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CONTENTS

A QUARTZ LIQUID-LEVEL SENSOR

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Introduction

Utilizing some basic principles of geometrical optics, a device can be constructed that is very useful in monitoring and controlling the level of a liquid in a vessel. Although such sensors are commercially available, a glassblower and an electronics technician can design a customized unit for a specific need.

This paper begins with a review of those basic principles of light and optics and applies them in a design for a liquid-level sensor of clear fused quartz. An ensuing discussion of the sensor's practical application, particularly in conjunction with a benchtop computer offers some insight into the possible means for automating certain laboratory or industrial processes, as well as into the inherent limitations of the device.

A Review of Some Fundamental Principles of Geometrical Optics

The velocity of light waves through a particular medium is a constant.* However, the velocity of light varies between different media. The denser the medium, the lower the velocity. Thus, the speed of light is greatest in a vacuum (3×10^8 meters per second), less through quartz, and still less through diamond. The ratio of the velocity of light in a vacuum to its velocity in a particular medium is that material's index of refraction:

$$\text{Refractive Index} = n = c/v > 1$$

where, c = velocity of light in a vacuum

v = velocity of light in the medium

Consider Figure 1. In this illustration, the light waves are passing through a medium (N_1) having an index of refraction n_1 to a LESS DENSE medium (N_2) with an index of refraction n_2. Thus, the speed of light in medium 1 is less than that in medium 2. Similarly, the distance travelled by a wave front in a given time interval through medium 1 (d_1) is less than the distance travelled in the same interval through medium 2 (d_2). Because the velocity of light varies between different media, a ray of light will bend (i.e., be refracted) as it passes from one medium to another. In this case, the light ray is bent away from the normal or a line drawn perpendicular to the boundary surfaces. If the light ray were passing into a denser medium, then the figure would be inverted and the ray would be bent toward the normal.

In 1621, Willibrod Snell discerned a constant proportional relationship amongst certain elements of this construction. This discovery was subsequently refined by Descartes in 1637 by means of the mathematical expression:**

$$n_1 \sin I_1 = n_2 \sin I_2$$

where, n_1 = the refractive index of medium N1

n_2 = the refractive index of medium N2

I_1 = the angle of incidence

I_2 = the angle of refraction

This equation (Snell's law), which relates the angles of incidence and refraction for two transparent media, is the fundamental law that dictates the passage of a light ray through an optical system.

Throughout this review emphasis has been placed on the passage of light from one medium to another of less density. It has been indicated that in so doing, the light ray is bent away from the normal. The significance of this becomes apparent if the terms of Snell's Law are rearranged:

$$\sin I_2 = n_1/n_2 \sin I_1$$

Note that if the angle of incidence ($\sin I_1$) is increased, the angle of refraction ($\sin I_2$) will increase at a geometric rate. When the sine of the angle of incidence reaches the value of n_2/n_1, then the sine of the angle of refraction will equal 1.0 and the angle of refraction will be 90°. At this point, and for any light ray having an angle of incidence greater than this point, the ray will be reflected back into the medium N_1. This is known as total internal reflection and occurs only if N_1 is denser than N_2. The angle of incidence at which this occurs is known as the critical angle:

$$\text{Critical Angle} = I_c = \text{arc sin } n_2/n_1$$

Taking advantage of Snell's Law and its corollary concepts of the critical angle and total internal reflection, a piece of quartz rod can be fashioned to create a liquid level sensor. Consider the following critical angles:

N_1/N_2	$Ic = \text{arc sin } n_2/n_1$
CFQ/AIR:	arc sin (1.0000/1.4585) = arc sin .6856 ≈ 43° 17'
CFQ/WATER:	arc sin (1.3330/1.4585 = arc sin .9140 ≈ 66° 4'
CFQ/ACETONE:	arc sin (1.3587/1.4585) = arc sin .9316 ≈ 68° 41'
CFQ/METHYLENE CHLORIDE:	arc sin (1.4241/1.4585) = arc sin .9764 ≈ 77° 32'
CFQ/CARBON TETRACHLORIDE:	arc sin (1.4601/1.4585) = TOTAL TRANSMITTANCE
CFQ/BENZENE;	arc sin (1.5011/1.4585) = TOTAL TRANSMITTANCE
CFQ/1,2,4-TRICHLOROBENZENE:	arc sin (1.5717/1.4585) = TOTAL TRANSMITTANCE

Observe the relatively large disparity between the critical angle of clear fused quartz/air and that of the other media. In fact, for those media that are denser than CFQ, there exists no critical angle and therefore virtually any light ray, regardless of its angle of incidence at the boundary, will be transmitted on through them. Thus, in general terms, the likelihood of internal reflectance for a set of rays decreases dramatically as the refractive index of the second medium increases relative to CFQ.

Because of the rather slight critical angle between CFQ and air (< 45°), a quartz rod acts as a conduit for light — i.e., as a "light pipe" (See Figure 2). Not all of the light rays travelling down the rod will be internally reflected, but a substantial and useful amount will be. And if the end of the rod is annularly ground at 45° and firepolished (Figure 3), a substantial and useful amount of light will be internally reflected back up the rod. If the tip of this rod is suddenly surrounded by a fluid medium other than air, and thereby radically increasing the critical angle between the two media, a majority of the light rays will not be reflected back up the rod, but will simply pass into the second medium. Note how the beveling of the quartz rod at 45° enhances the advantageous utilization of Snell's Law.

It becomes apparent that if a light source and a detector could be mounted in some way on the opposite end of the rod, then the functional basis for a device which can "read" the difference in light intensity caused by the presence or absence of a liquid at the end of the rod could be had (See Figure 4). This can be accomplished by first cutting a 90° step, 8-10 mm in depth and firepolishing the cut. An LED and a photodetector are then mounted on the lower and upper steps, respectively, with plastic shrink-tubing and a plastic block clamp. The electronic circuitry required for a demonstration model of a liquid-level sensing system has been appended to this paper.

Some Applications and Limitations of the Device

Because the glass blower can be directly involved in the fabrication of a sensor, the

interface between it and the vessel can be customized to meet the demand of a particular application. For example, an Ace-Thred and Bushing† can be employed in many instances. In situations where the purity of the liquid is essential or where the chemical environment is harsh (e.g. acids and organic solvents; exclusions: hydrofluoric acid and alkalis), elastomers can be avoided by fusing the rod through a CFQ standard taper joint or ball joint. In this case, it is of course desirable to avoid any bubbles or other occlusions in the seal. Therefore, use of a maria in the rod for fabricating the seal is an assured, effective means for maintaining the optical integrity of the light path.

There can be any number of uses for the sensor. The precise control of a fluid level such as in surface chemistry experiments is an example. Here, better resolution of the sensor seems to be gained by using a 6 mm CFQ rod rather than a larger diameter rod. Other examples would include overflow prevention, automatic liquid dispensation or introduction, and boil-off prevention.

A somewhat detailed consideration of a specific application will lend some further insight into the sensor's capabilities and limitations. In certain areas of radiation chemistry research, it is necessary to use extremely pure deuterium oxide or heavy water. To accomplish this, the water must be specially triple-distilled in a borosilicate and CFQ apparatus (Plate 1). Also, because of its cost ($400-$650 per liter for feedstock), the handling of the water and its distillation must be conducted with care to minimize any loss. In fabricating the triple still, it was apparent that it would be desirable to automate the process in order to avoid such losses and to avoid subjecting a technician to the tedium of manually operating it. Therefore, it was decided to employ the liquid level sensors in conjunction with a benchtop computer.

In Plate 2, the sensors are located at socket joint side necks of each of the three pots. A simple computer program can be written to control the feedstock pump and the three heating mantles. Figure 5 consists of two flowcharts of basic programs capable of handling the three elements of the still.

In this particular application wherein the sensor is immersed in the vapor-rich environment of a boiling pot, it was found that condensate on the sensor could provide the program with an erroneous signal. It appears that this can be overcome by "bleeding" the sensor — i.e., for example, by allowing the side of the rod close to the tip to come in contact with the sidewall of the vessel. Also, boiling stones must be added to the pots to minimize bumping and oscillation of the product. Once these impediments are overcome, the still can operate with minimum attention.

Conclusion

Considering recent developments in automating even some of the most complex processes, there is ample evidence that man's motivation toward eliminating tedious, repetitive work continues unimpeded. By combining well-known principles first discovered and formulated during the 17th century, it is possible for the glassblower and electronics specialist to help reduce the researcher's labor in the laboratory.

Acknowledgments

We are very grateful to Mr. Ralph Steinback, Notre Dame Radiation Laboratory Electronics Shop Supervisor, for his invaluable support and advice with regard to the electronics design. We thank Messrs. Paul Deranek and Michael Pecina for their preparation of the photographs and graphic materials, respectively.

The research described herein was supported by the Office of Basic Energy Sciences of the Department of Energy. This is Document No. NDRL-3200 from the Notre Dame Radiation Laboratory.

Footnotes:

* In order to simplify this discussion, assume that the light is monochromatic and that the media are at standard temperature (20° C).

** For an excellent explanation of the derivation of this formula, see Warren T. Smith's *Modern Optical Engineering: The Design of Optical Systems*, McGraw-Hill Book Company, N.Y. 1966, pp. 4-5.

† Products of Ace Glass, Incorporated.

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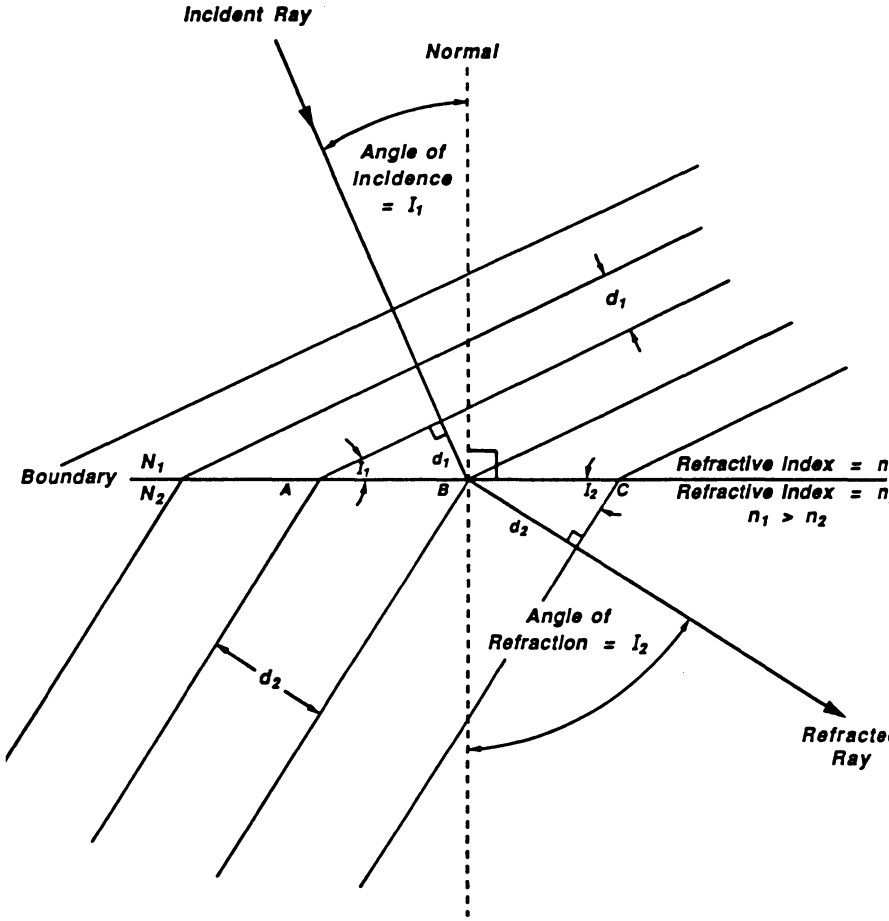


Figure 1

(Adapted from Figures 1.4 and 1.5, Warren J. Smith, *Modern Optical Engineering: The Design of Optical Systems*, McGraw-Hill Book Company, New York, 1966, pp. 4-5.)

