiving rather more heat than is desirable during the heating cycle. Having located the mid-point of the brick, draw two parallel lines equidistant from the mid-point to mark out the width of the opening required. Do not make the opening wider than necessary, for with the glass clamped in place, the remaining space must be temporarily closed over with insulation. A square hole is ideal as it provides a twelve inch diagonal access to the oven. A portion of the brick is removed by drilling starter holes at each corner and cutting out the section with a jigsaw or a keyhole saw. Try to keep the cut-away part whole, as it will be utilized to make the tampion. After the sides of the hole have been smoothed with a coarse file, place the top sheet back on so that it is located in its correct position, then mark the outline of the hole with a felt pen from underneath. Remove the sheet and cut out the piece which has been marked. The way to cut the material is with a fine-toothed jigsaw blade. Smooth and flatten the edges prior to replacing the sheet back on to the canopy. Refasten with pop rivets or use sheet metal screws. The worst part of the whole operation is now completed. In order to protect the exposed surface of the soft fire brick from damage when removing and replacing the tampion, U-shaped inserts are cut from stainless steel sheet and inserted against the walls of the entry port. These pieces are illustrated in Figure 1.

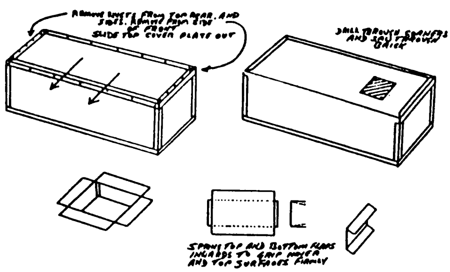

Figure 1

Select material which can be cut using metal shears rather than a thicker grade requiring workshop facilities because the same material will have to be cut in order to fashion the outer case of the tampion; a slightly more difficult task. The inserts are cut so that when the side pieces are bent slightly inwards there is enough spring to hold the piece in position when it is inserted. Note that the two plain pieces are placed in position first. The other two pieces have a small tongue, which will press against the inside of the plain pieces and will hold everything in place without any additional fastenings, provided everything has been cut to size, and pressed well in position. Make sure that the corners are good right angles, otherwise difficulty will be experienced making the box for the tampion.

Making the tampion is simplified if a cardboard model is first assembled and adjusted to fit easily into the port in the canopy. A clearance of about an eighth of an inch around the edges will make removal and insertion a simple matter. Try to avoid an excessive gap because of heat loss through the space, which would make the lid of the tampion unnecessarily hot. The folded out edges at the top of the box are screwed to the underside of the lid. Metal strips are cut and drilled, and the position of the holes is duplicated for the box edges and for the lid of the tampion. Material for the lid should be any strong heat-resisting material which is also an insulator. A thickness of half an inch is suitable, but try not to select anything thicker because of weight. When everything has been cut, bent, and drilled — and checked: the tampion can be assembled. The various steps are illustrated in Figure 2.

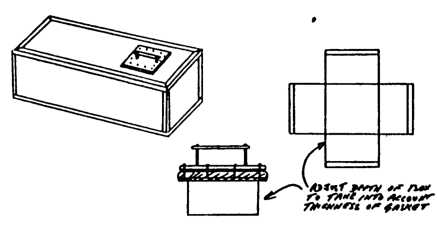

Figure 2

No specific dimensions have been indicated because individual requirements vary widely. However, allowance should be made with respect to the depth of the box in order to take into account the thickness of the layer of soft insulating material which seals the top of the canopy and the lid. Ceramic wool of the type used to line the tray of canopy ovens is an ideal choice of material. The wool compresses under load and the reduction in thickness should be noted so that the depth of the tampion box can be adjusted, so that when the tampion is in position, the underside of the box is more or less at the same level as the underside of the canopy roof. Thermal insulation of the tampion is achieved by utilizing the piece of fire brick which was removed from the canopy roof to form the entry port. File away material until the block fits into the box, and fill any free space around the sides with vermiculite. The space above the brick caused by making the box deeper than the thickness of the roof is best filled with ceramic wool. At this stage, remember to attach the handle to the lid before fastening the box to the lid. Prepare the gasket pad, then hold it in place with the metal straps. The oven now has vertical annealing capability.

A scaffold is constructed which supports a metal rod which, in its turn, acts as a point of attachment for conventional laboratory clamps. There are two basic approaches to fixing a scaffold. It can be fastened to the wall behind the oven, or it can be bolted to the metal plates which cover the elevating mechanism at the top of the main frame. In most cases these plates are five inches wide and a quarter of an inch thick, and they are spaced five inches apart. There is ample room to attach two vertical supports using rods which are attached to the inside surfaces of the plates by means of small U bolts. It is necessary to employ two rods in order to give sufficient stiffness to the scaffold to provide firm support to long items of glassware which are clamped to it. If half-inch diameter rod is chosen, the cross braces are readily assembled using standard laboratory rack fittings. Alternatively thin angle iron may be used, which is bolted to the oven. However, more work is involved in attaching the horizontal brace rods. If facilities are available, the scaffold can be welded together. There are two very important dimensions which must not be overlooked. *First* there is about half an inch clearance between the front surface of the scaffold mounting plate and the back of the oven canopy. Make sure that the nuts or bolts used to attach the vertical supports of the scaffold do not protrude more than a quarter of an inch beyond the plate; otherwise the projection may obstruct the free rise and fall of the canopy. *Secondly* make sure that the lowest part of the scaffold projections are at least an inch above the top of the canopy when it is raised up to its maximum height. Some possibilities are illustrated in Figure 3.

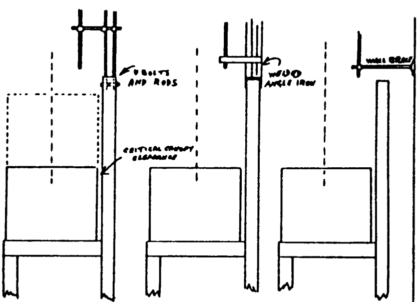

Figure 3

From time to time it is necessary to anneal items which have glass to metal seals, or flanges sealed to the ends. In order to avoid unsightly oxidation of these metallic components during the heat cycle, it is necessary to protect them with a reducing atmosphere, or at least an inert one. Such a procedure, somewhat difficult to do in a horizontal position, becomes simplicity itself when the item is introduced into the oven vertically. All that is required is a small cup, which may be glass or metal, which will accommodate the metallic component, and which can be sealed at the top with a metal plate which has a hole cut of a size to fit around the glass tube just above the metal portion, and cut in half. Forming gas, nitrogen, or carbon dioxide is allowed to flow slowly into the top of the object, being so directed that it emerges through the bottom, thereby filling the cup with gas and protecting the metallic surfaces.

All in all, it takes about a day for one person to perform the modification, taking into account several coffee breaks.

GLASS TECHNOLOGY IN ELECTRONICS; PRESENT AND FUTURE

Dr. Josef Francel

Glass technology has contributed significantly to the spectacular advances of the electronic industry. New glass products were developed for many critical applications like the microprocessor, fiber optics, lithium batteries, and low temperature sealing. The presently used materials will be compared to the glasses being researched and developed for the 90's and the year 2000. The dominating trend for future electronics is micro-miniaturization with its challenge for high reproducibility in materials and processing, high reliability of components and devices, improved dimensional control and new special glasses supplied in high quantities.

1. INTRODUCTION:

In electronics, glasses play an essential, important role as electrical insulators, protective coatings, planar solid dopants in diffusion, alkali getters, solder dams, photomasks substrates, thin and thick films in hybrids, sealants in hermetic cer-dip packages, in display panels and CRT's, in very high speed printers as chemically resistant nozzles and in fiber optics. In all these applications glass serves well. In many areas further developments in glass technology are expected to meet the stringent, challenging requirements of the 1990's and 2000's micro-miniaturizations for high reproducibility, high reliability in severe mechanical, thermal and chemical conditions.

This presentation will summarize the presently used materials and will project what to expect in the near future in glass technology in electronics.

2. MECHANICAL RELIABILITY:

The total efficiency of all electronic devices and components depends on the reliability of each member of this total system, e.g. microprocessor. All glasses used have direct impact on the electrical wiring network and strongly affect the signal pulse, which is the key element of any microprocessor. These processors are not just one component but a dynamic interaction of many contributors. So each member of this system depends on the others and consequently, if one fails, the whole processor becomes useless. All devices are subject to stresses during operations, thermal shocks and chemical attacks. Glass strengthening will be used more often in the next two decades. They will include chemical and thermal tempering, crystallizations and crystal additions.

3. DEVICES — MICROPROCESSOR:

Glasses are used for boron and phosphor diffusions in the form of

3.1 Solid Planar Dopants. They are superior to the other diffusion sources in efficiencies high yields, very low standard deviations in large size silicon wafers (3 inch and higher), excellent process controls and relatively simple reproducible processing.

In the future, antimony and arsenic sources will be added to the present boron and phosphor.

3.2 Protective Coatings — Passivation Layers are high purity alkalies-free glasses with good adhesion to silicon, with low expansions and high densities (to block migrations) and low defects populations. In the near future glasses with superior purity derived from organo-metallics, with high density (barium oxide containing) will replace present alkali-free alumino-silicates.

3.3 Applications Of "Device" Glasses

A. Sedimentation Process will use two layer systems (high and low dielectric) dispersed in a single mixture of 90% ethyl acetate + 10% isopropyl alcohol applied by high speed centrifuge and fired near softening point in about 5 minutes.

B. Electron-Beam evaporation is capable to deposit 50 micron layers in one hour.

In the future, the deposition rates will be increased by composition changes and multi-source applications. Removal of thermal stresses will be done by annealing after depositions.

C. CVD — Chemical Vapor Depositions. Present glasses will be replaced by high density alkali and lead free at temperatures of 400°C thicknesses of 10 microns will be obtained. Stress relieved by reannealing in humid atmosphere.

4. MULTILAYER CERAMICS MLC (hybrid thick film technology)

Active devices — chips are supported, protected and connected to other components by a ceramic base (usually alumina) and thick film screen printed network of conductors, resistors, capacitors and passivation coatings.

In the future, multilayers of 150 members will increase to 500 layers. They will require very fine line prints of components. Conductors of silver and paladium will be replaced by tungsten, molybdenum, copper and copper alloys (fired in reducing atmosphere requiring lead free glasses).

5. HERMITIC — CER-DIP SEALANTS

Seal glass-metals, glass-ceramic and ceramic-metal. Stronger seals will be required and developed by glass technology labs. Higher compressive stresses and thin metal imbedded in glass seals to relieve the stresses appear to have high probability answers for the next generation of microprocessors.

6. FIBEROPTICS

Transfers of signals will grow into a multibillion dollar business. These signals have an advantage over old metallic copper wires in extremely high bandwidth with transfer rates in 10^4 - 10^7 low electro-magnetic interference and security against tapping.

In the future, transmission loss will decrease from 4DB/km to 0.15DB/km solid state launchers and receivers will use complex photo-diodes to increase the signal speeds. Longer wavelengths will be common with even lower losses and less scattering. Fluorine complex glasses will replace the present 1.3 micron range by 2.5 micron region.

7. DISPLAYS

CRT tubes will have higher resolutions and increased contrast with less specular reflections.

Gas Panels: Further optimization of components (dielectric, conductors, substrate glass) will bring better-controlled process of making large display panels.

8. PRINTING

Very high speed printers will benefit in reliability by improved alkali and acid resistant glass nozzles with precise ID control.

9. CONCLUSIONS

9.1 Glass will maintain its key role in electronics for many decades in the future.

9.2 Glass will meet future tough requirements of multicomponent functional subsystems.

9.3 Higher reliability of glass components will be achieved by strengthening, improved reproducibility and purity with zero defects.

9.4 Field failures of devices and packages will be drastically reduced and time-consuming and expensive repairs will be minimized.

9.5 In the 1980's, CRT tubes stopped imploding, and in the 1990's fiberoptics will transfer billions of signals without failure.

9.6 Glass will serve well, and you glassblowers will be proud to work with glass to contribute to the solutions of future challenges to make life of next generations even better than ours.

COMPUTERIZED RECORD KEEPING

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How many of you have to keep shop records?

How many enjoy doing it?

Let me tell you what I have to do, and then how I go about making it easier with a computer.