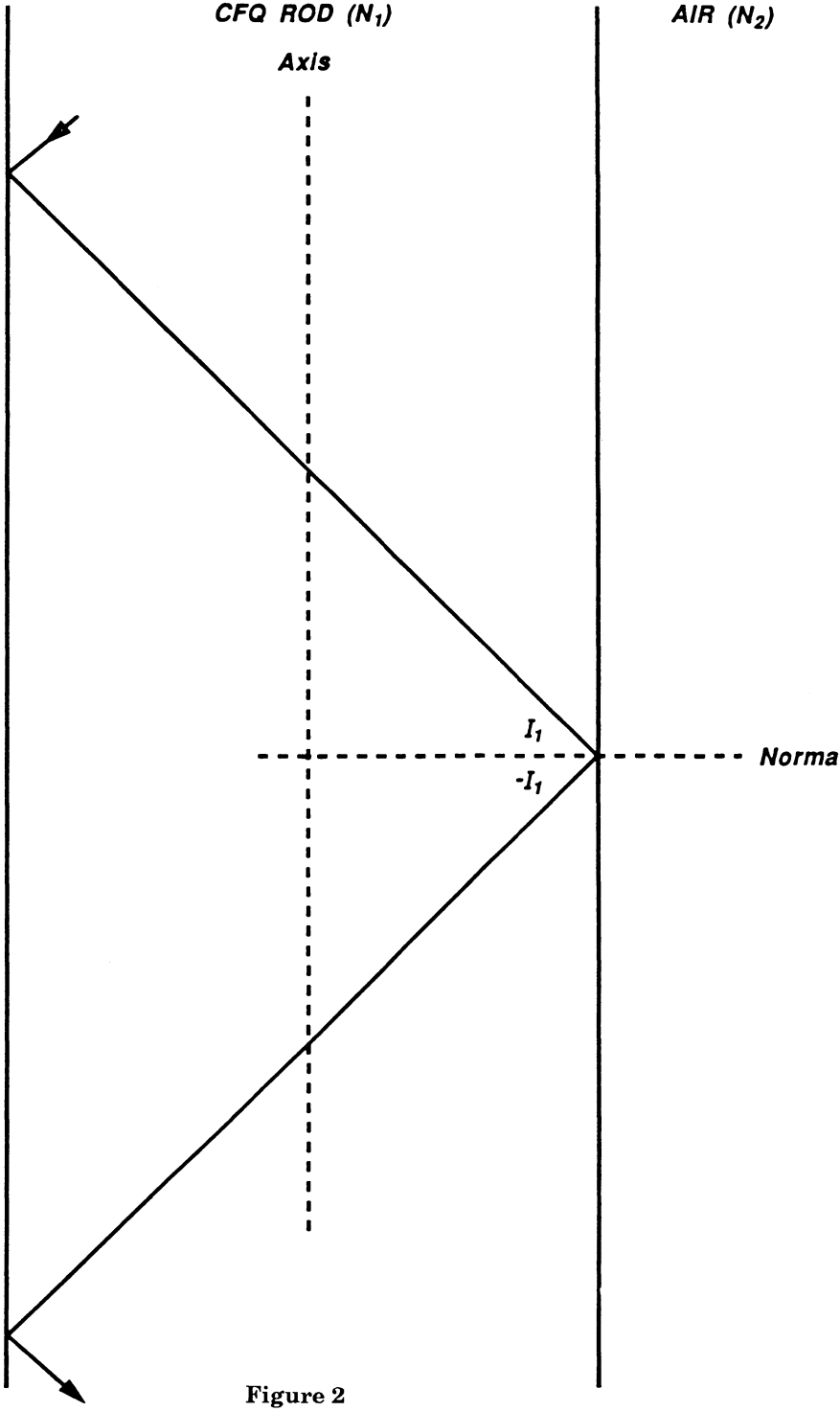


Figure 2

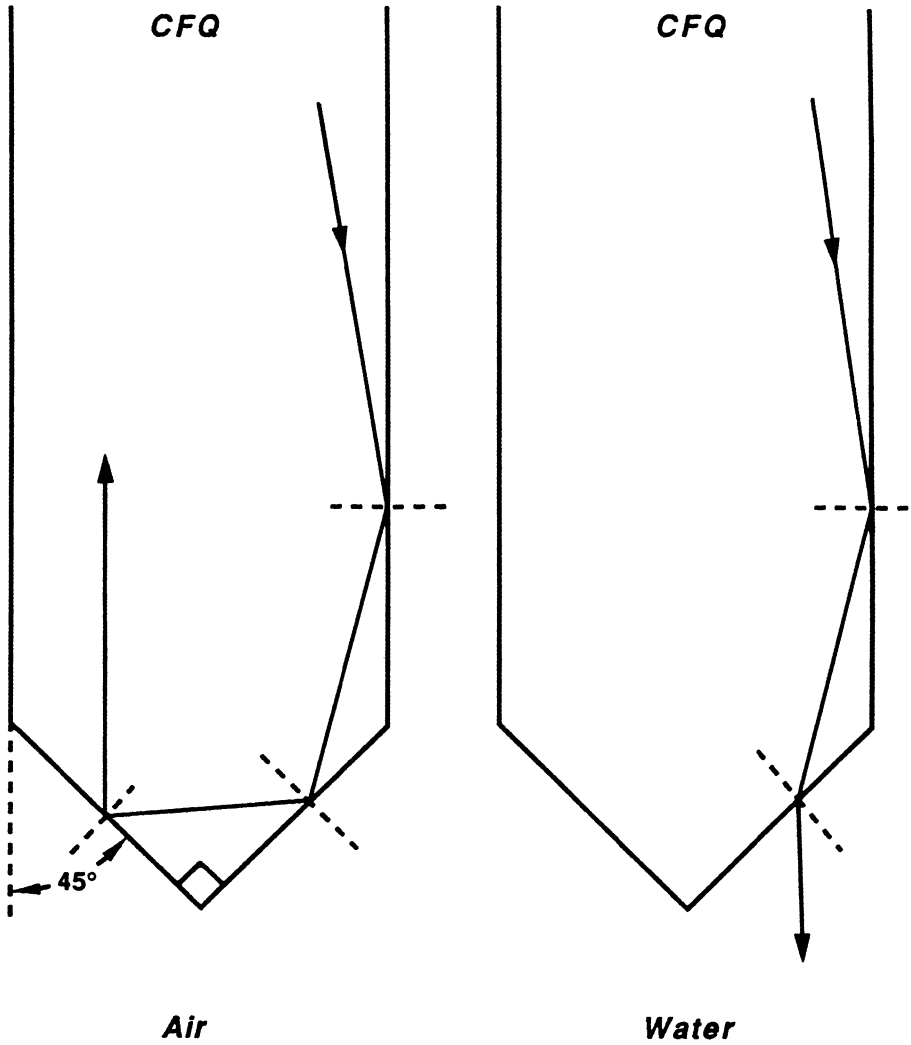


Figure 3

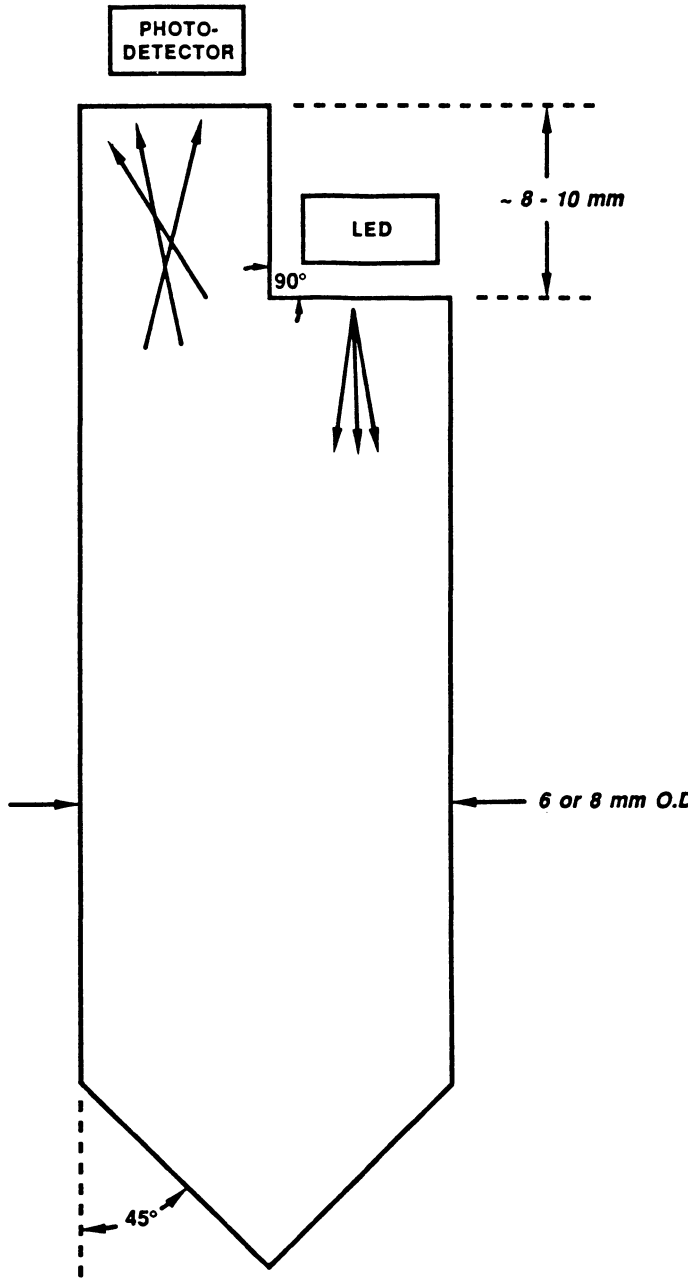


Figure 4

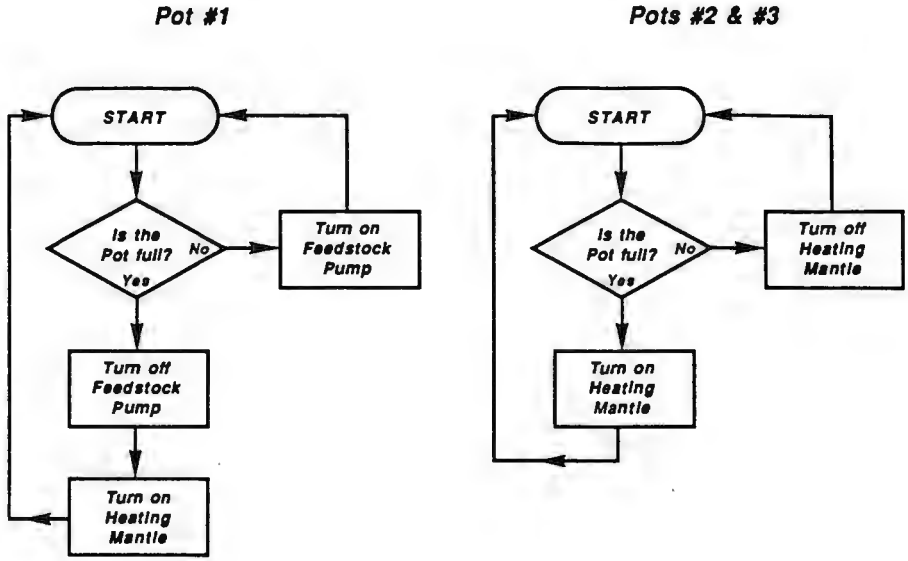


Figure 5

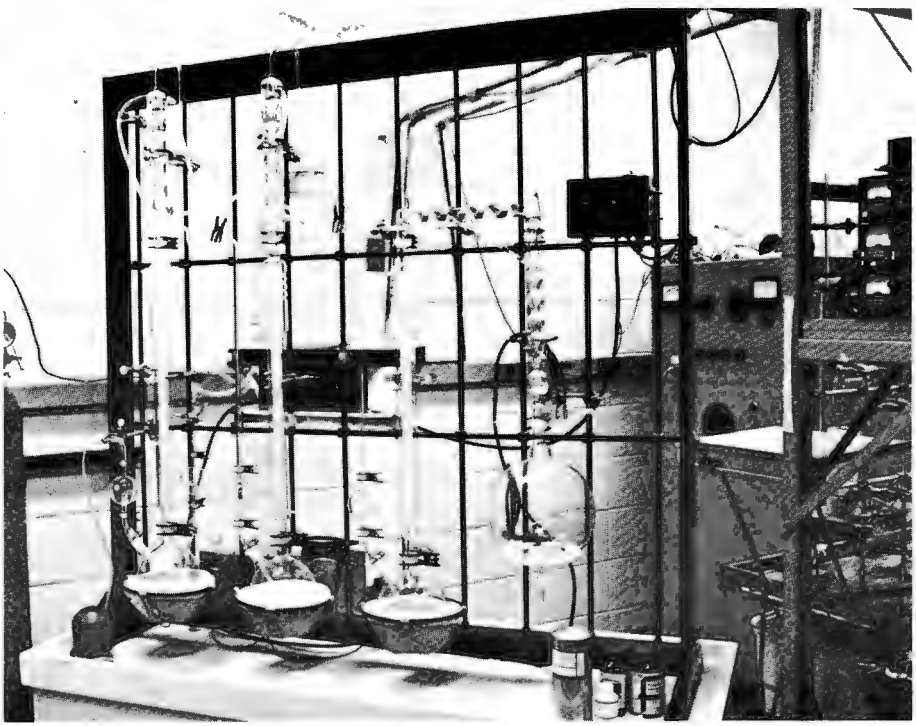


Plate 1

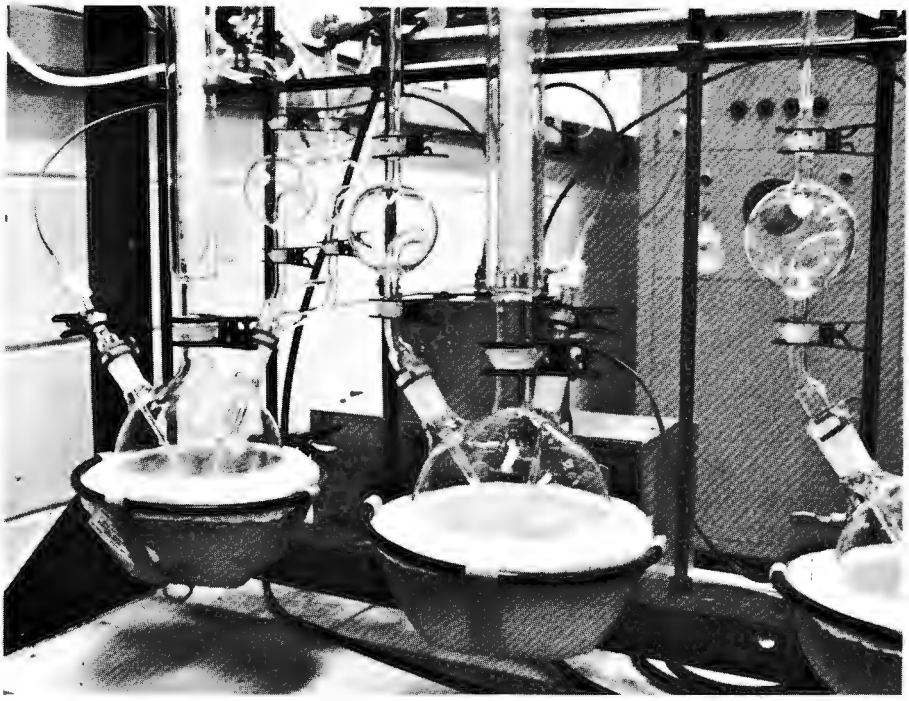
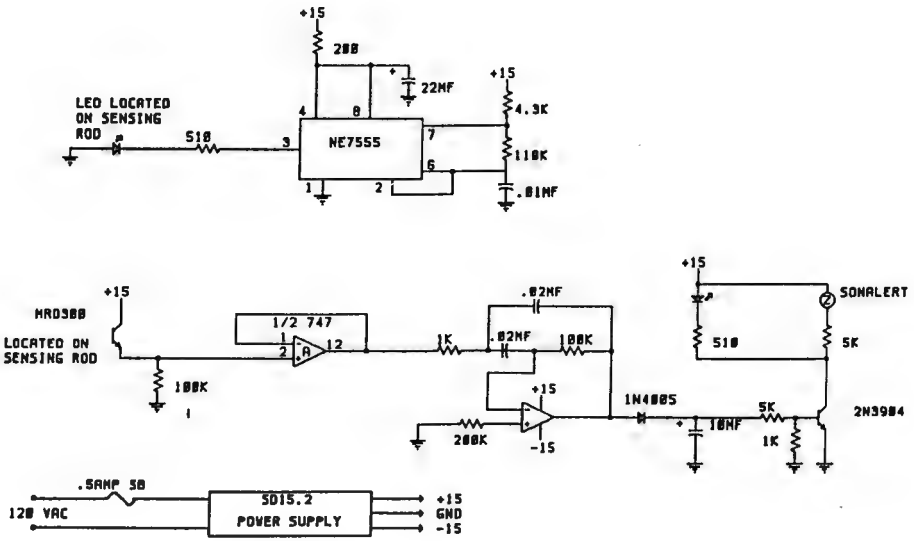


Plate 2



Appendix: Electronic Circuitry for a Demonstration Model of a Quartz Liquid-Level Sensor

"DETERMINATION OF THERMAL EXPANSION HOMOGENEITY OF CORNING CODE 9600 GLASS-CERAMIC BY SEAL TESTING"

Henry E. Hagy
Consultant

Corning Code 9600 Glass Ceramic is a transparent, near-zero expansion material for use in ring laser gyros, optics, and other applications demanding negligible expansion in a quality structure. Expansion homogeneity is also very important. This seal testing study evaluates homogeneity of cast Code 9600 in two sampling modes: firstly, by cutting specimens for test before ceramming to assess *chemical homogeneity*; secondly, by cutting specimens after ceramming to assess *thermal homogeneity*. Expansion differences determined are less than 20 ppb/°C at room temperature with *thermal* showing tighter values.

1. Introduction

Corning Incorporated recently introduced a remarkable glass-ceramic with special physical properties. Code 9600 glass-ceramic is a near-zero thermal expansion material characterized by a fine-grained crystalline structure and high homogeneity. It is an ideal material for ring laser gyros, optical components, and any other application requiring near-zero expansion and a stable, high quality body.

Code 9600 glass-ceramic is melted as a glass, cast into large blocks, and then heat treated (ceramming) to convert the glass into a transparent glass-ceramic. In many cases the original casting is cut into smaller pieces, like a ring laser gyro blank, before ceramming. One of the required properties for ring laser gyros is low helium permeability, which Code 9600 glass-ceramic easily meets.

The thermal expansion characteristics between -100 and 100° C are shown in Figure 1. Note the greatly expanded thermal expansion scale and that near-zero expansivity is attained at room temperature. The initial expansion determination shows hysteresis of 0.6 ppm, which is essentially gone in the second run. Competitive glass-ceramics also exhibit this type of hysteresis of about the same magnitude. However, recent developmental research at Corning Incorporated has essentially eliminated this hysteresis in Code 9600 glass-ceramic.

The near-zero thermal expansion is important to maintain critical dimensions as temperature changes are experienced. High homogeneity of thermal expansion is equally important, else stresses will develop upon temperature change and warp the body through thermal strain.

A plan was developed to measure thermal expansion homogeneity using end-tied sandwich seals. This approach is an easy, straightforward technique for evaluating expansion differences with high precision.

2. Experimental Method

2.1 Material, Geometry

It was decided to use a ring laser gyro blank, 4-1/4" x 4-1/4" x 1-1/2" in size, as the starting geometry. Two such blocks were cut from the same casting. One of these blanks was cerammed and then subsectioned. This blank was termed the thermal homogeneity blank. The second blank was first subsectioned and cerammed along with the *thermal homogeneity* blank. This second blank was termed the *chemical homogeneity* blank. Subsectioning was done by diamond saw cutting, mill grinding, and polishing, producing thirty-six small blocks 1-1/4" x 1-1/4" x 0.140" in size.

The point of evaluating two blanks in this fashion was to determine if thermal gradients in the blank during ceramming created thermal expansion differences over and above differences caused by possible compositional differences from melting and casting.

2.2 The End-Tied Sandwich Seal

The geometrical format of the frit-bonded, end-tied sandwich seal is shown in Figure 2. Two sub-blocks from nearly the same location (A in the figure) are made the outside members of the seal, whereas a third block from a more remote location is made the central member of the seal (B). These three members are sealed on their ends to two tie blocks, 1/2" x 1/2" x 1-1/4" in size, using a frit. The tie blocks were cut and ground from the same casting as that used for the blanks. The faces of the central member are polished to accommodate optical retardation measurements.

2.3 The Frit

The frit used for making the sandwich seal is a key element. It is an unreleased lead titanate glass-ceramic frit that matches the thermal expansion of Code 9600 glass-ceramic and fires below the upper ceramming temperature for Code 9600. The lead titanate frit fires between 700° and 800°C, whereas Code 9600 is cerammed above 800°C. This firing temperature differential of nearly 100°0C is important so as not to change the thermal expansion of the Code 9600 glass-ceramic.

The thermal expansion difference between the frit and Code 9600 is shown as a function of temperature in Figure 3. This curve was determined by another format of seal testing. Seals survive the high temporary mismatches at 300° and 500°C and the moderately high mismatch at room temperature by keeping the frit layers thin.

2.4 Optical Retardation Measurements

As shown in Figure 4, optical retardations are made using a Friedel polarimeter. Small windows, approximately 1 mm square, are painted on the viewing surfaces of the central seal member using black ink to restrict the view to the very central portion of these viewing surfaces. This greatly improves reading precision and eliminates bending stresses possibly caused by slight expansion differences between the outer seal members.

Not shown is the environmental chamber that surrounds the seal specimen that is heated electrically and cooled by liquid nitrogen.

Optical retardations are read by rotation of the analyzer to the nearest 0.1° which is equivalent to 0.29 nm. Filtered white light peaking at 522 nm is used as the light source.

2.5 Determination of Expansion Differences

Expansion difference is calculated from the first formula given in Figure 2, where:

$\Delta\delta$ = expansion difference during ΔT, ppm

λ = wavelength of light, 522 nm,

ΔA = change of analyzer reading during ΔT, degrees,

B = stress-optical constant of Code 9600, 0.209 nm/cm/psi,

P = optical path length (width of central member), cm.

$E_A = E_B =$ elastic modulus of Code 9600, 13.8 x 10^6 psi.

$t_A = t_B =$ thickness of outer and central members, cm, and

$\Delta T =$ temperature change, °C

Since the outer and central members of the seal have equal thicknesses, and the elastic moduli are the same, this equation reduces to:

$$\Delta\delta = 0.47\,\Delta A$$

The differential expansion coefficient is calculated using the second formula in Figure 2, or by curve fitting the δ vs. T function and calculating the derivative at 25°C. All values in this investigation are calculated at 25°C and are given in ppb/°C, since they are very small.

3. Experimental Results

3.1 Chemical Homogeneity

The blank sectioning scheme, expansion differences measured, and test values are shown in Figure 5. Edges vs. center and double diagonals show the highest expansion differences, thereby showing that extreme displacements relate and inhomogeneities are long-range.

Actual plots of expansion difference as a function of temperature are shown in Figure 6. All show linear relationships (constant $\Delta\alpha$) except seal no. 4, edge vs. center.

3.2 Thermal Homogeneity

Surprisingly, the thermal homogeneity study yielded much more favorable results. Figure 7 shows the sectioning scheme, comparisons made, and test results. These values are extremely good, which gives confidence that the ceramming heat treatment has been extremely well-developed and executed. The expansion coefficients determined are at the edge of experimental precision. All curves for these six comparisons gave linear relationships, showing constant $\Delta\alpha$ with temperature.

3.3. Accuracy

The accuracy of a single point on the expansion difference versus temperature plot is estimated as 0.19 ppm ($\Delta A = 0.4°$). The error that the expansion coefficient differential can experience is twice this value (0.38 ppm) divided by the temperature range covered (150°C) or 2.5 ppb/°C.

4. Conclusions

The frit-bonded, end-tied sandwich seal is an efficient and inexpensive test technique for determining thermal expansion differences with high accuracy. Uncertainties are estimated as 2.5 ppb/°C.

Corning Incorporated Code 9600 glass-ceramic has been shown to exhibit excellent homogeneity, with differences less than 20 ppb/°C. Ceramming contributes nothing to inhomogeneity of thermal expansion outside the experimental uncertainties of this study. This study was carried out two years ago and, since that time, developments have greatly improved the quality of Code 9600. Another study similar to this investigation is planned to update Code 9600 homogeneity which will probably be the subject of a forthcoming paper.

THERMAL EXPANSION OF CORNING CODE 9600 GLASS-CERAMIC

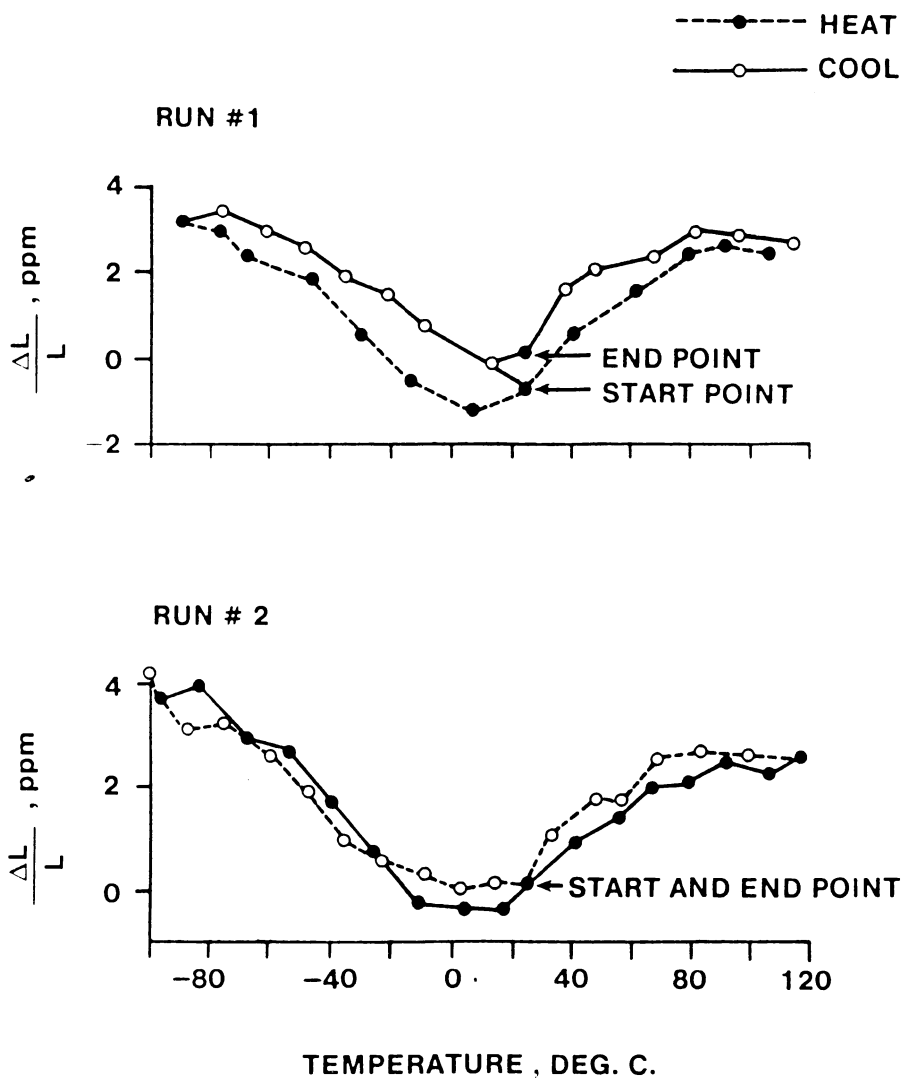
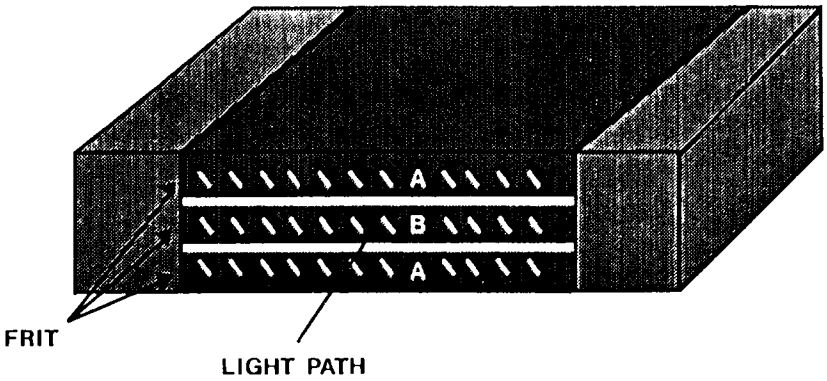