Once a month, I sit down and stare at a pile of completed work orders. If they don't go away, and they never have to date, I start to process them. I have to note the amount of time spent on each order, and bill it at different rates, depending on the source of the order. If it's for my own department, then it's one rate; if for another department, a second rate; if off campus, a third. Then I have to account for components used, and add a surcharge where it is applicable. Next, the components have to be charged against our inventory. Finally, the completed bills must be addressed and sent out to our customers.

None of these operations is complicated or difficult in itself. They all take time. They are all subject to small errors that seem to take forever to find. The computers that are readily available today are admirably suited to just these applications. Not only that, it is not necessary to be an expert to use one. In this regard, I should say a word about hackers. A hacker, often an amateur, always enthusiastic, can be your greatest help in getting a system off the ground. Given the technical nature of our profession, it should not be difficult to find such a person, or to enlist his help in customizing a program to suit your individual needs.

Next, we should talk a bit about what a database program is. Essentially, it is a number of lists that the computer can manipulate according to your instructions. The best example we have is the telephone book. When you look at a phone book, you see three lists: one of names, one of addresses, and a third, of numbers. If you have a person's name, it should be no problem to find the address and number to go with it. But if we go to the phone company, and use their equipment, we can do a lot more. If we have a number, we can find not only the appropriate name and address, but also what calls were made, how much they were charged, and even what phone was used to make an individual call. This is exactly what we do with our database. We even do incorrect billings.

Since I work for a university, the world revolves around research grants. All our work is charged against them. They are analogous to the numbers in the phone book. Like phone numbers, each account has an address and a supervisor's name attached to it. And like phone numbers, other people can make charges on the account with the owner's permission. Instead of long distance calls, we charge stopcocks and glass tube. As soon as I type in the account number, the machine "knows" to whom the bill is to be sent, and prints the stored address out on the bill. This in itself saves time.

```
MENU SELECTIONS:
"I"  INPUT REQUISITIONS
"M"  MODIFY REQUISITIONS
"R"  ISSUE REPORTS
"B"  BILLING PARAMETER
     CHANGE FOR LABOUR AND
     SURCHARGE
"Q"  QUIT PROGRAM
CHOICE:
```

Slide 1

The key to working with this system is the menu, or rather, menus, plural. The first one you see up on the screen is what comes up on the monitor to start off. As you can see, you are given a choice of five basic activities; entering new information, modifying what is already there, reporting what's been done, changing what can be done, and getting out.

If we are going to see what can be done, then let's look at what we have to work with. I've already talked about the address file, so let's start with that. The way to take a look at something is to make like you're going to change it, so we'll press "M" to modify things.

```
CHOICE "M" RECORD
MODIFICATION PROGRAMME
MENU SELECTIONS:
"A"  ADDRESS FILE
"R"  REQUISITION FILES
"I"  INVENTORY FILE
"M"  BACK TO MAIN MENU
SELECTION ______________
```

Slide 2

We see that we are asked to choose again, but this time the options have to do with what has already been stored. So we'll press "A" for address and come up with this:

```
CHOICE "M" ADDRESS FILE MODIFICATION
DO YOU WISH TO:
"A"  ADD A RECORD
"C"  CORRECT AN EXISTING ADDRESS
"D"  DELETE A RECORD
"R"  RETURN TO MAIN MENU
SELECTION: ______________
CHOICE "A"
NAME ______________
BUILDING ______________
STREET ______________
CITY/CODE ______________
PHONE ______________
```

Slide 3

And for the third time, we are asked to choose from a number of options. I think you will begin to see that the format so far is consistent. The machine keeps asking questions about what you want to accomplish. All you have to do is have an idea of what that is. So, we see that when it comes to addresses, you can cover most of the bases. You can add a new address, you can correct an existing address, you can get rid of one, or you can get out.

If you chose "A" to add an address, you will see our first typo, which is that I forgot to include the research grant number on the slide. Trust me; it's there on the disc. The information here is pretty straight forward. Once the computer can link an account with a name and address, it knows where to send the bill.

```
CHOICE "M" INVENTORY MODIFICATION ROUTINE
INPUT ZERO TO END
SHOP STOCK NUMBER ______________
CHEM STORES NUMBER ______________
DESCRIPTION ______________
UNIT ______________
SUPPLIER ______________
CATALOGUE NUMBER ______________
ON HAND 1 ______________
PRICE 1 ______________
ON HAND 2 ______________
PRICE 2 ______________
THIS NUMBER IS NOT IN THE INVENTORY FILE.
DO YOU WISH TO ADD THIS NUMBER (Y OR N)
SHOP STOCK - 999
DESCRIPTION ______________
QUANTITY ______________
PRICE ______________
```

Slide 4

The second list of information I want to talk about is the Inventory file. If the program is going to work as planned, this file should be updated before each billing. As with any other inventory, this is a simple matter of telling it what you bought in the last month. If there isn't enough stock to complete an order, by the way, the computer refuses the order until this file is corrected. In order to keep things clear for the computer and ourselves, we have made a list of all the components we use, and assigned each a number. Each size of glass tube, each type of stopcock, each size of ground glass joint is listed first by a three digit number, then by a written description. If the item is kept in stock by Chemistry Stores down the hall, then their stock number is included.

The units of sale are next. Tubing is sold by the meter, written "M", discrete items like joints are sold individually, written "EA" for each. If the item is ordered from a catalogue, then the company and their stock number is included. We have permitted restocking before running out of items by including two prices. When the first stock is used up, the computer automatically switches over to the second stock and price. Corrections can be made by simply overtyping on the display.

For specialty items there is number 999. If you know that you are only going to use an item once in a blue moon, and don't care to keep it in stock, you can apply this number to it. The computer knows enough not to try to store it, and asks for this information every time it is entered.

The third thing we should talk about is the Billing Parameter Change. The billing system that I work with is something that evolved over a long period of time. I work for the chemistry department. Our people don't get charged labor. Researchers in other departments are charged labor, and a service charge on any component parts they buy from us. People who come to us from off campus get charged even more. From time to time the people in charge decide to change the rules of the game on me and tell me to change the rates. Using this screen, I can change any or all the rates as needed.

```
CHOICE "B"                BILLING PARAMETER CHANGE

CATEGORY
"A"  C                    LABOUR/HR.                   $
"B"  O                      "                          $
"C"  P                      "                          $
"D"  C                    SURCHARGE/HR.                $
"E"  O                      "                          $
"F"  P                      "                          $

"Z"  CHANGES COMPLETE

SELECTION: ______________________________________________
```

Slide 5

With all the basic information stored away, we can get down to do some real work. The first thing to do is choose Menu Selection "I" to input information. The monitor will show something like this:

Next, you tell it how to treat anything coming in by choosing one of the Billing Categories. Once it knows what to do, you can give it the rest of the information from the handwritten order paper. In all cases, the program is designed to ask for the information needed. It is up to the operator to enter everything correctly. This is very important. One of the oldest sayings in the computer industry is, "Garbage in equals garbage out". From bitter experience I can tell you this is true. One small example of this is that billing, which is printed out by month, is controlled by the "Date Completed" input. If you enter the wrong month by mistake, the program will neglect that order when it comes time to do the billing. Then, of course, you have to go back and look for the error.

```
ORDER NUMBER 1234
      CATEGORY             DATE ORDERED          DATE COMPLETED
         0                   87.07.11               87.11.07
        DEPT                  GRANT                SUPERVISOR
      GEOLOGY                A12387                SMITH A.B.
      BUILDING                STREET                CITY CODE
      ROCKLAND             123 RICHMOND        LONDON ONT N6A 5A8
  SUBMITTED BY         PHONE          ROOM            TIME
     JONES          661.2582.1234      123            4.25

                              LABOUR
                              127.50

                              ITEMS
STOCK #          DESCRIPTION           QUANTITY         PRICE
105              P5                      0.500           0.10
148              P25                     0.250           0.62
413              CNB24                   2.000           7.50
800              PYREX FLAT 1/16 SQ     20.000           2.60
                 CM
```

Slide 6

That brings me to correcting mistakes. Very often I don't know what I'm doing at the best of times. Anything I do HAS to be subject to massive correction at any point in the process, not only when the information is first being put in, but also after everything is completed.

```
CHOICE "M" REQUISITION MODIFICATION PROGRAM
TYPE 0 TO END
SHOP REQUISITION NUMBER ____________________
"A"  CATEGORY
"B"  ORDER NUMBER
"C"  DATE ORDERED
"D"  DATE COMPLETED
"H"  SUBMITTED BY
"K"  TIME
"M"  DELETE THIS RECORD AND ITEMS
"Z"  CONTINUE TO ITEM MODIFICATION
ITEM 1
"A"  SHOP STOCK NUMBER
"C"  QUANTITY
"Z"  NEXT ITEM
"M"  DELETE THIS ITEM
DO YOU WISH TO ADD AN ITEM TO THIS REQUISITION - __ ?
(Y OR N)
```

Slide 7

When I ask the computer to correct an error, I want the largest number of options possible. By typing in the appropriate letter, I can choose exactly which part of an order to correct, or if I get really fed up, I can delete the whole order by typing "M". The same applies to the components which have been billed. Any item can be deleted from an order, and re-inserted into the inventory at any point in the process. Items can be added to orders at a later date as well. In designing a system, always work on the assumption that if something can go wrong, it will. Try to give yourself as much flexibility in correcting situations as you possibly can.

The last part of the operation is to report what you have done. Our customers and the accounting department want two things from us: they want to know what was done on each order, and how much was spent in each month.

```
                 GLASS SHOP BILLING FOR November
GRANT #      DEPT                 RATE/HR          MATERIAL
A123B7       GEOLOGY              $ 30.00          SURCHARGE
                                                      15.00%
   BUILDING          STREET               CITY CODE
   ROCKLAND          123 RICHMOND         LONDON ONT NGA 5AB
  SUPERVISOR         PHONE                ROOM
  SMITH A.B.         661.2582.1234        123
   ORDER #           LABOUR($)            MATERIAL ($)
   1234              127.50               12.44

           TOTAL CHARGE TO A123B7   $ 139.94
```

Slide 8

The individual order report tells us what has been typed into the program. It tells us the order number, how the order is to be treated, when it came in, when it was finished, the grant number, and who ordered it. The grant number tells us who owns the account, and where to send the bill. The item list tells us what was used, what quantity, and what price for individual items.

The billing sheet completes the report. It starts out by telling the purchaser what are the conditions of sale: the hourly rate and the surcharge on materials. Then it goes on to report the total for each order completed, and the total amount billed for the month at the bottom.

Cutting Characteristics Of Diamond And Abrasive Cutoff Wheels, With Mounting Considerations

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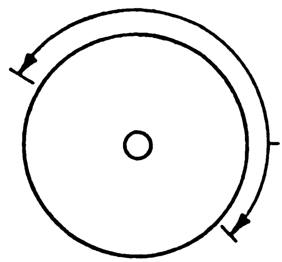
Nothing affects quality cutting more than selection of the proper wheel. In order to accomplish this, from time to time we need to review the essentials of wheel theory and terminology and then try to SEE just what happens during abrasive cutting. This is important when cutting something familiar, such as glass, but even more important when working on an unfamiliar material.

THEORY OF ABRASIVE CUTTING

Abrasive wheels consist of a vast number of sharp abrasive grains embedded in a carrier such as rubber, resin, fiberglass, or metal. As long as edges of the grains are sharp, they slice away tiny shavings of the product being cut. When the edges of a grain become worn, the entire grain will break off from the carrier due to increased pressure of cutting, and new sharp grain is exposed to continue cutting. The grain must be harder than the material being cut, of course. Thus, unlike conventional metal working tools which have to be dismantled and sharpened from time to time, the abrasive wheel is always sharp. Assuming that the proper wheel was used for the material being cut, the cut will be of much higher quality than cuts made with metal saw blades.

SURFACE FEET PER MINUTE (SFPM)

The concept known as SFPM is very essential in understanding abrasive cutting. As an example, consider a typical machine using a 14" diameter wheel. Circumference is 14" x 3.1416, or 43.98", which is 3.66 feet. Multiply 3.66 x 1800 (the number of rotations the spindle makes in a minute) and you get 6588, which is the number of feet a particular abrasive grain on the cutting edge of the wheel will travel in one minute. This is what SFPM means, and in this case the abrasive grains are moving into the work piece at approximately 75 miles per hour. This is a good speed for most wet cutting applications. Wet abrasive wheels cut efficiently at 5000 to 7000 surface feet per minute (SFPM). As the wheel wears down, the SFPM drops because the constant-speed motor is unaffected by wheel diameter. Since SFPM affects the quality and speed of the cut, be certain you understand this concept known as SFPM.