Figure 1

FRIT-BONDED, END-TIED SANDWICH SEAL



$$\Delta\delta = \frac{\lambda\Delta A}{180\ BP}\left[\frac{1}{E_B} + \frac{t_B}{2t_A E_A}\right] 10^6\ (PPM)$$

$$\Delta\alpha = \frac{\Delta\delta}{\Delta T}$$

Figure 2

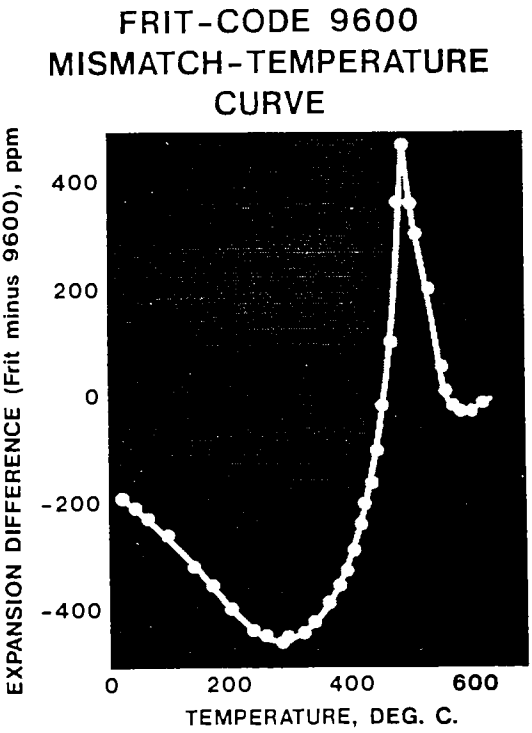


Figure 3

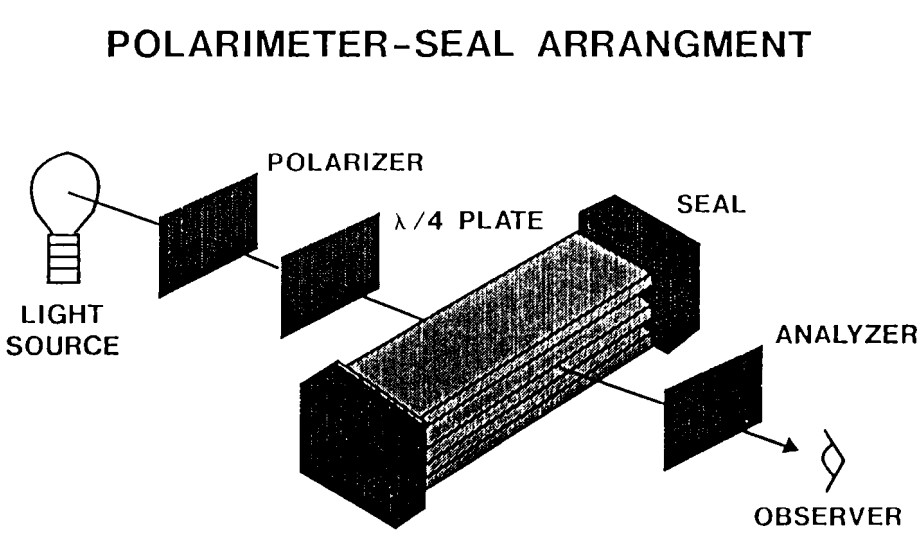
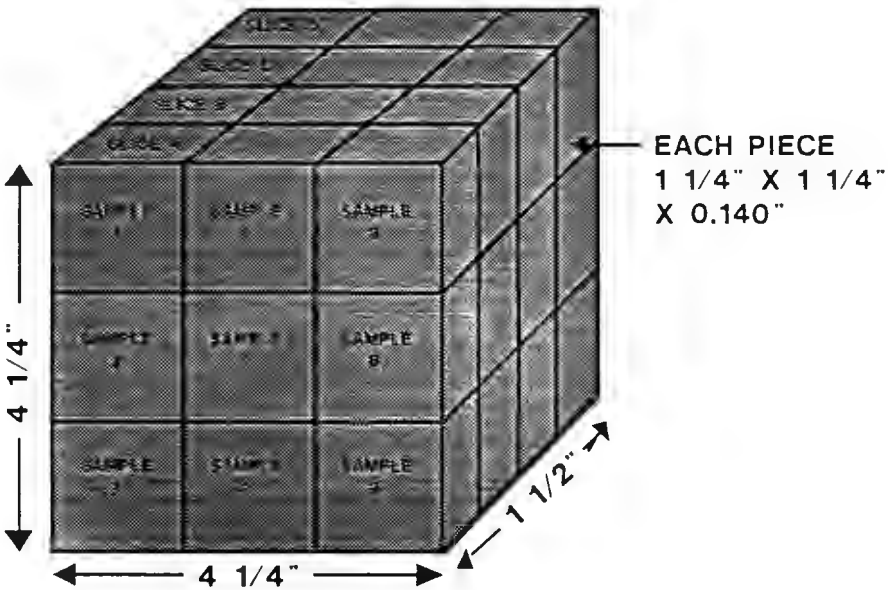

POLARIMETER-SEAL ARRANGMENT
POLARIZER
λ/4 PLATE
SEAL
LIGHT
SOURCE
ANALYZER
OBSERVER

Figure 4

CORNING CODE 9600 GLASS-CERAMIC

CHEMICAL HOMOGENEITY



SEAL NO.	COMPARISON MADE	SAMPLE DESIGNATIONS			$\Delta\alpha$, ppb/°C
		OUTSIDE 1	CENTER	OUTSIDE 2	
1	Corner vs Center	B1	B5	B3	-6
2	Diagonal Corners	C1	C9	D1	-5
3	Edge vs Center	B2	A5	A2	-15
4	Edge vs Center	C6	C5	D6	+19
5	Edge vs Edge	A4	A6	B4	+9
6	Double Diagonal	A7	D3	B7	-15

Figure 5

CODE 9600 GLASS-CERAMIC THERMAL EXPANSION DIFFERENTIALS CHEMICAL HOMOGENEITY

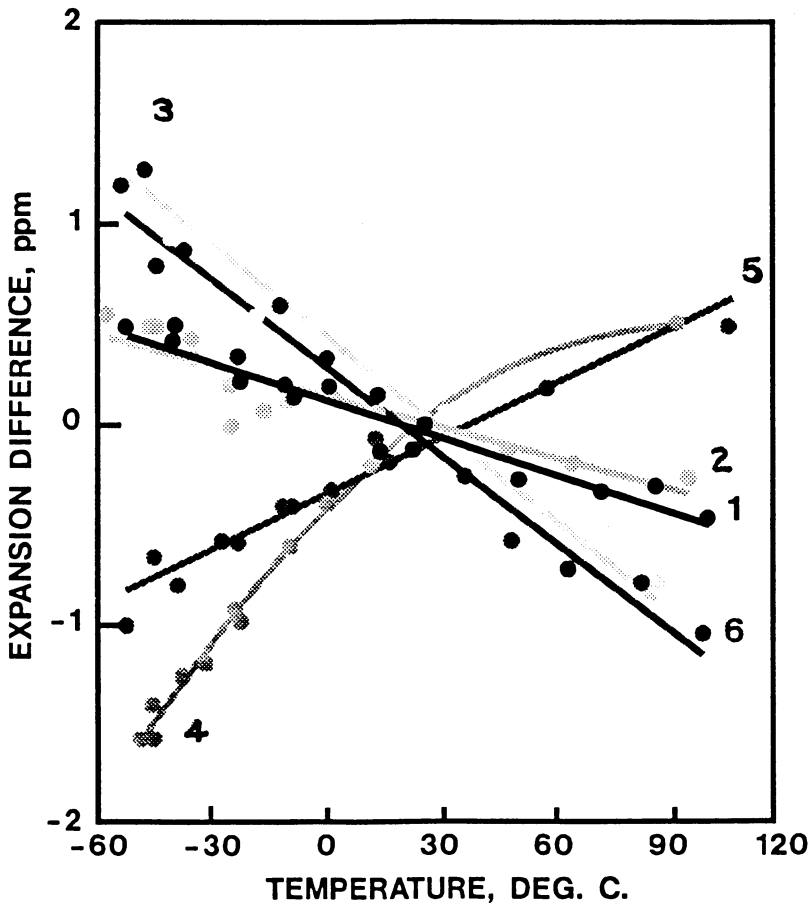
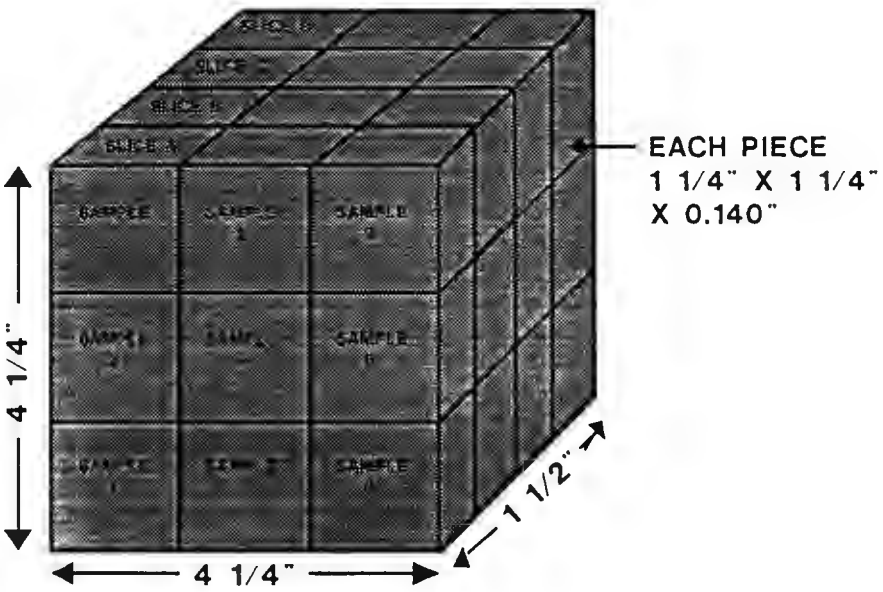


Figure 6

CORNING CODE 9600 GLASS-CERAMIC

THERMAL HOMOGENEITY



COMPARISON MADE	SAMPLE DESIGNATIONS			$\Delta\alpha$,
	OUTSIDE 1	CENTER	OUTSIDE 2	ppb/ ° C
Corner vs Center	B1	B5	B3	0
Diagonal Corners	C1	C9	D1	+1
Edge vs Center	B2	A5	A2	-3
Edge vs Center	C6	C5	D6	-4
Edge vs Edge	A4	A6	B4	-1
Double Diagonal	A7	D3	B7	-1

Figure 7

HEALING CRACKS IN LARGE HEAVY-WALLED VESSELS

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I am sure that every scientific glassblower has had a piece of apparatus crack during construction, or has had to repair a piece of glass that had cracked in use. Those of us who work in a service shop often encounter these types of repairs. I would like to share with you a technique I developed that will enable you to successfully heal almost any cracked piece of glassware. I use the word heal rather than repair because this technique will in most cases reverse the crack, causing it to disappear with little or no trace. While this technique may be applied to any size glass apparatus, it seems to work best on heavy-walled glassware.