Surface Foot

As the wheel wears away, the speed of the cutting edge drops considerably, even though the RPM remains constant at 1800. Table 5-1 shows the SFPM of various diameters, all running at 1800 RPM.

Wheel Diameter (inches)	Approximate SFPM
14	6588
13	6126
12	5654
11	5183
10	4712
9	4241
8	3769

When the SFPM drops below 5000, cutting efficiency drops noticeably, more so with some wheels than others. Cutting time lengthens. This could become important in a production-type operation. Wheels tend to act softer as the SFPM drops. Machines with low horsepower, i.e., 3/4 or 1 HP, tend to require softer wheels for a given job than the same machine equipped with a 3 or 5 HP motor because fresh, sharp abrasive is more available in the soft wheel. You have to push harder with a dull saw, and abrasive cutting is no different.

Many shops use a second machine with a higher speed spindle to use up the smaller wheels on smaller work. This can pay off well if a large number of wheels are used, and a variety of work sizes is encountered. It is generally not a good idea to use variable speed drives on cutoff machines for several reasons:

1. Safety — there is the possibility of running a wheel at a too high, and, therefore, unsafe speed.
2. Electronic variable speed (EVS) systems usually provide constant torque, rather than constant H.P.; therefore, the ability to maintain a useful production rate at the lower RPM required by a full size wheel is poor. Actually, this type of drive works out backwards, in that you need high HP at the low RPM, and EVS give the opposite, i.e., the high HP only at the high RPM.
3. Mechanical variable speed drives do maintain constant H.P. (or rate of doing work) and would be suitable for this application except for the safety aspects described above, and the cost which is usually high enough to make the payback on wheel cost savings rather long term.

AREA OF CONTACT OR ARC OF CONTACT

The amount of material in contact with the cutoff wheel is a prime consideration in the efficiency of cutting. If this area is relatively large, the cutting action will be slow, the horsepower requirement will be large and the wheel will tend to clog with the chips produced. The converse is also true; if the area is small, the cutting action will be fast and the wheel will unclog itself readily. These factors must be taken into account when using one wheel for several types of jobs; it can be readily seen that a crude compromise is often the only possibility.

WHEEL SELECTION

Numerous manufacturers produce wheels which are suitable for use on various wet cutting machines. Wet-cutting wheels use aluminum oxide, silicon carbide, diamond, and Borazon grains in various bonds.

ALUMINUM OXIDE WHEELS

Aluminum oxide wheels bonded with rubber are used for cutting steel and many other alloys and metals. Hard metals and hard alloys are most economically cut with wheels with a strong bond ("hard" wheels). Hard metals and hard alloys are cut quickest with wheels that have relatively large spaces ("open") between the abrasive grains; however, wheel life is longer if the voids are smaller ("dense"). The quality of the cut can be managed by wheel selection. Soft wheels give the highest quality cut in the shortest time; however, wheel life is shorter than with medium or hard wheels. In the case of very hard materials, it may be that a soft wheel will be the only wheel that is capable of making the cut, because new sharp grain is constantly available to do the work. With some materials, a medium hard wheel may provide the happy combination of speed, quality, and reasonable wheel life — however, this happy combination is rather unusual.

SILICON CARBIDE WHEELS

Silicon carbide wheels are used for cutting glass, quartz, some ceramics, titanium, tungsten, zirconium, uranium, beryllium and germanium, fiber, plastics (such as phenolics), and fiber-reinforced plastics. As with aluminum oxide wheels, there are variations in wheel density and bond hardness, which should be considered when selecting a wheel for a particular material.

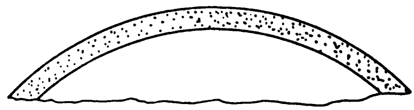
DIAMOND WHEELS

Diamond wheels are manufactured in metal bond or resin bond. The metal bond is available in three styles: continuous rim, notched rim, and segmented rim. Resin bond is available in continuous rim only.

The manufacture of fine diamond wheels is an art, rather than a science, and new developments are constantly being made with these different bonds, blends of various types of diamonds, and other techniques. If you have had bad experience in the past with diamond wheels on a certain material, do not assume that diamond wheels are all alike, made alike or formulated alike. There have been great changes in this field within the last few years. Again, as the manufacture of these wheels is as much an art as it is a science, and each manufacturer has his own special field of expertise, it is recommended that several manufacturers be contacted. The more information you can give concerning the end result desired, the better any diamond wheel manufacturer will be able to serve you.

CONTINUOUS RIM

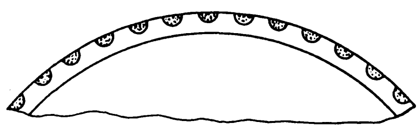
The continuous rim, illustrated here, is available in several depths, most commonly 1/8 inch or 1/4 inch depths. The rim is embedded with diamond particles in a bond which is available in various hardnesses to suit the material to be cut. Continuous rim wheels can be used on glass, quartz, ceramics, carbides and other materials that are hard and brittle.



Continuous Rim

NOTCHED RIM

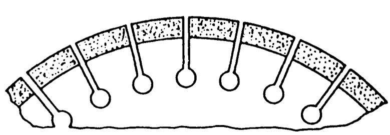
The notched rim, illustrated here, has small notches in the rim filled with diamond-bearing metal. This is the least expensive diamond wheel and is used to cut stone, brick, mineral specimens, and other similar materials. These wheels will produce a rough, chipped cut on heavy glass or ceramic sections, and while these wheels have a very limited use on glassware, these wheels have proven to be very economical on certain special types of work



Notched Rim

SEGMENTED RIM

The segmented rim, illustrated here, is used mainly on heavy stone, mineral sections and concrete. These wheels have almost no use to the glassworker. This type wheel is designed to get the most possible coolant into the cut.



Segmented Rim

The four main considerations in formulating a diamond wheel for a specific job are diamond type, bond type, grit size, and concentration. Diamonds come in a variety of types, primarily natural and man-made, each type having certain characteristics better known to those who specialize in making these wheels. There are also various coatings used on the diamonds, such as nickel and copper — used to control heat. Bond types are metal and resin, and there are various hardnesses in both. Bond type will affect cutting action, life of the wheel, and quality of cut. Grit size will affect both cutting rate and finish achieved, just as it does in woodworking. A chain saw with a few big teeth cuts very fast and produces a very rough cut. A 100-tooth circular saw blade produces a very fine cut, but you cannot push it very hard, because there is not much space for the sawdust between the teeth. Diamond wheels are similar; 120-grit wheels will produce a rough cut, and 320-grit wheels produce a very smooth cut.

Concentration refers to the actual amount of diamond powder within the bond matrix, and is expressed by a number, such as 25, 50, 75, or 100. These are the most common, although other in-between numbers are used on special formulations to achieve specific results. "100 Concentration" indicates there are 72 carats by weight in each cubic inch of bond material on the rim, 50 concentration means there are 36 carats by weight, 25 means 18 carats, and so forth. Back to our calculations, a 14" wheel, .070" thick with a 1/8" diamond depth of 100 concentration on the rim, would contain about 27.7 carats of diamond powder.

$$14'' \times 3.1416 \times .125 \times .070'' \times 72 = 27.7$$

I am told that, in theory, each carat of diamond in the wheel will cut 500 square inches of glass. I have not checked this theory, and offer it only as a general guide as to what performance you might expect from a particular wheel. This theory would indicate that a 50 concentration wheel would do twice as much work as a 25 concentration wheel. I do not think that this is precisely true, because too many other factors enter into the cutting situation.

There is a wide variety of diamond wheel formulations available for cutting many hard, brittle materials. Generally there is no such thing as an all-around diamond wheel, just as there is no all-around abrasive wheel. The mythological perfect wheel would give you long life, fine finish, easy or low feed pressure and low cost — and this wheel does not exist! You will always have to give up something to gain one of these desirable features. Our biggest problem is getting a user to decide exactly what he wants.

All of the high quality diamond wheels are "Tensioned" for some particular speed, and will often NOT RUN TRUE at other speeds — making these wheels run true at some particular speed is one of the "Black Arts", and the men who do this work keep their methods to themselves. When ordering diamond wheels, you MUST tell the manufacturer what RPM it will be run at to get optimum results.

MOUNTING CUTTING WHEELS

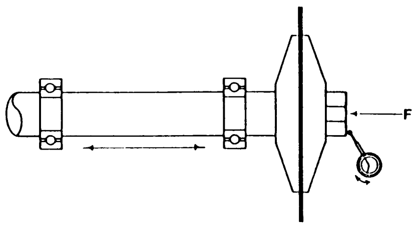
General

The four main considerations in properly mounting a wheel concern the SPINDLE BEARINGS, the SPINDLE itself, the FLANGES, and, of course, the WHEEL.

SPINDLE BEARINGS generally tell you in no uncertain terms their condition — bad bearings are very noisy, or become noticeably loose. The bearings can sound and seem OK, but have another problem — end or axial float.

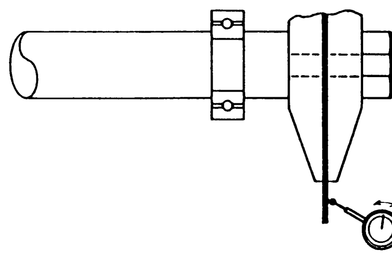
This will rapidly destroy cutting accuracy (and the wheel) if not corrected. To test for end float, pull on the spindle axially and see if it moves in and out. This is end float. Sometimes new bearings are the only cure. If you have this condition, talk to the builder of your machine. You are wasting your money by mounting an expensive diamond wheel on a spindle with much end float. Axial float must not be confused with side runout, although they show up about the same way.

Side runout is a defect in either the spindle, flange, or wheel. You can have this condition even though you show no axial float. With the test setup shown, pulling on the nut will show axial float, and rotation of the spindle will show side runout, although it will not tell you what is at fault.



Axial Float

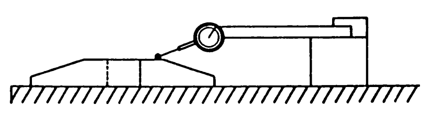
Next the SPINDLE itself: The best method to test the spindle is with a dial indicator mounted on some rigid part of the machine, testing the "run out" of the portion of the spindle where the wheel is mounted. This should test within a few thousandths; however, be realistic — a machine using rubber wheels does not need to be as accurate as one for diamond wheel use because rubber wheels will wear quickly, dressing themselves, and compensate for this type of inaccuracy. You cannot afford to dress a diamond wheel to compensate for an inaccurate spindle — but that is exactly what you would be doing by "wearing it in" by cutting into something to "dress" the diamond wheel. An accurate wheel on an accurate machine should not need any "dressing" before it will cut properly. It WILL need an occasional cleaning, by cutting into something such as a soft brick, to clean out the spaces between the diamonds — but this is not actually "dressing", because you are not correcting an out-of-round, or other eccentric condition. More critical is that portion of the spindle that the flanges mount against; this should be clean, square, and should run within a thousandth or two.



Side Runout

The FLANGES are very important. They must be flat, with both faces parallel — and this is best tested on a surface plate with feeler gauge and dial indicator.

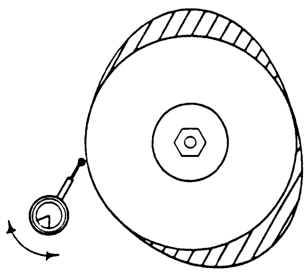
The side that goes against the wheel can be very slightly concave, but NEVER convex, as a convex side will not support the wheel properly, because it would only touch the wheel in the center — not around the edge where the support is needed. It is possible to bend flanges into a convex condition by over-tightening, particularly on soft flanges made of brass or aluminum, so test your flanges occasionally. The flanges should be flat and free from any bumps and dents; any of these should be machined out.



Check Flanges For Flatness

The WHEEL itself should be inspected for cracks, chips, and other sources of possible failure. Wheels with cracks or chips should not be used. This applies to both diamond and rubber bonded wheels. Rubber bonded wheels that are twisted from improper manufacturing or storage should be tested very carefully and, if mounted, should be left to run without cutting for 5 minutes or so and then checked to see if it has improved.

Sometimes a wheel will have to be cleaned occasionally, to make it cut well again — this is often called "dressing", but cleaning is probably a more accurate term to describe what is going on. Very little wheel material is removed in cleaning, just the debris from cutting that has packed up between the sharp abrasive or diamond grains is removed by introducing some material that will scour the cutting surface of the wheel.



Radial Runout

Sometimes an out-of-round wheel will be encountered.

Here the center of rotation is not on the center of the wheel. This can be caused by a variety of reasons that we will not go into here. It is not very practical to try to correct an out-of-round condition on a manual feed cutoff machine because the light table weight and light travel characteristics of a machine for glass cutting works against you, producing more of a cam follower action than a dressing action. It is possible to mount an out-of-round wheel on a machine equipped with power feed, and dress the wheel by cutting into some material that has a tendency to wear the wheel quickly, and back into true round.

INSTALLATION OF WHEEL — CHECK LIST

1. Clean flanges, spindle shaft, and threads. Clean loose abrasive and dirt from wheel.
2. Install inner flange on spindle. A small amount of waterproof grease can be used on all mating metal surfaces to facilitate removal. Do not put grease on diamond wheels, however, as this will affect the ability of coolant to "stick" to the wheel. Actually, a used and rusted wheel will carry coolant into the cut better than a new wheel.
3. Be sure spindle and flanges are designed for thickness of wheel used. Measure wheel if you are not sure of its thickness. Inspect each wheel to be absolutely sure that the center bushing is not loose. WARNING! A WHEEL WITH A LOOSE CENTER BUSHING SHOULD NEVER BE USED.
4. If a wheel has an oversize bore, it is advisable to press in (or epoxy in) an accurately machined bushing to fit the spindle, although it is possible to center an oversize bore on a spindle.
5. Install wheel on spindle against flange.
6. CAUTION! DO NOT TURN WHEEL DURING INSTALLATION BECAUSE THIS MAY DISLODGE ABRASIVE GRAINS AND INDUCE WHEEL WOBBLE.
7. Place outer flange on spindle against wheel.
8. Apply a small amount of waterproof grease on threads of spindle to make removal easier.
9. Engage spindle lock if your machine has one.
10. Put nut onto spindle and tighten with wrench.
11. Do not overtighten nut — observe machine builders recommendation on tightening.

STORAGE OF CUTTING WHEELS

All wheels, diamond or abrasive, should be stored in a cool, dry place. Rubber wheels should be stored between flat metal plates with some weight on them. Some rubber bonded wheels will take a permanent "Set" if stored wet after use, and these wheels are useless in this condition — we know of no cure for this condition. Rubber bonded wheels can be hung up to dry, but ideal storage is flat. If wheels are packed in sawdust, they should be unpacked and dusted off, as sawdust contains moisture and moisture tends to change rubber bonds over time. Wheels should never be stored on edge, even for a short time, and should not be stored near any heat source,as heat will tend to change the cutting characteristics of wheels over time.

BALANCING OF CRITICAL COMPONENTS?

We often see evidence of balancing on machine components, in the form of small holes or spots where metal has been removed to balance the component. Is this really necessary? We have had some parts checked on very sophisticated balancing machines, and come to this conclusion: for most work using rubber bonded wheels, balancing will not make much difference unless the spindle runs about 3000 RPM. If a machine is to be used with diamond wheels exclusively, the extra cost of dynamic balancing is probably going to save money in the long run.

We have checked several diamond wheels for balance, and they have been generally good. The components to look into for balance defects are the spindle, the flanges, and the drive sheave or pulley. These can be checked with a static balancing stand, but the ultimate accuracy can only be achieved on a dynamic balancing machine. We have located competent people with this type equipment, and can refer you to them if you have a problem that can be solved in this manner.

SOME NOTES ON COOLANT AND COOLANT SYSTEMS:

The glass cutoff machine uses wheels which are water saturated during operation. On some machines the coolant is supplied by a pressurized coolant system which eliminates external hoses and pipes. Other machines use a variety of hoses or tubes to deliver the coolant to the cutting point. Whichever system your machine uses, it is most important that the coolant be delivered to the point of wheel-work contact. Coolant that hits the side of the wheel and bounces off does little good, and gives only the appearance of an effective job. It is also most important that both sides of the wheel receive equal amounts of coolant, and failure to consider this very often produces crooked cuts.

We are asked about additives to the coolant for cutting glass, and generally find that the glassblower would prefer nothing in the coolant to contaminate his work. A very small amount of detergent will decrease the surface tension of the coolant, helping to get the coolant into the cut. Only a couple of drops are needed. You do not want to create suds in the cut, as this would be detrimental to good cutting. Any oily additive to the coolant will create a cleaning problem on the work, and remember that you will be breathing a bit of any additive carried in the fine spray. My personal choice is plain water, with nothing added. I can repaint the machine, but I only have one set of lungs.

SAFETY CONSIDERATIONS

About wheel speed, RPMS — All rubber bonded wheels are marked with the safe MAXIMUM operating speed, such as "MOS (Maximum Operating Speed) 2250" or "MAX RPM 3810". These are MAXIMUM numbers, and are not necessarily ideal for any particular use.

Diamond wheels, as we noted before, are usually made to run at a specified speed. Do not exceed this speed without checking with the manufacturer.

Any wheel can break if improperly used or handled, and this can be a very dangerous situation. Always use wheels according to the manufacturer's instructions. We find that the most common cause of wheel breakage is lack of support under one side of the work piece. This condition will almost always result in wheel breakage or damage sooner or later.

You can cut yourself with any of these wheels, although diamond wheels are considerably safer than abrasive wheels. Keep your fingers away from the work area, and make sure your holding methods, jigs, fixtures, etc. are designed with operator safety in mind.

The material being cut can produce trouble long after the machine has been turned off and the operator gone home. Some materials are toxic in one way or another, and the debris from cutting can cause health hazards. Read up on the material being cut. Some materials act totally different when finely divided than they do in a massive form. We found the coolant in the tank of a cutoff machine bubbling merrily several days after cutting a batch of stainless steel parts, followed by a batch of aluminum. The nickel from the stainless steel acted as a catalyst, helping the aluminum break down the water — into explosive hydrogen. Be careful of materials in combination, unless you are sure what is going on. If your coolant starts to bubble — get rid of it.

This paper has been very brief, and in no way should be considered a complete discussion of the subject. Please feel free to call or write if you need any further, or more detailed, information.

Sources Of Information And Special Services:

Diamond Wheel Manufacturers Institute
712 Lakewood Center North
Cleveland, Ohio 44107
216-226-7700

Grinding Wheel Institute
712 Lakewood Center North
14600 Detroit Avenue
Cleveland, Ohio 44107
216-226-7700

Balancing Stands:

Stuhr Mfg. Co.
5005 27th Avenue
Rockford, Illinois 61109
815-398-2460

Balancing Machines:

Schenck Trebel Corp.
535 Acorn Street
Deer Park, New York 11729
516-242-4010
This company also publishes a book on balancing.

Contract Balancing:

J. D. J. Balancing Co. Inc.
230 Rose Inn Avenue
Nazareth, Pennsylvlania 18064
215-759-3315

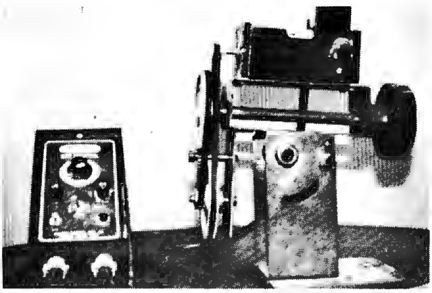
A SIMPLE METHOD OF REPRODUCING GLASS COILS

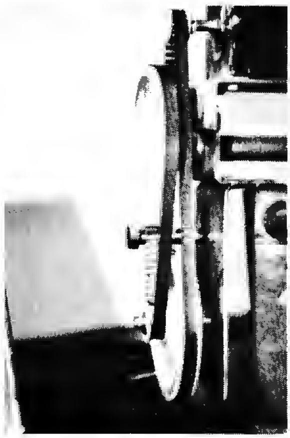
Peter H. Clarke
Procter And Gamble Company
Ivorydale Technical Center — Glassblowing Shop

In our shop at Procter and Gamble we have tried many ways of coiling borosilicate tubing ranging from freehand bending at the bench burner, to bending around a piece of glass tubing chucked in the lathe. The method we finally developed is a hybrid of a number of machines we have seen and read about.

The things we considered when designing our coiling machine were: 1) constant slow mandrel rotation to bend the tubing without deforming it, 2) variable pitch of the mandrel to allow spacing of the loops, and 3) a method of holding the mandrel.

We accomplished the slow rotation by using a Dayton 4Z140 DC motor with a Dayton SCR controller.

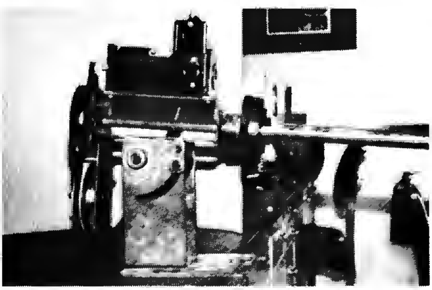




We geared this down to 36:1 with 1/4" timing belts and a series of timing belt pulleys.

This allowed us to rotate the mandrel very slowly, eliminating any jerking caused by the motor or slipping belts. With the motor turning 1000 rpm, the mandrel rotates at only 27 rpm.

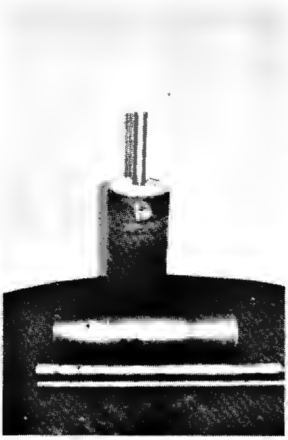
The base of our machine is made of 1/4" steel. The weight of the steel assembly makes it stable on the bench top and makes clamping unnecessary. The support for the motor and chuck is hinged at the rear with curved slots milled in each side.



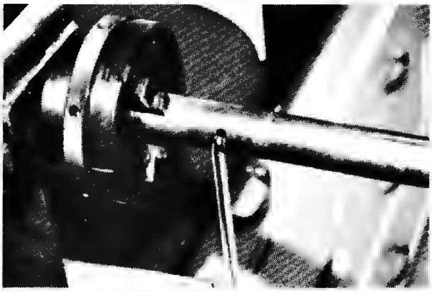
Set screws through these slots allow the pitch of the mandrel to be varied.

We use a chuck from a small metal lathe to hold the mandrel. This allows us to hold up to a 3" mandrel without modification. When we need to use a larger mandrel, a 1" spindle is mounted in the center of one end, and this in turn goes into the chuck. The chuck is mounted on a 3/4" steel axle which connects to the pulley system.

We use metal mandrels to take advantage of the coefficient of expansion.

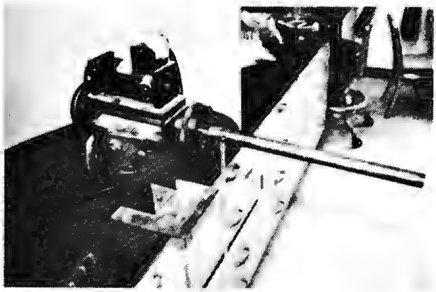


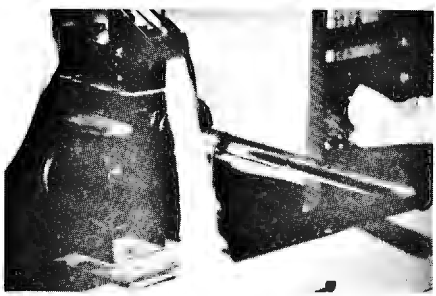
When making coils of 1/4" ID to 3/4" ID, we use brass rod. Generally we use copper water pipe for sizes of 3/4" to 6" diameter. Above 6" we get a piece of rolled sheet metal with a spindle mounted that fits the chuck. Each mandrel has a hole drilled near the end which goes into the chuck for starting the coil.



To make a coil, first we heat the mandrel, which expands. Then we hook a length of tubing into the hole in the mandrel and warm it just to the softening point with a very bushy flame. Notice that the mandrel is extended from the bench top and the tubing is hanging straight down.

When the tubing is soft enough to bend, but not deform, the coiling machine is turned on.