The following items and equipment will be needed for this procedure:

1. Litton Annealing Burner
2. Cannon Burner
3. Hand Torch with Long Gooseneck (~12 inches)
4. Long-neck Needle Torch (Hand)
5. Several Pieces of Thin Glass Rod
6. Two Floor Stands for Holding Torches
7. Glassblowing Lathe

The Litton Annealing Burner is a gas/air, surface mix burner. The burner is mounted on a floor stand and placed on the back side of the lathe facing the glassblower. The Cannon burner is a large gas/oxygen, pre-mix torch. The Cannon burner may also be mounted on a floor stand placed on the glassblower's side of the lathe or held by the glassblower during the procedure. The hand torch is a gas/oxygen, pre-mix torch and will be held by the glassblower during the procedure. The hand torch is equipped with a gooseneck which is approximately 12 inches long. This will enable the glassblower to use the hand torch inside the glassware. This also, for comfort sake, puts some distance between the glassblower and the hot glassware during the procedure. If the opening in the glassware will not accommodate a gooseneck, a needle-neck torch will be needed. If a needle-neck torch is not available, a long-neck torch tip may be made from a piece of small-diameter glass tubing or quartz tubing.

It is also advisable to have several pieces of 2-to 3-mm glass rod present. This rod is used if the crack should separate or open during the healing process. The glass rod can be used to fill in the opening and the process may then be continued.

The first step in the procedure is to anneal the glassware in an oven. Annealing relieves any strain that may be present in the glass and will also burn out any traces of organic residue. After annealing, determine if the glassware requires additional cleaning. If additional cleaning is needed, one may choose between mechanical cleaning or chemical cleaning with a 5% solution of hydrofluoric acid, concentrating on the area to be worked. It is important that the crack is free of residue. The residue could burn into the crack, leaving a line or blemish in the glass.

The second step is to place the glassware into the lathe chuck. Position the crack so it is centered as much as possible. Start the lathe and begin heating the glassware with the Litton annealing burner. Start with a small, all-gas flame and gradually increase to a large bushy all-gas flame. Allow the glassware to become covered with

a heavy layer of black soot. The layer of soot insulates the glass from thermal shock and serves another function that will be explained later.

When the glass is covered with a heavy layer of soot, the third step is started. Begin adding air to the annealing burner flame and gradually increase the air and gas feed every 3 to 5 minutes until a hot, bushy, gas/air flame is achieved. Allow the glassware to soak under this flame until about half of the soot has burned off the glass. To avoid rushing the warm-up process, it is advisable to walk away from the lathe and work on something else, returning every 3 to 5 minutes to increase the gas/air feed. The size and weight of the glass will determine how much time to allow between increases in flame temperature.

The fourth step is to heat the glassware with the Cannon burner while continuing to heat with the annealing burner. Start with a medium all-gas flame and slowly add oxygen until an air gap is present between the Cannon burner tip and the base of the flame. Doing this will produce a warm, bushy flame that appears to be "jumping off" the Cannon burner. Using a flame of this type promotes healing and discourages spreading of the crack. Gradually increase the gas and oxygen pressure while maintaining the air gap between the Cannon burner and flame. These increases in pressure are made until a hot, bushy flame is achieved. Allow the glass to soak under both the annealing and Cannon burners until all the soot has burned off.

The fifth step is to begin healing the crack with the hand torch. During this step, continue to heat the glassware with both the annealing and Cannon burners while the lathe is still turning. It is important to use a *soft*, blue, gas/oxygen flame on the Hand torch for this step. A sharp blue flame could cause the crack to separate and open. Begin heating the end of the crack with the hand torch for only a second or two, pulling the flame away as the crack in the glass rotates away from the glassblower. Reapply the flame to the crack as it rotates back around, again pulling the flame away after only a second or two. Continue this procedure until the crack begins to heal or reverse itself. When this happens the intensity of the hand torch flame may be increased slightly, and the duration of the heating may be gradually increased until the flame is being applied almost constantly. As the crack heals, follow it slowly with the hand torch until the entire crack is healed.

The sixth step is to go over the healed crack, inside and out, with a sharp, hot hand torch flame to completely seal the crack. The outside of the glassware should be done first. With the lathe still turning, continue to heat the glassware with both the annealing and Cannon burners while sealing the healed crack with the hand torch. To seal the healed crack inside the glassware, the lathe will have to be stopped. Continue to heat with both the annealing and Cannon burners for the entire step. Work inside the glassware with the hand torch for only 30 seconds to a minute. Remove the hand torch and turn the lathe on, allowing the glass to rotate under the two burners for approximately two minutes. Turn the lathe off and return to the inside of the glassware with the hand torch, again working for only 30 seconds to a minute. Remove the hand torch, turn the lathe on and allow the glass to rotate under the burners for about two minutes. Continue this procedure until the entire length of the healed crack has been completely sealed.

In many instances the crack will completely disappear after the healing process, making it difficult to locate for this step. It is advisable to mark the ends of the crack with a grease pencil (china marker) or a diamond scribe before starting to heat the glass in step two. In doing so, the path of the healed crack may easily be retraced.

The seventh and final step is to flame anneal the glassware and to place it in an oven for thorough annealing. It is a good idea to have a hot oven ready to receive the glassware immediately after completion of the flame annealing.

This technique may also be applied when working on a new piece of apparatus that cracks during construction. Assuming that the piece is already hot, the procedure may be picked up at step four, where the Cannon burner is first incorporated. The crack will usually heal, leaving no scars or blemishes to mar the finished product.

The layer of soot that covered the glassware in step two serves as a fairly accurate indicator of when steps three and four can be started. It is important to note that at no time throughout the procedure was the heating of the glass with the annealing and Cannon burners interrupted, and the lathe was always rotating except for step six, when it was necessary to go inside the glassware with the hand torch. When the words slowly or gradually are used in this paper, one may interpret this as allowing 3 to 5 minutes to pass between moderate increases in gas, air and oxygen pressure.

In my 20 years of glassblowing experience, I have found this to be the most successful technique for healing cracks. Using this technique, I have healed cracks up to 18 inches long on flasks, dairy jars, bell jars and other heavy-walled vessels. As unbelievable as it may sound, a success rate of over 95% may be achieved if one masters the fundamentals of this technique.

To summarize, here are the important points of this procedure.

Preparation: Have all equipment and materials readily available for use when needed.

Step 1: Anneal and, if necessary, thoroughly clean the glassware.

Step 2: Slowly heat and cover the glass with a heavy layer of soot using the annealing burner.

Step 3: Increase the heat of the annealing burner until approximately half of the soot has burned off.

Step 4: Using the Cannon burner with an air gap in the flame, burn off the remaining soot.

Step 5: Use the hand torch with a soft blue flame to heal the crack. Incorporate the heating, removing, heating, removing technique.

Step 6: Completely seal the crack inside and out using the hand torch with a hot, sharp flame.

Step 7: Flame and oven-anneal the glassware.

When faced with a repair that involves healing a crack, one should always determine whether it is more economical to repair the damage or build a new piece of apparatus. If the decision is to repair the apparatus, then please give this technique a try.

Good luck!

Respectfully,

William Wasemiller

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I would like to thank Aldrich Chemical Company for allowing me to present this paper and making their services available to me for the production of this paper. I especially want to thank Dieter Damrow and Bill Szabo for their help, encouragement and support to make this paper possible.

LEAK DETECTION IN VACUUM GLASSWARE

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When a glassblower makes scientific apparatus that is meant to hold a vacuum, there are certain precautions he must take to make sure it will indeed maintain that vacuum. However, even the best of us make a mistake sometimes. And there are a variety of ways to find this error. This paper will present and discuss the different methods most commonly used to detect leaks, from our ears and eyes to Mass Spectrometer Leak Detectors.

The first, and most familiar method used to detect leaks, are our eyes and ears. (see Slide 1 - Eye & Ear) We will either hear the all too familiar gurgling of a roughing pump or hear a turbo pump whine down. Periodically, this leads to the visual discovery of a crack or other defect. But if this doesn't work, we can use our eyes in a different manner — to watch the vacuum gauge while we spray our system with an alcohol such as Methanol or other solution like Acetone. There are also commercially available sprays to squirt over your vacuum lines for the specific purpose of helping you find leaks. While pumping, spray the suspect area with the tracer fluid. Watch your gauge while doing this. When you spray the leak, the pressure should rise. One problem of this technique is that it is possible to plug up small leaks with either the liquid being used or by the movement of dirt around the leak. But if you watch the gauge closely enough, you will be able to tell if this has happened. The gauge shows an increase in pressure but returns to a good vacuum in a few moments, and, when the area is re-tested, the leak doesn't show. It is important, however, to find the leak and repair it. You should have an idea where it approximately is.

If none of the previous methods appeal to you, it may be because your favorite method of testing for leaks is the one invented by Dr. Nikola Tesla, the Tesla coil. Tesla coils, invented in the late 1890's, were one of the earliest forms of leak detectors, though that wasn't the reason for their invention. Tesla coils, or spark coils, are useful for finding leaks in systems that can be evacuated to pressures ranging from 10 to 10-2 Torr. Be careful — the coil produces high-frequency, high voltage oscillations which are about 40 to 50 thousand volts. The amperage output of 3 to 5 milliamps isn't enough to kill you, but you probably won't enjoy the feeling. A Tesla coil can be something as simple as a home-made device made with any high-frequency transformer such as a television flyback transformer, or the commercial type consisting of an adjustable interrupter, a usually vibrating spark gap, condenser, resonator coil and gap tip.

The main way to use a Tesla coil to detect leaks is to pass the tip of it over the item being inspected. (Slide 2 - Passing Over.) When the probe passes to within about 6mm of the leak, a spark will jump to the leak and a very bright spark can be seen going into the system where the leak is located. (See Slide 3 - Leak.)

The scanning speed of this technique can be as fast as several meters per minute, and the little skill needed in using this technique makes it easy for even the most inexperienced operator. This works best on either an all-glass system, or one composed of chiefly glass, since the spark will readily jump to the nearest metal surface. (See Slide 4 - Metal Jump.)

But there is a drawback of the Tesla coil that many of us are probably familiar with — that is, the ability of it to make a leak in vacuum glassware using the same powers it has to detect leaks. This electrically induced puncture most often occurs at a point where glass is weakest, such as where two pieces were joined together, or where a thin

wall exists. It is also most often made by one who is inexperienced in the use of the coil, as experience dictates that one doesn't hold the coil over the same spot for long periods of time. If the leak is especially difficult to find, or if there are glass-to-metal seals in the apparatus that are suspect, a Tesla coil might not be adequate. In cases like these, a Gas Leak Detector might be the right tool for the job.

Gas leak detectors, (see Slide 5 - Thermal Conductivity Tester) or Thermal Conductivity leak detectors, are usually small, hand-held units that can sniff out leaks as small as 1 x 10-5 cc/SEC. This is done by pressurizing the item to be tested with any gas mixture possessing thermal conductivity values different than air. The instrument's probe is then passed over the item, and the internal pump draws a sample into the specially selected low volume thermal conductivity cell. Many of these instruments use a thermal conductivity detector in a Wheatstone Bridge circuit. (See Slide 6 - Wheatstone Bridge.) You can see the air is drawn in by a fan or pump across 2 filaments — one from the probe tip, another to sample the ambient air. The electronics compare the two, and give a readout based on whether it detects a difference between the two. The relatively low operating temperature of the filaments makes the hot wire bridge leak detector safe to use under most conditions. Just a note of caution, however, many leak detectors like this are not designed to detect leaks of combustible gases. A combustible gas detector should be used for determination of combustible gas leaks in hazardous conditions. (See Slide 7 - Gauge Close-up.) If the thermal conductivity properties of the sample vary from the ambient air, a needle on the face of the detector deflects, indicating a leak. The center of the gauge is zero, so if the tracer gas you're using is lighter than air, such as helium, the gauge will deflect to the right. If the tracer gas is heavier than air, such as argon, the gauge will deflect to the left. And remember to start testing for leaks at the bottom of the apparatus if you're using a light tracer gas such as helium, or start at the top if the gas you're using is heavier than air, such as argon, so you don't track the escaping tracer gas as it goes into the atmosphere. The leakage sensitivity depends on the relative differences of the thermal conductivities of the different gases that are used. (See Slide 8 - Therm. Conduct. Chart.) This chart shows that helium has a larger difference in thermal conductivity than air, and is therefore more sensitive to leaks. But, don't forget, the smaller the leak is, the less tracer gas will leak out, which also affects the leak sensitivity. A drawback of this leak detector is that, due to the relatively long response time of thermal gauges and the slow gas sampling rate, the user may tend to pass over the leak before it registers. So the leak may have to be located by successive passes of the sampling tube. Another disadvantage is that you have to be careful about where you breathe, because the moisture in your breath will cause the gauge to deflect. The placement of your hands is crucial, too, as the moisture from your skin will also cause the gauge to deflect. Leaks as small as 1 x 10-5 can be detected if the operator is skilled. The simplicity of this instrument, along with it's relatively low cost ($750-$950), make it easy for even modest Glass Shops to own and use.