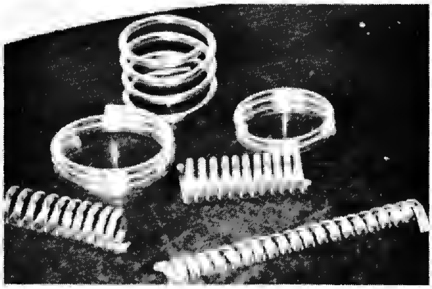


The rate of rotation and the angle of the mandrel are determined by trial and error, but with a little practice waste becomes minimal.

It is necessary to slow the rotation of the mandrel to compensate for the weight loss as the length of uncoiled tubing decreases. Letting the mandrel cool after the coil is made causes it to shrink from the inside of the coil and facilitates removal without use of a release agent.

Once parameters for making a certain size coil are established, minor adjustments to the speed of the mandrel are used to maintain even loop spacing. The flame temperature is not changed.

The machine described above is not meant for use in a production shop. It does, however, give the glassblower doing custom work a way to reproduce a wide range of coils.



TRICKS OF THE TRADE FROM THE GREAT LAKES SECTION

David G. Daenzer
Wayne State University, Detroit, Michigan

Dear Ladies & Gentlemen:

The following paper is a collection of lampshop hints compiled from members of the Great Lakes Section of The American Scientific Glassblowers Society. It will touch on the following areas:

1. Preparation of thin walled tubing from standard wall tubing
2 Fabrication of ball check valves
3. Interchangeable torch tips using syringe needles
4. The 'Ace Bandage' as a holder for ring and dewar seals
5. A handy steel 'V' plate for constricting and cutting tubing
6. A stopcock plug of woven ceramic tape for use during apparatus fabrication
7. Use of 'bubble pack' for glass saw maintenance
8. A method for making holes in soft glass bottles

I expect that most of you will be familiar with one or more of the suggestions to be made here. Indeed, some of you may be aware of all of them. It is my hope that most of you will find one new idea or that one of these suggestions will enable you to discover a solution to some problem that you have or may encounter.

I begin with a method for preparing thin wall tubing from standard wall tubing. This process is particularly useful whenever a short piece of thin wall tubing is needed immediately but is not readily available. For this discussion the tubing which is being thinned is 19mm O.D. standard wall. 25mm O.D. standard wall tubing will be used as the mold. (See Figure 1) The 19mm tubing is sealed and the end heavied as indicated. A blow tube is attached as presented at the left side of the illustration.

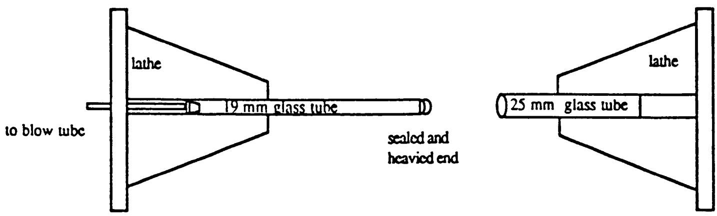


Figure 1

After the 19mm tube has been sealed and heavied, and while it is still molten, the mold tube (25mm O.D. in this case) is brought over the first 5-10mm (1/4-1/2") of the hot tubing. (See Figure 2)

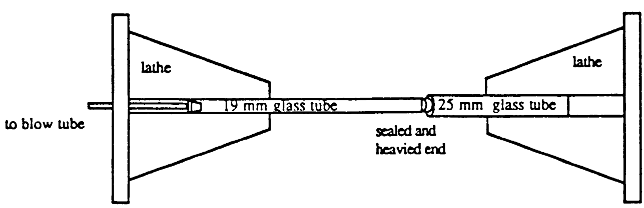


Figure 2

With the mold tube in position, air is blown into the blow tube expanding the molten 19mm tubing into the mold tube. (See Figure 3)

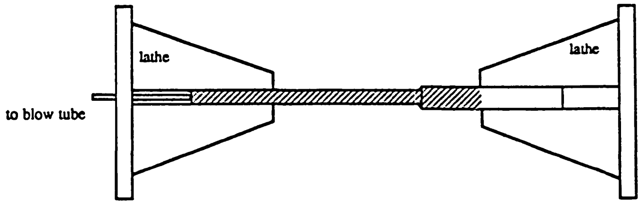


Figure 3

The mold tubing is then backed off of the now thin wall tubing and the process is complete.(See Figure 4)

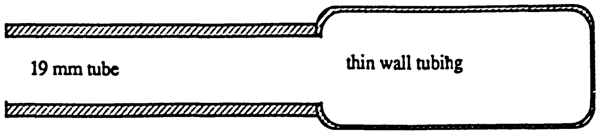


Figure 4

If the hot, smaller diameter tubing sticks to the mold tubing it indicates that it is being blown into the mold tubing while it is too hot. Allowing the hot, heavied end to cool a few seconds before blowing it into the mold should alleviate the problem. The process can be carried out with practically any diameter tubing, the measurements used were for illustration. The process does seem to work better when the mold tubing is slightly larger in diameter than the tubing to be thinned, but it is possible to work with tubing of identical diameters. With a little practice to determine the timing, it should be possible to form uniform thin wall tubing a few centimeters in length using tubing of the diameters of this discussion.

The following is a useful procedure for making ball type check valves. Typically, these would be used with a mercury system, although they will also work in other liquid systems as surge check valves.

For this example, the valve will be made in 10mm standard wall borosilicate tubing. Begin by making a constriction in the tubing. The goal here is to maintain the outside diameter of the tubing while reducing the bore and is accomplished by pushing the tubing together while forming the constriction, thus feeding glass into the area of the constriction. This operation may be done by hand or in the lathe. (See Figure 5) The next step is to form a ball approximately 7mm in diameter on the end of a 4mm rod. (The diameter of the ball should be slightly smaller than the inside diameter of the valve body.) By attaching a small diameter rod to the ball using a 'cold seal' technique, it should be possible to form a fairly spherical ball. (See Figures 6 & 7)

Figure 5

Figure 6

Figure 7

The ball is knocked off the smaller rod and allowed to cool. The roughness caused by the 'cold seal' will not be a problem since it will be removed during the grinding process. (See Figure 8)

Figure 8

The valve body is now cut to leave a short portion of glass extending beyond the constriction. The protruding piece should be short enough so that the ball will extend past it when contacting the constriction. This cut may be made by score and break method or using a glass saw. (See Figure 9)

Figure 9

Next prepare a slurry of silicon carbide grit (#400 works well) on a rubber pad. Place the ball on the pad and place the valve body over it as indicated in the drawing. (See Figure 10) Move the tube in a figure-eight pattern to grind the ball and valve body together. This process should take only a few minutes. Rinse both pieces in dilute HF followed by distilled water.

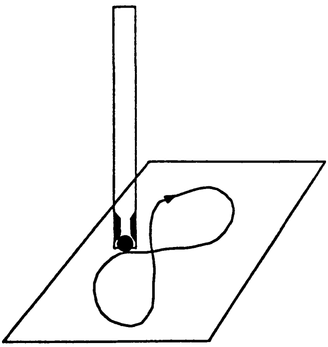


Figure 10

Figure 11

Figure 12

Seal another 10mm tube to the valve body as indicated. (See Figure 11) Use a small sharp flame and keep the heat directed away from the constriction as much as possible. It is fairly easy to do this seal without distorting the ground valve seat.

Place the ball into the valve body and with a small sharp flame, heat a spot and make an indentation with a graphite rod to trap the ball near the valve seat. (See Figure 12)

The check valve is now completed and may be sealed into a piece of apparatus. Figure 13 is an example of one use. In the illustrated bubbler situation the valve is used with mercury. It would also work with oil as a back surge preventer due to the close clearance between the ball and valve body. Indeed, if a gas surge impinges on the valve, the ball will normally seat.

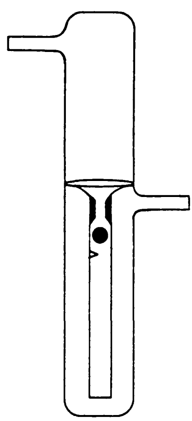


Figure 13

Often the glassblower finds himself in need of a small torch to reach inside a vessel or into a tight space. This may be accomplished by using a torch modified to accept syringe needles. For the example a National hand torch has been used, but any premix torch with interchangeable tips may be used. The end of a #5 OX tip is machined to accept a standard syringe needle holder. A Luer-lok holder may be used. Discussion as to its merits will follow later. (See Figure 14)

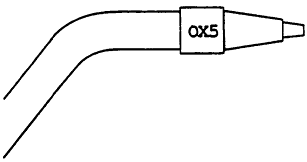


Figure 14

Figure 15

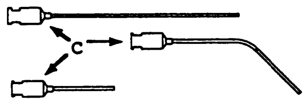


Figure 16

Now syringe needles of various lengths and gauges may be put on the holder to work in the restricted area. Gauges of 16, 17, and 18 seem to work best. Figure 15 shows a standard configuration. Figure 16 indicates some possible needle shapes and sizes.

Occasionally, when working in the confined spaces where this torch would be useful, the conditions will lead to a flalshback. This flashback may cause the needle to pop off the holder, which may damage the piece being worked. A Luer-lok holder alleviates this problem since the needle is locked on. In Figure 17 (A) represents a standard syringe holder and (B) indicates a Luer-lok holder.

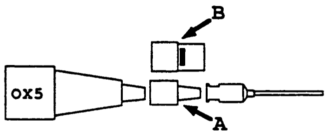


Figure 17

The next three figures suggest a possible use for the torch just described. Figure 18 shows a jacketed vessel. The dotted rings indicate through wall seals. With the large ring seals at each end, if there is a large temperature difference between the interior and exterior of the vessel there is the potential for seal failure in the dotted regions due to the differential expansion of the interior tube relative to the exterior tube. Figure 20 shows a more desirable configuration. The short stubs on the side wall seals can absorb some of the differential expansion by flexing slightly. This additional length for flexing is often enough to avoid failure of the seal. Figure 19 demonstrates how the torch described might be of aid in the fabrication of this vessel.

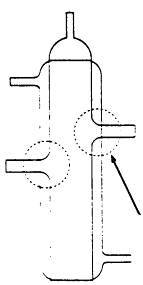


Figure 18

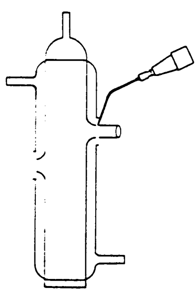


Figure 19

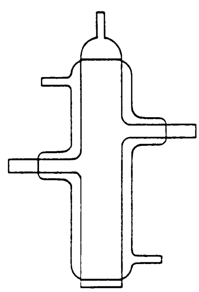


Figure 20

The side wall stubs must be fairly short to allow insertion of the central tube prior to making the end ring seals. The side wall stubs must be added after the end ring seals are completed (or at least after one of them is made, at which point the central tube becomes fixed relative to the outer jacket). The small torch using syringe needles makes it possible to accomplish this seal.

There are probably as many methods for holding two tubes concentric, such as for ring and dewar seals, as there are glassblowers in the Society. Perhaps the holder of choice has been corrugated cardboard, or corks, or pads of ceramic tape, or paper, etc. Here is yet another holder, the 'Ace bandage'. (This has become a generic term for the elastic bandage used to support injured joints.) Three things recommend it as a holder. It can be wrapped tightly for a good fit. It will conform to non-cylindrical shapes. It can be blown through even when tightly wrapped. The drawings indicate some possible configurations. (See Figure 21)

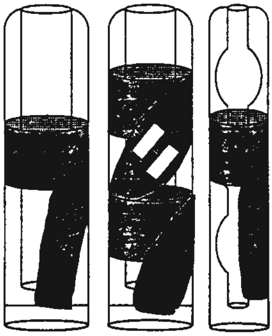


Figure 21

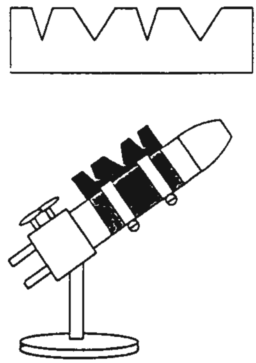


Figure 22

It is important to leave a 'tail' of the bandage for pulling it out upon completion of the seal. When extra length is required to achieve more thickness or for additional supports, as in the case of a long tube, the ends of two bandages may be taped together.

The elastic will take a fair amount of heat, but after completion of the main seal it is advisable to remove the elastic before further work on side arms and the like is performed. Residue remaining on the inside from the bandage will be removed during the annealing process.

A useful tool to have near your burner is made from a piece of 1/8" steel. This piece of steel has a number of 'V' notches cut into it. It may be screwed to the front of the bench, mounted on top of the bench using an angle bracket, or even clamped onto a bench burner. (See Figure 22) It may be used to assist in making constrictions or for knocking off the short ends of tubing which have been scored. Sharpening the edges of the 'V' will aid the latter operation and may even be used for the scoring process.

When attaching stopcock barrels to apparatus it is often useful to be able to switch between open and closed bore. A plug rolled from one of the heat resistant woven tapes on the market can serve the purpose. By drilling a hole in the plug it may be used to open or close the stopcock by a simple quarter turn.

For those of you who still have glass saws which recirculate the cooling fluid, the following suggestion may save you some maintenance and slimy clean up work. Float a sheet of bubble-pack packing material, bubble side up, in your fluid tank. It will catch most of the residue and let the cooling fluid run off. It has the added feature of catching those small pieces that slip from your hands and fall into the tank.

Although terrariums in large glass bottles are not the rage they were a few years ago, the following technique for making holes in soft glass bottles may be of use in other situations. The method involves the slow, careful heating of a circle on the glass

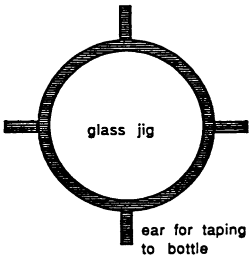


Figure 23

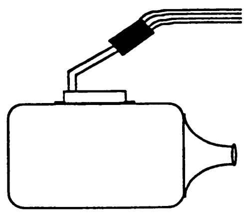


Figure 24

bottle. The heat sets up a stress in the glass and causes a crack to form in the shape of the heated area. For best control, a circular pattern (made of borosilicate glass for this example) is made and taped in place so it will not wobble. Figure 23 represents the jig. Figure 24 shows the jig taped in position on the bottle.

Using the OX-1 tip with a small, sharp flame, the torch is run around the inside of the jig at a moderate speed. It is important to heat the glass evenly, so be sure to keep the torch at an even distance away from the bottle. After a minute or two (longer for thick bottles) a distinctive crack will be heard. At this time a neat circle crack should be visible. Remove the jig and heat in the center of the circle which will still be wedged in the bottle. This heating will cause radial cracks to form out to the edge of the circle. If the hole has not broken out after the radial cracks have formed, take a blunt object and tap lightly in the center of the glass circle. Several taps are usually necessary for the plug to break out. It is a good idea to place some soft material, paper towel for example, in the bottle to cushion the blow from the pieces of the plug which will fall into the bottle. Figure 25 represents the finished bottle with hole. This procedure works well, approximately 95% success, with large 5-gallon carboys. The results with 1-gallon jugs are not as good. The hole sizes would typically run from 2 inches to 5 inches in diameter.

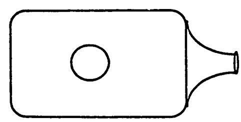


Figure 25

Thank you for your attention. I would like to thank the following members of the Great Lakes Section for their contributions to this paper:

Peter Severn, *University of Michigan*
Alvin Ditchburn, *University of Windsor*
Scott Bankroff, *Michigan State University*
Mike Souza, *Dow Chemical Company*
Larry Novak, *Dow Chemical Company*
David Luptak, *Quartz Scientific, Inc.*

A SYSTEMATIC APPROACH TO GLASS SHOP SAFETY

James J. Mann
Rohm & Haas Company

One of the major problems concerning safety in the work place is that people rarely concern themselves with safety issues, until someone is injured or someone has contracted a serious health problem due to overexposure to hazardous materials or chemicals.

To eliminate this problem, a systematic approach to glass shop safety is necessary. I did this in my glass shop at Rohm and Haas Company with the help of our safety department as guidance. I realize that most glass shops do not have a safety department as part of their organization; however, once you understand the system, any glass shop can successfully implement it.

My approach was to first make an itemized list of all materials and chemicals used in the glass shop. Included with that list should be the name of the actual supplier of that item. An MSDS or Material Safety Data Sheet can then be acquired from your supplier of these items. This is simply accomplished by calling your supplier and requesting one on the phone. Most suppliers will readily comply. The MSDS can also be requested on your next purchase order for each of the items ordered. Simply state on the bottom of the order "MSDS required on all above items". Once the MSDS's have been acquired, you will notice a large amount of information is contained in them, some very technical in nature. This technical information can be helpful but is not essential to our purpose. Initially, there are only two sections of this sheet that are necessary to understand and they both are presented in plain language that all can understand.

Here we have close-up slides of the health hazard and protective equipment sections. Both sections together will tell you if the material or chemical in question is hazardous and how, and if so, what precautions and protective equipment are necessary to adequately protect yourself from the hazardous material.

Once all the MSDS's are acquired and have been read, make a new list of items but list them starting with the most hazardous down to the least hazardous. Later on you will deal with them starting with the most hazardous as you proceed through the complete list. On this list also include in a separate column all the glass shop jobs associated with the material or chemical. At this point we will be looking for non-hazardous substitutes. To accomplish this, call suppliers, friends in the business, other glass shops and make a point to discuss it at local meetings and symposiums. In the case of asbestos, you will notice I have listed three (3) different jobs or uses. The main reason for listing all the jobs with the materials is that I can now begin to look for a suitable substitute for that hazardous material based on its usage. If I can't completely eliminate the hazard, I may be able to do so partially. When no substitute exists, I must face the fact and utilize the information contained in the MSDS's under sections (Protective Equipment, Spill and Leak Procedures and Storage) and effectively deal with the safe handling of these hazardous materials.

When no substitute can be found, a PHA or Physical Hazard Analysis of each job should be done and is very helpful in bringing out any deficiencies in your present handling procedures. The PHA consists of detailed write-up of the job itself, as it is presently done, even all its seemingly mundane aspects. This is done so you can later pick apart and change any aspects of that job that increase the hazard such as: inadequate exhaust or ventilation, protective equipment, poor storage, fire hazard, unnecessary handling and the possible contamination of larger areas than necessary. Here we see the PHA I did on asbestos usage. At the top is the way I used to handle asbestos. Below is the section with changes of procedure. Once written up, they then can be used as a glass shop procedure for all employees.

Now that we have looked at the overall system, let's take one material and look at it using this system. Let's look at asbestos, probably the greatest health hazard existing in the glass shop. Because health problems arise from asbestos use after long exposure, the hazards are sometimes overlooked and not dealt with immediately. For instance, if you ever got hydrofloric acid under your fingernails because you neglected to use gloves, I am sure the next time you used H.F., gloves were standard operating procedure. The hazards from asbestos usage are more subtle and have been put off too long by most of us, even after the hazards have been well known. To continue looking at asbestos, I have acquired the MSDS on asbestos and am aware of the hazard. In my glass shop, asbestos was used for three jobs or functions, which are indicated on the itemized list. In the first instance, asbestos tape used to join two dry standard taper joints, ceramic and graphite tapes were found to be adequate substitutes. The second case, supporting glass tubes inside glass tubes before sealing, glass fixtures and a graphite sponge tape were found suitable. Both uses involved about 90% of my asbestos usage in the past. Since the changeover to these substitutes, I have effectively reduced my exposure to this hazard accordingly. However, the third case, using asbestos as a heat sink, no substitute was found, although I am still looking for a substitute. I had to then deal with the remaining job necessitating the use of asbestos. The PHA report on the present procedure was written up. Two additional people were called in to assist in the changeover discussion. The new procedure was then formulated. The changes consisted of:

1. All stored asbestos tape will be labelled "asbestos".
2. The removal of the tape from the roll will be accomplished in the hood with scissors rather than tearing.
3. After the glassware has been annealed and cooled and taken to the sink for asbestos removal, the glassware is put in a plastic bag, filled with water, asbestos removed from the glassware in the bag, the glassware removed from the bag; the top of the bag was partially closed and the water drained into the sink. The bag was then placed in a second plastic bag, the bag was then labelled "waste asbestos" and stored in a labelled fiber drum for disposal later.
4. A tray will be used in the annealing oven to contain all glassware annealed with asbestos on it and when cooled, taken to the sink and rinsed clean. A tray will be used to prevent oven contamination.
5. Disposal of the used asbestos tape will be handled with the mechanical department's regular disposal of asbestos material and buried in an appropriate landfill.

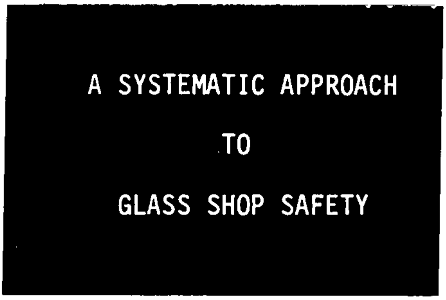
To look at a few other hazardous chemicals briefly —

Ammonium hydroxide used in silvering solutions was handled as the MSDS suggests since no substitute was found.

1. All pouring and silvering is done in the hood.
2. Operator must wear splash goggles.
3. Operator must wear impervious gloves.
4. A safety shower must be nearby.

Hydrofloric acid on the other hand was completely eliminated in my glass shop, utilizing a fine diamond wheel (300 grit) for cutting glass tubing and picking the edge of the hot glass with tweezers.

In conclusion, a systematic approach of looking for substitutes for hazardous materials and chemicals, utilizing MSDS information and PHA reports when no substitutes are found, will eliminate or minimize the hazards and a safer glass shop environment will be realized.



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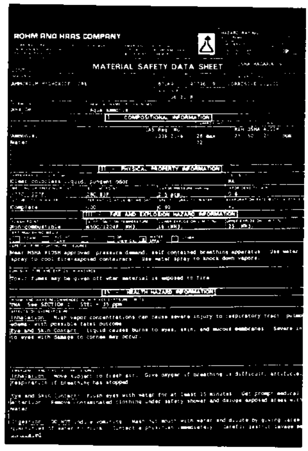

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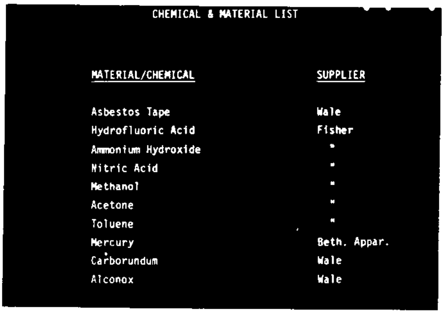

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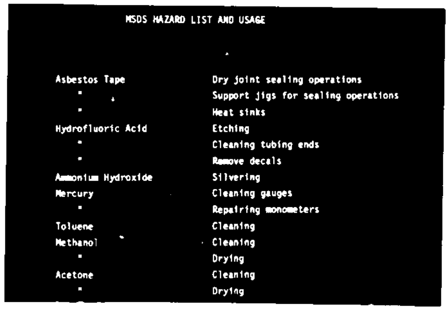

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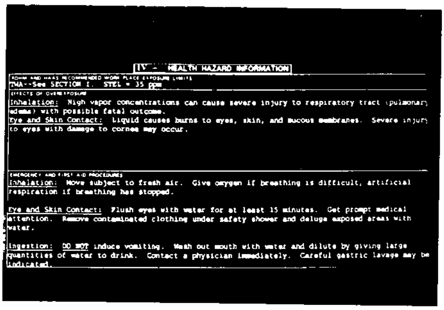

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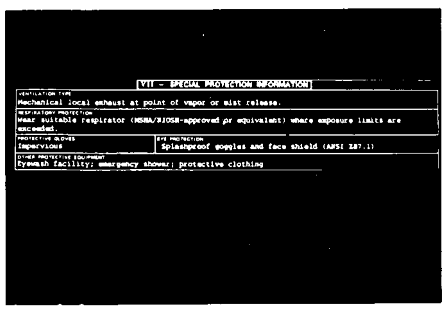

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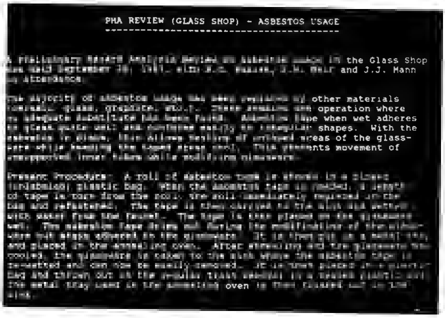