(See Slide 9 - MS18-AB.) If even more sensitivity is desired, and cost isn't too much of a problem, one of the many models of Mass Spectrometer leak test stations can be purchased. (See Slide 10 - Detail Dwg. MS18-AB.) These usually consist of a mass spectrometer, a complete vacuum system and all the electronics necessary for the proper operation of the spectrometer tube. The mass spectrometer leak detector is one of the most sensitive and accurate instruments known for indicating extremely small leaks, by measuring the rate of flow of helium through the leaks. Leaks as small as 6 x 10-12 cc/SEC of air at atmospheric pressure can be found with these instruments. Maximum operating pressure is about 3 x 10-4; many units have special throttling valves so items with larger leaks can be tested. Here's how they work: (See

Slide 11 - Det. Dwg. CEE Tube.) The gas molecules from the object being tested enter. Since neutral atoms and molecules of gas cannot be separated by a mass spec, they must first be converted to positively charged ions. This is accomplished by the ion source. Inside the ion source is a tungsten filament which is heated by an electric current. The hot filament emits a regulated beam of electrons. When these electrons collide with the atoms and molecules of gas, they "knock off" electrons, producing positive ions. Upon formation, these ions encounter the electrostatic fields established within the ion source by the ion repeller, the ion chamber, the focusing plates, and the object plate. The effect is to accelerate the ions in a well defined beam. Since the gas entering the tube contains atoms and molecules of different kinds, the ion beam will also contain a variety of ions, such as nitrogen, oxygen, carbon dioxide, and, if a leak is found, Helium. The magnetic field separates the helium ions from the remainder of the ion beam, and deflects these ions on to the detector. Only helium has the correct mass to pass through the magnetic section and through the baffle openings to the other side. Most of the other ions will be deflected too much or too little, and intercepted by the baffles between the two magnets. The helium ions must now pass through another series of baffles which further defines the beam. Located behind these baffles is the target. As an arriving helium ion strikes, the target becomes positively charged, and an electron flows towards the charge of the ion. The flow of these electrons constitutes a minute current — about 10^{-15} microamps. (See Slide 12 - Ion Collector and Source.) The current flow is then detected and amplified, which appears as a visual indicator on the leak indicator gauge. One disadvantage of this type of leak detector is that it must be turned on in advance to leak detection so the diffusion pump can warm up. A turbo pump on this type of equipment would be nice, but it makes an already expensive piece of equipment all the more expensive. Also, a turbo pump would not handle the rapid changes in pressure that a leak detector of this type would be likely to encounter. Testing is done by one of three ways. (See Slide 13 - 3 Way Testing.) The easiest, in my opinion, is to pull a vacuum on the item to be tested from the leak detector. If the leak is small enough, which means it will pump down to at least 3×10^{-4}, most leak detectors will be able to pump on it unassisted by the operator. However, if the leak is larger, you may have to use the throttle valve. This valve allows the operator to just barely open the item being tested to the high vacuum side of the pumps and the mass spec tube, which allows you to still check the apparatus for leaks even though it may have a relatively large leak. Once an adequate vacuum is obtained, the object is then sprayed with helium while watching the leak indicator gauge. As before, watch how you spray the helium. Too large of a flow may give a reading of a leak due to stray helium around the apparatus, or from starting at the bottom and going up, surrounding the whole apparatus immediately with helium. When the gauge deflects, the leak has been found. Most gauges are set up in such a way as to measure the actual rate of leakage, should you desire that information. But if you have used the throttle valve, you will get an inaccurate reading as to the size of the leak — you will just find out where the leak is located. Like the gas leak detector mentioned earlier, sniffing for the leak is also possible. The object is pressurized with helium, and a sniffer probe is attached to the leak detector using a flexible rubber vacuum hose. When the sniffer is passed over a leak, the outflowing helium enters the system by the sniffer and is detected by the mass spectrometer. Pressure testing is useful, however, it's sensitivity is less than that of vacuum testing since the sniffer admits some surrounding air which dilutes the helium tracer gas. This method just shows you where the leak is — you can't use the gauge to see how big it is. Pressure-vacuum testing is also a good way to test for leaks; however, you don't know where the leak is located or how big it is — you just know whether the tested object leaks or not. The object is filled with helium, and

placed in a chamber evacuated by the leak detector. You then watch the gauge for any signs of helium being present. Since the object being tested is surrounded by vacuum, no dilution occurs, and maximum sensitivity results.

If the world were a perfect place, leaks in vacuum glassware would not exist. And no matter how hard we try, even the best of us make mistakes sometimes. But with the proper use of the proper leak detection method, those mistakes should be seen by no one but ourselves.

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Figure 1

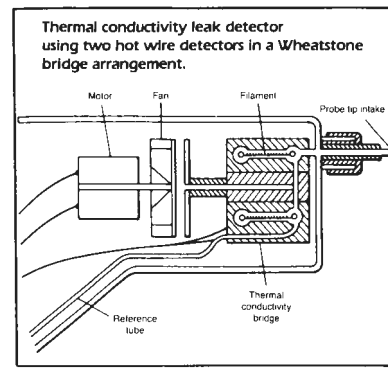

Figure 6

Gas	Chemical Formula	Molecular Weight, atomic mass units	Thermal Conductivity[b] BTU/hr (ft²)(°F/ft)	W/m K
Air	(Mixture)	29.9	0.01478	0.02557
Acetylene	C_2H_2	26	0.01128	0.01951
Ammonia	NH_3	17	0.01333	0.02306
Argon	A	39.9	0.01016	0.01758
Benzene	C_6H_6	78	0.00538	0.00931
Butane	C_4H_{10}	58	0.00822	0.01422
Carbon dioxide	CO_2	44	0.00873	0.01510
Carbon disulfide	CS_2	76	0.00410	0.0071
Carbon monoxide	CO	28	0.01360	0.02353
Ethane	C_2H_6	30	0.01102	0.01906
Ethylene	C_2H_4	28	0.01025	0.01773
Halogenated hydrocarbon F-11	CCl_3F	137.4	0.00470	0.00813
Halogenated hydrocarbon F-12	CCl_2F_2	120.9	0.00542	0.00938 0.00958
Halogenated hydrocarbon F-21	$CHCl_2F$	102.9	0.00554	0.01142
Halogenated hydrocarbon F-22	$CHClF_2$	86.5	0.00660	0.00758
Halogenated hydrocarbon F-113	$CClF\text{-}CCl_2F_2$	187.4	0.00438	0.01088
Halogenated hydrocarbon F-114	$CClF_2\text{-}CClF_2$	170.9	0.00629	0.15120
Helium	He	4	0.08740	0.18637
Hydrogen	H_2	2	0.10770	0.01332
Hydrogen sulfide	H_2S	34	0.00770	0.00934
Krypton	Kr	83.8	0.00540	0.03239
Methane	CH_4	16	0.01872	0.04602
Neon	Ne	20.2	0.02660	0.02041
Nitric oxide	NO	30	0.01180	0.02579
Nitrogen	N_2	28	0.01462	0.01600
Nitrous oxide	N_2O	44	0.00975	0.02578
Oxygen	O_2	32	0.01490	0.01600
Propane	C_3H_8	44	0.00925	0.02578
Sulfur dioxide	SO_2	64	0.00514	0.01600
Water vapor	H_2O	18	0.01087	0.01881
Xenon	Xe	131.3	0.03000	0.05190

Figure 8

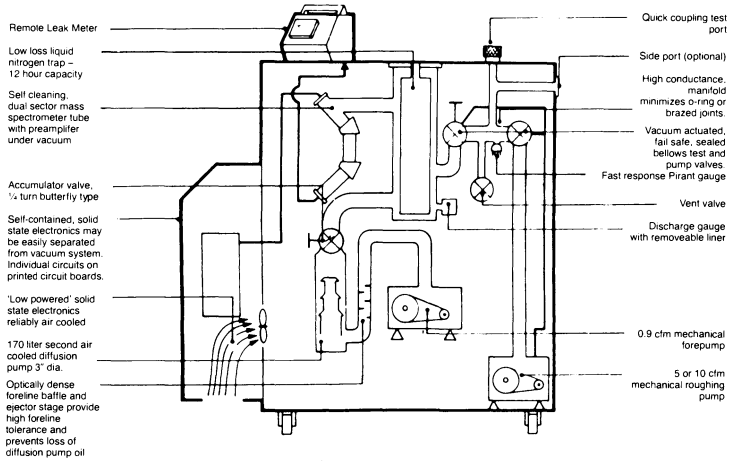

Figure 10

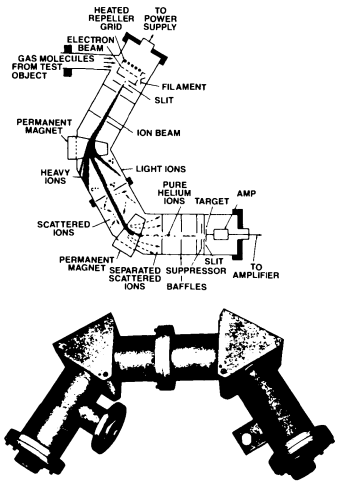

Figure 11

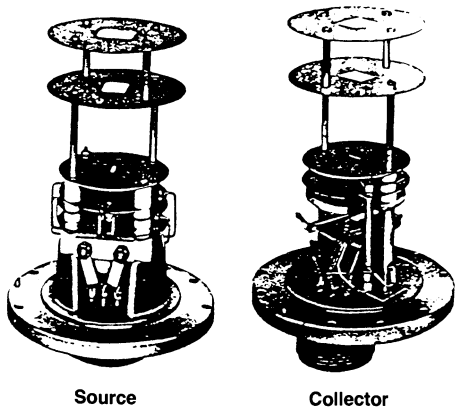

Figure 12

MASS SPECTROMETER LEAK TESTING METHODS

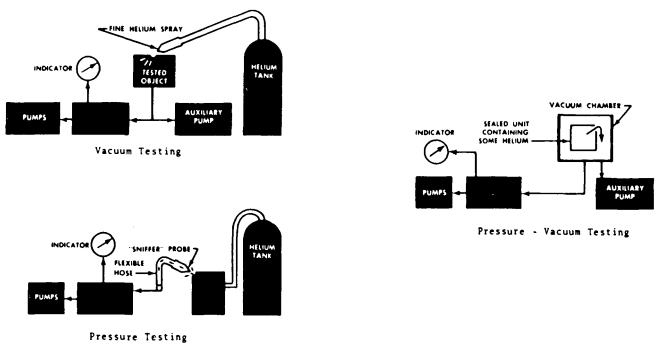

Figure 13

FABRICATION AND SEALING OF QUARTZ FLANGES

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Introduction

This paper deals with the fabrication and sealing of quartz flanges. We will try to show, step by step, how to create a flange from quartz plate and then a technique used to seal it to the required tubing. Although the use of flanges has diminished, it still has its advantages in certain applications such as: Reaction Kettles, Furnace Tubes, and Bell Jars.

The seal between two flanges or a flange and another flat surface can be accomplished in a number of ways. The most common means is the use of a rubber O-ring. The O-ring is placed between the flanges which are then held together by an appropriate sized clamp. Seals may also be obtained through the use of a rubber gasket, gaskets fabricated from RTV 630 or a similar silicone rubber compound and, in the case of flanges used on bell jars, a sealing wax which will produce a vacuum tight seal. In all cases it should be noted that the flange's sealing surface should be dirt-free, scratch-free and flat so a vacuum tight seal will be obtained.

Fabrication Equipment

The fabrication of a flange (fig. 1) is a simple process which requires minimal grinding experience and basic machine shop equipment. The flange is drilled and ground using a simple drill press, using drills machined from stock brass with 150 grit silica carbide powder as the grinding medium.

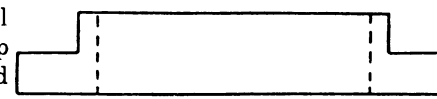

Figure 1

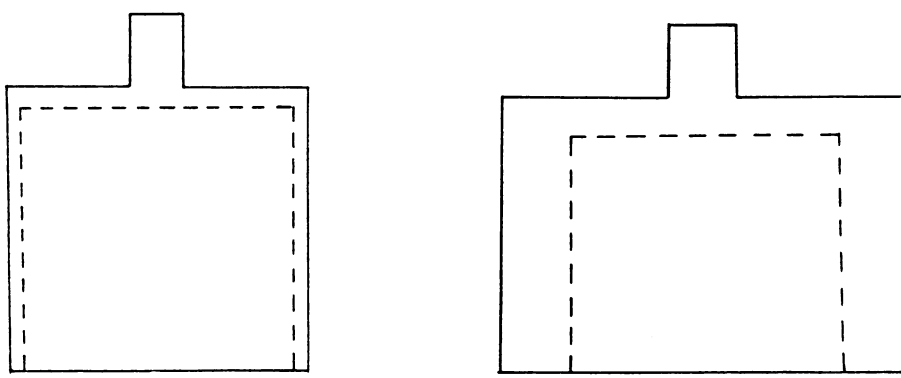

Figure 2

What is initially required are three brass drills (fig. 2), each one machined to a specific size to achieve the desired dimensions of the flange. It should be noted that the size of the drills should take into account an added 15 mil. loss of material due to the grinding process. The first two drills used will cut the glass stock to the desired I.D. and O.D. required of the flange. The wall thickness of these drills will be

approximately 1/16 inch. The inside depth of the drill must be deep enough to accommodate the thickness of stock plus the amount of wear. The drills are made with added depth (approximately 3 inches) so they can be used again, whether for fabrication of flanges, discs or other processes. The smaller of the two drills will be used to cut out the I.D. of the flange. The critical measurement of this drill will be its O.D. and it should measure 15 mils. less than the required I.D. of the flange. The larger of these drills will be used to cut the O.D. of the flange. Its critical measurement will be its I.D. and it should measure 15 mils. greater than the required O.D. of the flange. The third and last drill required will be used to grind away the excess glass, thus leaving the desired size tubing wall coming off the base of the flange. Its I.D. should be 15 mils. greater than the O.D. measurement of the piece of glass that the flange will eventually be sealed to. The O.D. of the third drill should be slightly larger than the required base of the flange. The depth of this drill will carry the same perimeters of the other two drills.