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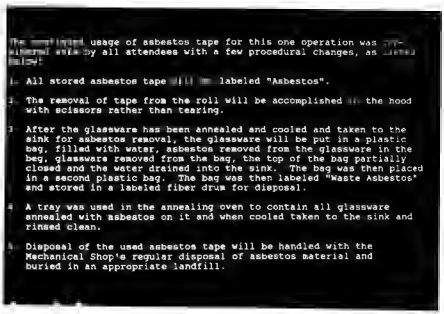

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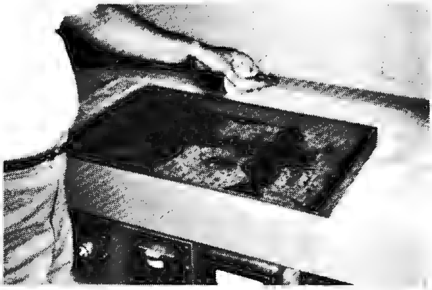

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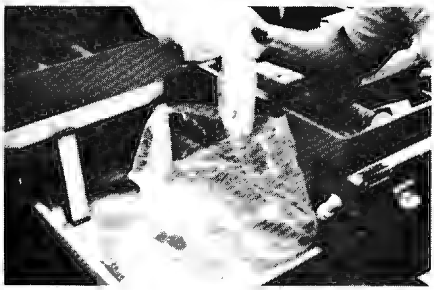

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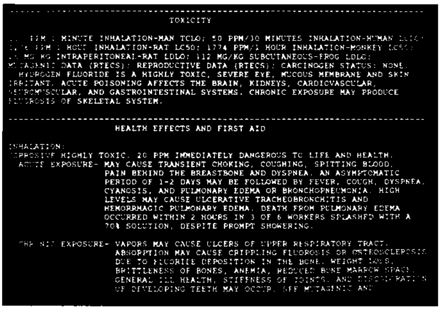

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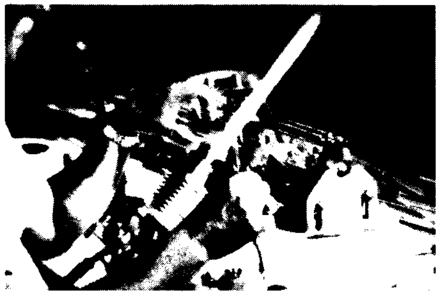


Slide #24

METALLIC MERCURY SAFE HANDLING PRACTICES IN THE WORKPLACE

Bruce J. Lawrence, President
Bethlehem Apparatus Company, Inc.

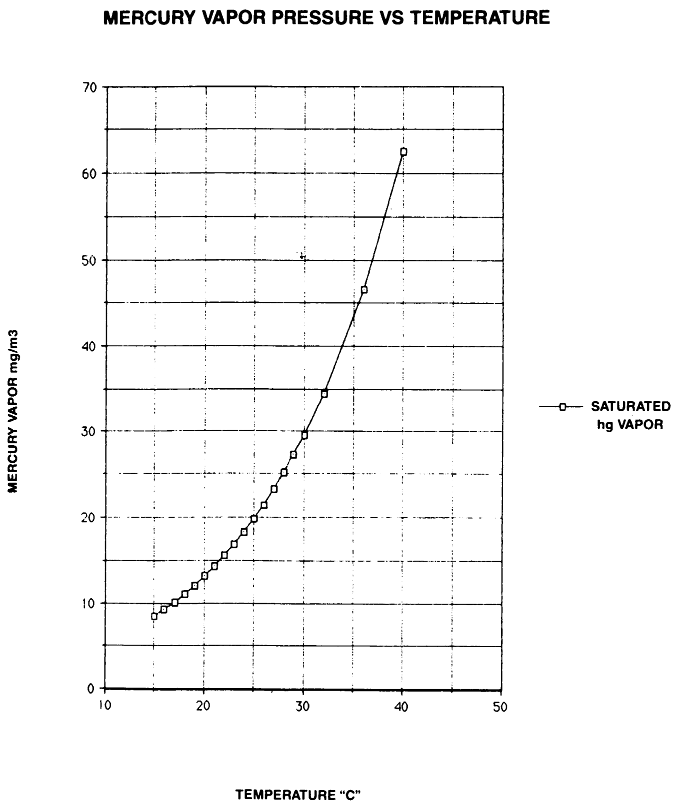
Practical Application in Handling Mercury and Mercury Vapor:

A good program for working with metallic mercury should include a coordinated program involving a qualified physician, biological monitoring, and controlled workplace practices. In this report I will be working only with the workplace practices portion of the program. This is not intended to be the only program followed in handling inorganic mercury and mercury vapor. Medical and biological information can be obtained from our publication titled "Safety and Health Practices for Working With Metallic Mercury" by Woodhall Stopford, M.D., Duke University Medical Center, Durham, North Carolina. In addition, your local office of the Occupational Safety and Health Administration can supply you with current data regarding mercury. The following information should be reviewed only as a supplement to a good comprehensive program.

Temperature:

The relationship between mercury vapor pressure and temperature is shown on the graph (Figure 1). As you can see, mercury vapor pressure greatly increases with temperature. The net effect is that you can have an area with an acceptable mercury vapor level at 20 degrees C (68°F), but when the temperature increases to 30 degrees C (86°F) your vapor levels have more than doubled. The temperature referred to here is of the mercury itself and not necessarily the room air.

An example of the above can be mercury droplets on an electric motor. When the motor is off, the droplet's temperature/vapor pressure would be the same as droplets in the general room. However, when the motor is turned on and heats up from use, then the mercury droplets on that motor will give off more mercury vapor.



Find the Source From the Perspective of the Macro Environment:

There are several factors that can affect the mercury vapor levels in a given room, or macro environment. All of these factors relate to the source of the mercury vapor itself. If a pool of mercury is in the center of a room, and the vapor level of that room is .15 milligrams of mercury per cubic feet of air, then any change of ambient temperature or room ventilation will affect the vapor level.

If you're presented with a situation like the mentioned room where the vapor level is 50% higher than the acceptable OSHA (Occupational Safety and Health Administration) standard of .1MG/3M, and 150% above the recommended NIOSH (National Institute of Safety and Health) standard of .05MG/3M, then obviously the first thing to do is remove that pool of mercury. But suppose you need that pool of mercury to be used in some apparatus. The next best thing to do is cover the pool. Mercury vapor can readily evolve into the room air when exposed, but a tightly kept cover can remove the vapor better than any other measure. Sometimes a cover is awkward or would render the apparatus useless. Another solution can be to cover the pool of mercury with water. Since water may evaporate too quickly, mineral oil can be substituted. In both cases, the rate of mercury vapor being allowed to contaminate the room will be greatly reduced.

So far we've talked about very controlled situations with respect to the source of mercury vapor. In many cases in industrial applications, the source or sources of mercury vapor are not so readily available to control. When mercury is being dispensed into an instrument or product, or when we're just pouring the mercury from one container to another, we are exposing the mercury to room air. This repeated exposure can cause the mercury vapor levels to increase in the room. Even more mercury vapor can be generated if it is spilled. Then, even if we have cleaned up the spill, or treated the contaminated area, mercury vapor can still be released. This is where room ventilation and ambient temperature control can be most helpful.

If a room has a mercury vapor level of .15MG/3M, then we can reduce the vapor level of that room into acceptable levels simply by the addition of a ventilation fan. The exact quantity of air to be displaced can be calculated. However, since there are many factors that can affect the vapor levels in a room, it is recommended that you include a large safety factor. Warm days, electric motors, and unexpected spills need to be factored into your requirements.

The most important factors in ventilating a room for mercury vapor control are the location of the ventilation fans and the source of the air. Since mercury vapor is heavy, you should always move the air from the top of the room down to the floor and out.

In some other cases, the most practical measure for controlling mercury vapor may be simply the refrigeration of the room air, or air conditioning. A facility that is located in a warm climate can effectively keep its mercury vapor level within acceptable standards by keeping the room temperature at or below 68°F. Since temperature levels play such an important role with the amount of mercury in the air, it may be a disadvantage to introduce warm air into a room with potential mercury vapor. As with ventilation, the amount of refrigeration to be used should have a safety factor involved due to the different causes of the mercury vapor levels.

Another factor to consider in mercury vapor control is the trade off between cooling the air in the room or introducing fresh air. Depending on the vapor concentrations you have, it may be more advantageous to do a combination of introducing fresh air into your room along with recirculating the room air. This can be readily done using dampers and air circulators normally used in air conditioning.

Micro Environment:

A micro environment is an area that may have higher than room levels of mercury vapor. In our example above, we mentioned a pool of mercury. If you were to take a mercury vapor detector and point it directly over the pool of mercury, your mercury vapor level could be more than three times greater than the general room vapor level. If that pool of mercury is sitting just below an individual's breathing zone (micro environment) at a job site, then that individual could be inhaling large amounts of mercury vapor even though the general room levels were acceptable.

One of the most common errors in controlling the micro environment is the use of fume hoods and general room ventilation. If the source of the clean air is forced to pass over the mercury and then go directly into an individual's micro environment, then the ventilation can be doing exactly the opposite of the desired effect.

Another factor to keep in mind when installing ventilation is the source of fresh air. If you put in a fan and do not allow an opening for fresh air, then the amount of air exchange you actually have will be much lower than the rating of the fan. We have also found that you can control the amount of air you move by putting dampers on your source of air. On a day where you need some ventilation but not the full value of the fan or blower, you can control the air inlet rather than change the speed of the motor.

Once a decision has been made to ventilate a room or work area, be sure to monitor the results. Air movements are not always as predictable as you might think. When you install a fan to remove air, you can also mistakenly introduce source air from a contaminated area that previously was not a major problem. It is also a good idea to test variables like what happens when the window is closed but the ventilation fan is left on.

Using Mercury Vapor Masks:

Sometimes after you've tried to control vapor levels with room ventilation, micro environmental ventilation, refrigeration, and coverings you still don't have the desired result. Now mercury vapor masks should be worn. Tasks that generate dust, like general room sweeping, may require an individual to wear a mercury dust mask.

We use both dust masks and vapor cartridge masks at our facility. The dust mask is very convenient because it is lightweight and is generally more comfortable to use. The cartridge mask is a must, however, when mercury vapor levels are higher than recommended standards.

All masks should only be used in accordance with current state and federal regulations, as well as the manufacturer's instructions.

Protective Clothing:

Gloves: When an individual is required to work with mercury and his hands can come in contact with mercury, we have him wear rubber gloves. The Playtex brand dishwashing gloves have proven to be the best for our operation. On other heavy duty operations we use both the rubber glove and a leather or rugged cloth outer glove. One thing we noticed about the heavy duty gloves is in the dirtier jobs mercury would get inside the glove. If you were to wear these gloves without the rubber inner glove, then the mercury would be rubbed against the skin of the hands. If you repeatedly use gloves in your operation, you can check the inside with a mercury vapor sniffer. If there is mercury in there, the vapor level will go up dramatically.

Work Shoes and Carpets: We require all mercury area employees to keep their work shoes in the plant at all times. This prevents mercury from being carried out of the building.

A related problem with mercury and work shoes is that when you walk from a mercury work area onto a carpeted area, you can deposit mercury onto the carpet. Mercury does not readily vacuum up from a standard carpet. After a period of time you may be generating more mercury vapor from your carpeted areas than from your work areas.

Disposable Clothing: Whenever we have a job where a worker can come in contact with mercury and dirt, or with splashing mercury, we have him wear disposable clothing. Used clothes are then sent to a hazardous waste landfill that can accept trace amounts of mercury.

The following is a list of items that are available for mercury use. Mercury vapor detectors, mercury vacuum cleaners, mercury pick-up vacuum pumps, mercury personnel monitoring badges, mercury vapor and dust masks, mercury spill kits and mercury decontamination materials.

One final item that should be mentioned is the governmental regulations involved with mercury. In the past 15 years, there has been an almost constant change to the requirements for mercury. Environmental, transportation, and workplace regulations required by either the federal or state agencies are subject to change at almost any time. Since your state's requirements may be different from another's, we suggest you contact them to see where your requirements stand.