The remaining materials and equipment are basic and, if not, a stock glass shop item that may easily be acquired. What is needed is glass stock of either quartz or pyrex. This stock should be at least 1/2 inch thick so the fabricated flange will have enough depth and, therefore, enough strength. Standard plate glass can be used as backing for the stock that is to be drilled. This plate should be large enough to hold the stock plus have room to be clamped down. This backing plate should be at least 1/4 inch thick for strength and drill-through clearance. The stock is held to the backing plate be means of wax, which is melted between two pieces of glass. The two pieces are pressed together and the wax is allowed to harden. The set-up is clamped in a standard manual drill press (fig. 3) and then drilled to the desired dimensions of the flange, using the previously mentioned brass drills and a slurry of 150 grit silica carbide powder as the grinding medium.

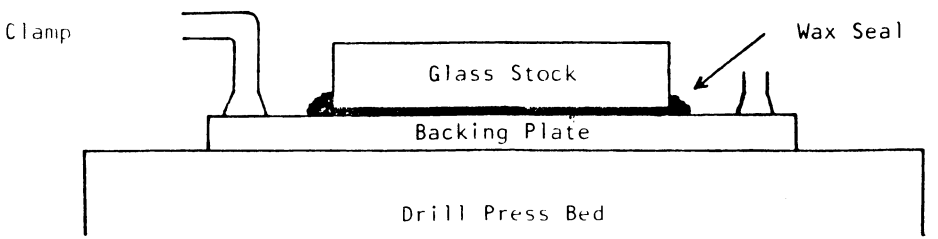

Figure 3

Fabrication Procedures

The process by which a flange is fabricated follows a simple step-by-step procedure. With the proper equipment and material, the process should take approximately three to four hours to complete.

The first step in the fabrication procedure is the set-up of materials. The stock glass is attached to a backing plate by means of red jewelers wax or a similar wax. The wax is dripped onto the backing plate by holding it in the gas flame of a torch. The stock is then placed on top of the backing plate and wax. The material is placed in an oven and then heated just long enough for the wax to flow evenly. The material is removed and pressed together to remove air pockets and obtain an even distribu-

tion of wax under the entire surface of stock. When the wax sets up, the material can be centered on the bed of the drill press and firmly clamped down (fig. 3).

The second step in the process is the drilling of the stock. The drill speed should be set to approximately 800 rpm. The first two drilling operations will be performed with the type 1 drills. It makes no difference whether the O.D. or I.D. of the flange is drilled first. With the drill in place, a well made of Apiezon Q Sealing Compound (or any formable putty) is made slightly larger than the O.D. of the drill. The well will be used to contain the silica carbide slurry. A sufficient amount of slurry, made of 150 grit silica carbide powder and Doo All Water Soluble Coolant or water, is placed inside the well. With the drill press on, the drill is manually lowered to the surface of the glass stock. A repetitive up and down motion allows fresh slurry to come between the drill and surface of glass stock. Fresh slurry can be added as needed. As the drilling process proceeds, the depth the drill has penetrated the surface should be noted. The drill should go down the thickness of the stock plus 1/8 inch. This will assure that a straight wall is formed. As a check to make sure the drill is through the stock, you can look through the edge of the backing plate to see if the drill has penetrated through and into the backing plate. Both the O.D. and I.D. of the flange are drilled in this manner.

With the O.D. and I.D. of the flange drilled, the third drilling process, using the type 2 drill, will finish the process of fabricating a flange. Before the third drilling process takes place, the excess scrap stock should be removed from around the outside of the drilling area. This excess glass is removed by gently tapping a razor blade between the edge of the excess stock and the backing plate. This will lift off the excess stock. A new well is formed around the stock, filled with slurry and drilled using the same process as the other two drilling procedures. Glass is ground away to half the thickness of the original stock (fig 4). If possible, the drill should be faced off and the last 1/32 of an inch taken off so that a square and flat surface is obtained.

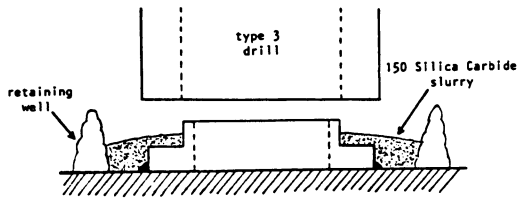

Figure 4

With the drilling process complete, the flange is then removed from the backing plate. The backing plate and flange are warmed in an oven until the wax is softened. Upon softening, the flange is removed from the backing plate. The flange is cleaned of wax using acetone as a cleaning solvent. Once cleaned of wax, the flange is ready to be used.

Sealing Procedure

As in most glassblowing operations, there are many different ways to perform any given task. The same holds true with the sealing of a flange to a given piece of apparatus. The major problem encountered in working a flange is that it is relatively short; it is, therefore, hard to hold and at the same time make air tight. We will describe a technique for sealing quartz flanges that will address both of these problems very successfully.

The first step in the sealing procedure is to support the quartz flange on a piece of quartz tubing. This set-up is supported in one chuck of a glassblowing lathe with the flange side away from the chuck. Placed in the opposite chuck is a short piece of quartz whose I.D. is slightly larger than the O.D. of the flange. A blow hose is

connected to this piece of quartz. The quartz tubing is placed just over the flange. The quartz is preheated, then softened just enough to press the tubing down on the inside edge of the flange (fig. 5). The flange support is removed and the flange is now supported by the outer tubing with a blow hose connected. The flange and tubing holder should be kept heated until final processing. With the flange and holder supported in one chuck, the apparatus the flange will be sealed to is supported in the second chuck. The seal can now be fused without worry of support or not being able to blow into the apparatus (fig. 6).

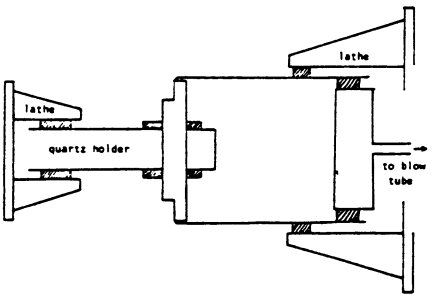

Figure 5

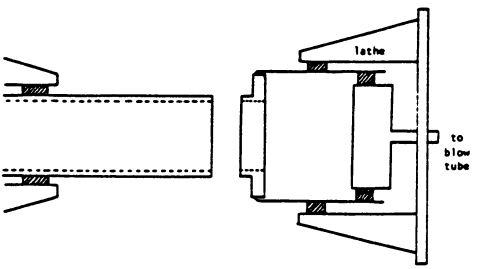

Figure 6

The final step in this process is the removal of the glass holder. If care was taken not to fuse the holder onto the flange, the tubing can be cut away close to the flange and ground off with a wet belt sander. The excess quartz will just fall off and final touch-up can be made with the belt sander.

Acknowledgments

The authors would like to thank Mr. Edward M. Ballard for his advice and cooperation in helping prepare this paper.

CONSTRUCTION OF A 90MM INFRARED SPECTROPHOTOMETER CELL THAT ALLOWS EASY MIRROR ALIGNMENT

Larry Harmon
Carnegie-Mellon University

I don't know about you, but when I am asked to do something different, I want to know what the scientist is working on. Many times by knowing what he is trying to accomplish, you can input design changes from the glassblower's prospective. Often this makes for a better design, easier to repair, and the bonus is you've learned something new.

The piece that I was asked to build was a reference cell body, for an Infrared Spectraphotometer, that sets on top of the smokestacks of electric power generation plants.

By the way, you may be interested to know that the typical pH of rain in the eastern United States is below 5 and sometimes as low as 4. This is caused by Sulfur Dioxide and Nitrous Oxides that exit these stacks. The Infrared Spectraphotometer is one method that is used to monitor these effluents.

The existing cell that I was asked to duplicate was a 90mm cell body, with a tooled ridge for supporting the mirrors and a sidearm for filling with the reference gasses. (see figure 1)

However, the design of the original cell made mirror alignment slow and tedious, sometimes taking several hours per cell because the slight curve on the mirror support ridge required repeated aligning and testing.

The cell design that I suggested, and ultimately made, was to seal borosilicate "rings" inside the 90mm tubing. (see figure 2)

To get the exact spacing and near perfect alignment required, I started with the machine shop. They turned a large piece of graphite to fit inside a 90mm tube, then faced off one end dead true. Inserting the glass tube in the tail stock, and the graphite mandrel in the head stock, I tilted my lathe to approximately 30 degrees above horizontal and slipped the ring in the tube to rest on the mandrel. (see figure 3)

I warmed the tube and ring using a gas/air annealing burner. When the tube was up to temperature, I removed the annealing burner and made the initial stick. Then I immediately lowered the lathe to horizontal and, speeding the lathe, sealed the ring inside the tube.

I found that by heating deeply enough into the tube and ring, just before deformation of the ring, the subsequent centrifugal force causes enough flow at the interface to overcome any reentrant angle problems.

It is important that you now immediately get the annealing burner back on the piece.

Tilt the lathe again and insert the second ring. Using accurate calipers, set the space between the rings.

Repeat the procedure of the first ring.

Using your blowhose for the first time, seal the fill tube onto the side of the 90mm tube. The graphite mandrel will act as a stopper. See figure 2 for placement of fill tube.

Remove the glass from the lathe and place into a preheated annealing oven.

When you remove the annealed cell from the oven, saw the excess tubing from the cell, bringing it to the final dimension. Again refer to figure 2.

The final step is to sandblast the mirror supports. This makes better bonding of the epoxy adhesive that holds the mirrors in place.

After the cells go back to the lab for mirror installation, they are returned to be evacuated to 10-5 Torr, prior to backfilling with; Sulfur Dioxide, Nitrous Oxide, Carbon Dioxide, and Carbon Monoxide.

Acknowledgements

I would like to thank the following for their help in preparing this paper:

Behm Quartz Industries, Dayton, Ohio — supplying rings for use during the photographing of the slides for this presentation.