ARTISTIC GLASSBLOWING AT SALEM COMMUNITY COLLEGE

Dennis Briening

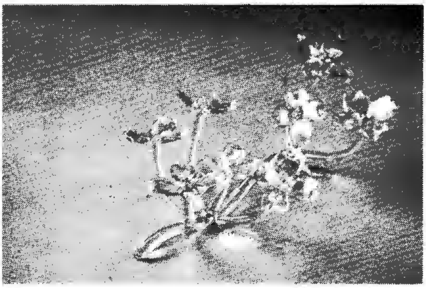
Since 1979 education in America has changed as well as my ideas on education. Most of us have been involved in training or teaching first hand; as a result we all have ideas of what education is and how to achieve our goals.

Education in America has been heavily criticized of late. Employers regularly complain that applicants cannot correctly fill out applications. High school graduates' scholastic ratings are at an all time low. I have had many college students that cannot write a proper sentence, let alone get across an idea in written word.

But education is America's greatest resource. Without properly trained workers America can hardly compete in the world market.

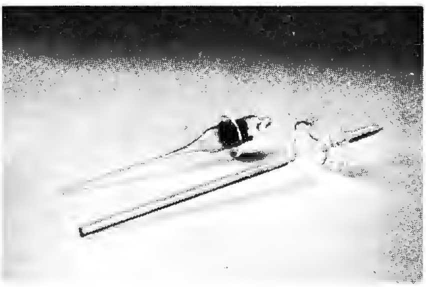
What I would like to do is give an overview of the Art Glass course now being presented at Salem Community College, and raise some questions as to what should be presented to complement scientific glassblowers' education, as well as general education students and society.

One specific goal of the course is to develop hand techniques which enable a student to complete various projects. Another goal is an understanding of sequence of operation, or the ability to complete a project without working oneself into a corner or having a piece crack upon completion.



This project stresses sequence of operation, preheating and a good understanding of flame annealing. A dogwood candelabra is actually a rather simple piece if attacked properly.

First the flower is made and a holder is attached to the flower. Next the candle holder is made. Seal a piece of 10mm rod to 25mm tubing. Blow cut two inches up the tube and flare. This is good hand or lathe practice for students. A holder is made, wrapped with glass cloth and inserted into the candle holder.

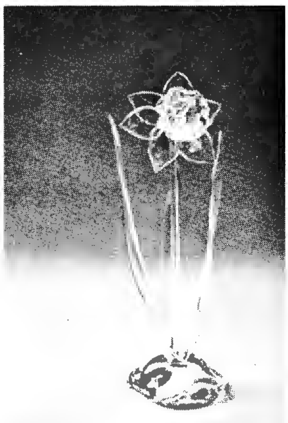


A piece of 10mm rod is pulled out to fabricate the main stem. Melt off one end of the curved rod and use to form the legs. Seal the legs to balance the piece. Flame anneal the main body and preheat the flower. Add the flower and remove the holder. Flame anneal this section. Add a rod to the end of the main stem where the flower was just added. Now preheat and melt off the other holder. Preheat your candleholder and seal; remove holder from candleholder. Flame anneal only the candleholder and approximately one inch of the main stem. When cool, remove the other holder. The project is completed and ready to be oven annealed at a later time. Once mastered, it is relatively easy to move on to a double dogwood candelabra.

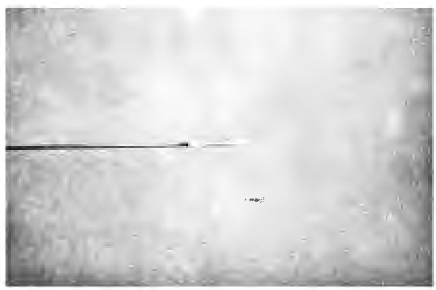
This piece is very similar to the single dogwood candelabra. The same sequence of operation is followed. From the dogwood candelabra is a natural progression in the dogwood centerpiece. No training was used on this piece, although it is very important to have all of the parts ready before beginning assembly.

The dragon is a similar piece. It is made from sixteen inches of 5/8ths rod. The dragon must be worked through chasing strain and preheating at the same time. One cannot jump, for example, from the head to the main body and back to the head. A student's first dragon is more a lesson on annealing and preheating than design, or art.

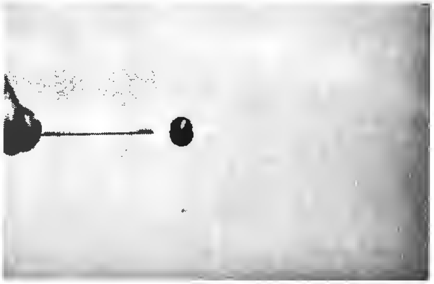
I feel the course should include more than just the making of objects. Lectures on types of glass, manufacturing techniques, history and other areas to give a student a good rounding picture of the rich heritage of glass are also important. Presentations by guest artists such as Paul Stankard and Joe Luisi are included, as are visits to Wheaton Village and the Center for Creative Glass.



Lampworking has possibilities no other artistic technique possesses. This is Joe Luisi's "Liberaci", complete with a glass piano.



For students who are more inclined to non-representational art, pieces along these lines are possible. This particular piece has four feet of 1-1/4 inch rod and over six feet of one inch rod.

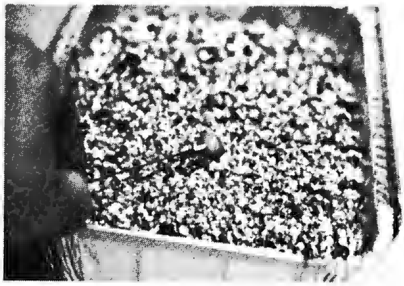


Nature is a powerful source of inspiration, as shown by this daffodil.

Joe Luisi has taken figurative sculptures in glass to its highest level.

"Crown Imperial" by Paul Stankard is an important work in soft glass art.

Now add your colored soft glass. The sleeve gives the colored glass a place to seal without disturbing the kiln wash separation.



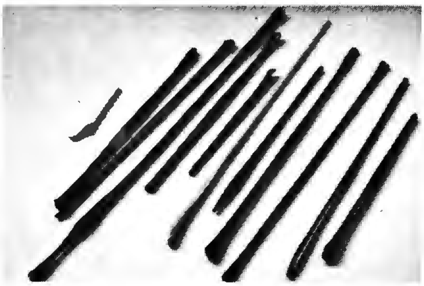
This is "Spring Beauty", cloistered botanical with sprouts. Both artists continue to push their talents to the limit. No avenue of glass should be ignored. Many new avenues are being opened as new types of glass are manufactured. Lampworking soft glass is a wide open field. In light of these innovations, soft glass is now being taught also.

One way around this is sliding a glass sleeve over the metal rod and sealing, just as you would seal 7052 over a Kovar pin. In this case the sleeve was made of R 6. It seems to work well in this application and is compatible with many soft glasses.

We begin by coating a stainless steel or brazing rod with kiln wash and allowing to dry. Kiln wash keeps the glass from sticking to the metal rod and allows easy removal of the bead upon cooling. Kiln wash is available from most ceramic shops.

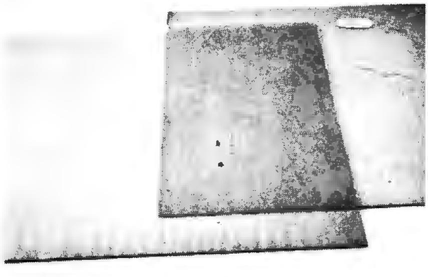
Soft glass can then be wrapped around the metal rod, taking care not to knock off the kiln wash. But you may encounter problems with this method. When completed, place the bead, while still on the rod, in a hot oven or in vermiculate to cool slowly. Beads are a good elementary project to give students an understanding of annealing points, softening points, coefficients of expansion and compatibility of various glasses. The design of the beads and incorporation into jewelry is limited only by the students' imagination and skill. A good source on beads is "The History of Beads", published by Harry Abrams. Another good basic project is slumped jewelry. This slide shows a pendant and some earrings. Pieces of colored plate are cut and overlaid with bits of lampworked colored rod to form various designs. These are then fired in an oven at approximately 1400°F. The fired product is then ground or otherwise reworked into earrings, brooches, pins, tie clasps, pendants, and other jewelry. The techniques are simple and yet very challenging to both beginning and advanced students.

Technique is important to these projects but not overwhelming.

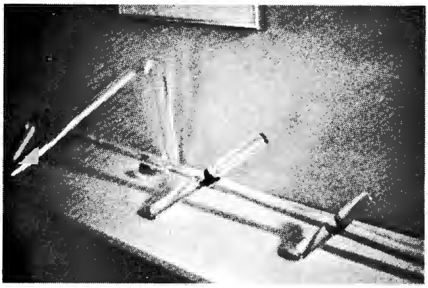


Kuglar glass comes in both rod and powders. Kuglar glasses are very high quality and come in a very large selection. Almost any color desired can be purchased. Unfortunately, the raw material is approximately one and one half inches in diameter. But this can be easily redone by preheating in an oven to 980°F. Next pick up a piece with a hot glass rod and pull out in a highly oxidizing flame.

Stainless steel plates are coated with kiln wash and allowed to dry.



Sheets of Bullseye tested compatible glasses are cut to shapes desired. Bullseye sheet glass comes in about 30 various colors, translucent, opaque, irridescent and swirled. These plates can then be melted into rods to be lampworked and fused into the base plate. This avoids compatibility problems, but this isn't always possible or desirable. Other glasses are compatible.



Another type of glass available is Thompson Enamels. These glasses are very fine and great for overlaying completed projects for shading and highlights.

Using three different types of glass, as you might suspect, could be a compatability or instructor's nightmare.

Bullseye has a coefficient of expansion of around 90 x 10^{-7}. Kuglar has an advertised coefficient of 83 to 86 x10^{-7} but is actually a little higher.

Both of these glasses are available from C&R hoo of Richmond, California.

Kuglar is also available from the Littleton Company of Spruce Pine, North Carolina.

The dark rods in this slide are transparent and don't show light until in thinner sections. These pulled out rods can then be flame worked in an oxidizing flame. Due to a high lead content, a reducing flame will turn the glass gray. Kuglar rods can then be lampworked into flowers, trees, or non-representational designs. These pieces can then be fused into windows, jewelry or encapsulated into paperweights.

NOT AVAILABLE

When sheet glass of known coefficient is used, another test is even simpler. Cut strips of known sheet and overlay with powders or chunks of glass in question. Place on kiln shelf on kiln wash coated stainless plate. The strip to the left is overlaid with Thompson enamels, the center is Kugler and right are other colors of Bullseye sheet glass. Raise oven to 1400°F to insure good fusion, lower rapidly to approximately 1000°F to avoid de-vitrification. Anneal at approximately 980°F and lower from this temperature as slowly as possible to avoid introducing stress to the test strip. Thompson enamels come in a large variety of coefficients of expansion and should all be tested. Many were formulated for fusing into window glass which has a coefficient of 84 to 86 x 10^{-7}. Thompson enamels are available from Thompson Enamel of Newport, Kentucky. Fortunately, there are two simple tests to determine compatibility. The first is familiar to most scientific glassblowers. Lay two molten rods over each other and pull out. The amount of bend upon cooling determines the amount of difference in coefficient of expansion. Once cool, view in a polariscope. To the trained eye, strained pieces will be obvious. Extremely strained pieces will separate upon cooling. A good book on this subject is "Fused Glass", also available from C&R hoo. Armed with these technologies and techniques, a beginning student can complete some rather elaborate projects in a short period of time. Many projects are not hand skill intensive and do not require a high degree of eye and hand skill, which borosilicate does. So a beginning student avoids some of the frustrations pyrex can cause. Also, these projects invite a student to concern himself with design as well as technique. These projects also complement

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a beginning scientific glassblower's understanding of softening points, working time, annealing points, compatibility, and coefficients of expansion.

One problem it presents is the amount of trouble it creates in keeping a large number of glasses in order. Also, many of these glasses contain a high lead content. The powders and frits are particularly dangerous, and cleanliness is imperative. But the pros exceed the cons. These techniques open doors never before open. Functional bowls and plates, large windows, architectural glass tiles, and three dimensional sculptures are now possible. Glassblowers are inventors, artists, scientists and craftsmen all rolled into one. As glassblowers, we must constantly be creative and experiment with new methods to solve problems. The art course is one way to keep our minds open.

The History of Beads: From 30,000 B.C. to the Present by Lois Sherr Dubin, Published 1987 by Harry Abrams, Inc.

Glass Fusing, by Daniel Schwoerer and Boyce Lundstrom available from C&R hoo Inc. 415-232-0276

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