Mellon Institute — Photography and Graphics Department

Mellon College of Science Machine Shop

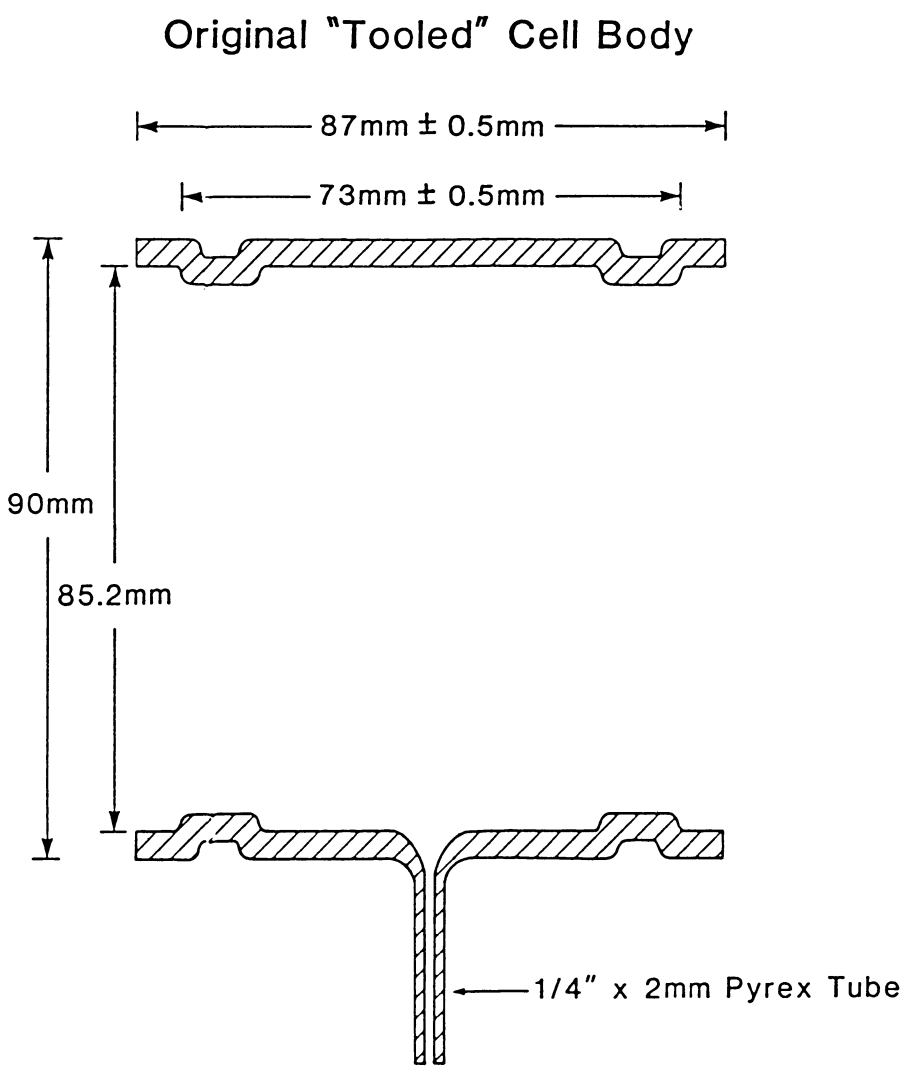

Figure 1

Improved Cell Body

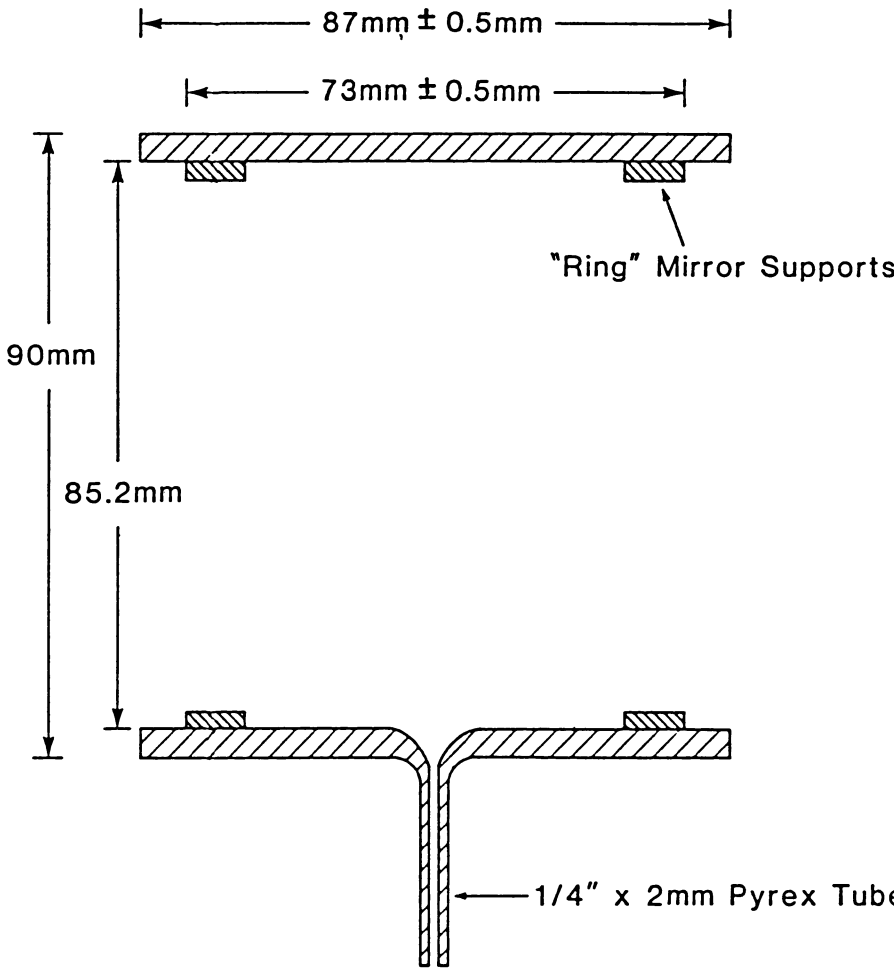

Figure 2

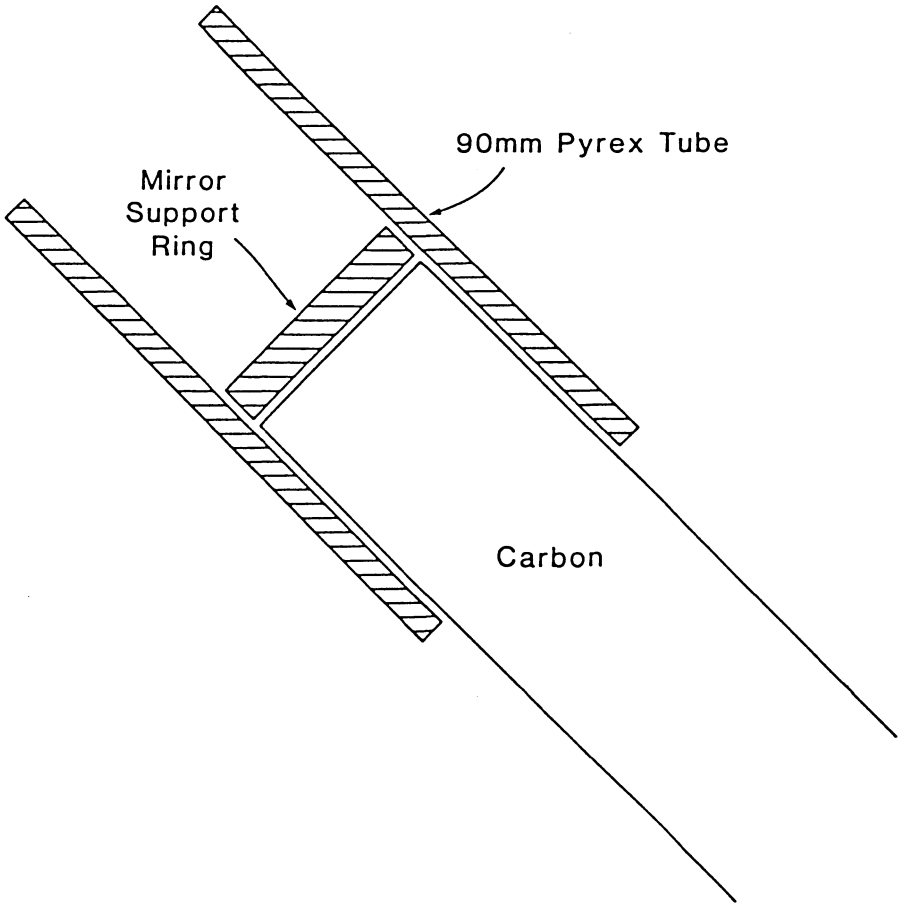

Figure 3

ADVENTURES WITH IONIZED GAS LIGHTING
David Grant Maul

Many sleepless nights went into accomplishing this project. My early interest in plasma globe construction was sparked by a conversation with Jimmy "Neon" Morris in Munich, Germany at the A.S.G.S. International Symposium in 1986. Six months later in the spring of 1987, Kim, my wife, Robert (then three months old), and I flew to the west coast to visit Jim Morris at his log cabin palace north of Seattle, Washington. At that time he gave me a short reprint of an article about the electronic power supply construction. I had hoped to see a globe while in Seattle but we couldn't locate one. I knew if I could see one I could build it. Back in Michigan, Randy Hansen, a co-worker and buddy, returned from a trip to California where he had seen some globes. He said we could do the glassblowing. Now I was getting closer to my goal of building a plasma globe.

Then there were long distant calls to my old high school buddy, Kim Heard, who grows computer chip crystals in a plasma environment. He described to me how plasma is the fourth state of matter. Enthusiastic Mark Ward, another friend of mine, showed me a set of plans he had obtained for the construction of a plasma lamp made from a five gallon water bottle. Then, after conferring with veteran neon artists Robert Hansen and Robert Maul about rare gases and pressures, all the parts of this detective story were now coming together .

Although it is not my intention to tell all there is to know about plasma globes, I will show how a skilled glassblower can build and fill a homemade globe. There are numerous expenses though. Like in anything you want to do, you always have to do something else first; like make equipment. You will need an annealing oven; vacuum pump; rare gases; a vacuum manifold; Tesla coil; diffusion pump (optional). A university glassblower could build one at his lab at less expense to himself.

Since I was originally trained as a neon sign glassblower, I approached filling this globe like filling a neon sign. In constructing the manifold, I used Ace #15 o-ring joints to attach the lead glass flasks of rare gas to my pyrex manifold. A system of double 2mm glass stopcocks was used to introduce the rare gas. A small mercury manometer was used to read vacuum and a homemade easy-read gauge to read rare gas pressure. The manifold should have a minimum of 15mm $I.D._1$ Some manifolds have been made with compression fittings and metal tubing for use with compressed gas cylinders. If you're doing large flasks and lots of them, this might be the way to go.

After you have your manifold system built and mounted on or near your annealing oven, it's time to build the plasma globe. At first I thought I needed a lathe to do this job but alas, I had an idea for a super flask holder. It cost about $9.00 to build. To avoid scratching the expensive flask, I used three rubber roller wheels set into a massive block of wood. I ordered the 12 liter flask from Chem Glass. After I marked and score popped the ring neck off the flask, I placed a damp Fibre Frax hear sink on the top shoulder of the flask. This kept the main body of the flask cool so I could roll it. The electrode assembly consists of 7/8" heavy wall tubing sealed inside some 2" and 3/4" O.D. tubing like a dewer or cold trap, then blown off, flame polished, and welded on neck of flask. Then I sealed the flask to the pumping manifold and annealed it at 565°C for 1/2 hour. When the oven cooled to 450°C, I turned on the vacuum pump and let it pump all night. This is where the sleepless nights come in. Make sure your vacuum pump and motor can make it through the night. After the pump down process is complete, the flask can be filled.

A small bunch of stainless steel wool, (Chore-Boy™), is inserted into the inner electrode tube. This is attached via a high voltage neon cable to the power supply or

Tesla coil. I used various combinations of argon, neon, zenon, and helium. You can try other types of inert gases to achieve different colors. This gets expensive. Much to my surprise, a chart in Wheeler's book on Scientific Glassblowing covers various types of gases and colors obtained when ionized.[2] The flask has to be under partial vacuum for the plasma globe to work.

If you don't want to go through the bake-out ritual, just anneal your clean flask and fill and evacuate with argon four times. This will purge or out-gas practically all contaminants, leaving only argon. Other trace amounts of gases can be added to achieve different colors and hues. With the flask hooked to the power supply, you can watch the different plasma arc movements while pumping down and refilling. The hard part here is to figure just where you want to stop and seal off. By varying the gas pressures and frequencies, you get a multitude of wild lightning bolts.

Igniting the globe is accomplished by a power supply that provides 10,000 volts alternating current at a 25,000 cycle per second frequency, this ionizes the gas. The flask behaves like a capacitor and is a low impedance path to a high frequency current to ground. The gas inside the flask acts as one plate of the capacitor, the glass flask acts like the insulating dialectric, and the outside air as the other plate.[3,4]

There is much more research to be done on the plasma state, including control of color and movements. Future uses could be flasks used to contain electronically generated holographic images; also globes hooked to 3-D image computers and more. Many artistic lighting creations in combination with other materials used as sculpture are envisioned. This is an ongoing adventure that is right up our avenue as Professional Scientific Glassblowers and Artists. If for nothing else, these globes make for a nice romantic night light. They are also a great conversation piece at your office or social gathering. Make one, it's fun.

References:

1. *Scientific and Industrial Glass Blowing and Laboratory Techniques*, by W. E. Barr and Victor J. Anhorn, pg. 243-47
2. *Scientific Glass Blowing*, by E.L. Wheeler, pg. 348
3. *Fiber Optic, Infra Red, and Laser Space-Age Projects*, by Robert E, Iannini.
4. *Radio Electronics Magazine*, March 1988

Slide 1

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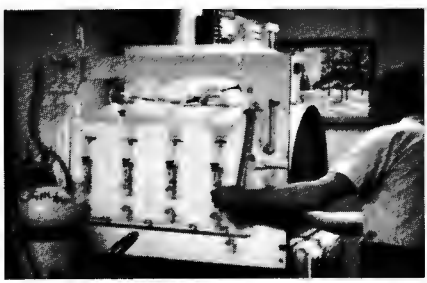

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INDEXING THE LITTON LATHE

Gordon A. Smith
Section of Engineering
Mayo Clinic — Rochester, MN

There are a number of items which I am called upon to construct which require stopping the glassblowing lathe at the same point after each operation. I felt these jobs could be better performed if somehow I was able to control the stopping point of my Litton EE lathe. After discussing this problem with one of Mayo's electronic technicians, we were eventually able to develop an inexpensive and fairly simple device which should work on most Litton lathes.

Figure 1

Since I work for a medical institution, each year I must construct a variety of tissue baths in large quantities. Several types of these baths require two 1/2" o.d. x 1-1/4" long support rods attached to the jacket of the bath. (Figures 1,2, and 3)

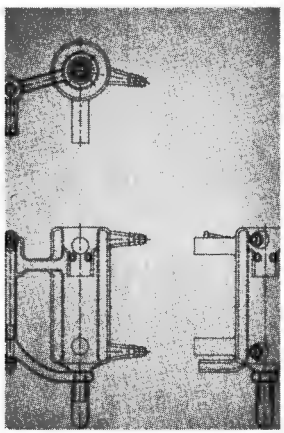

Figure 2

Figure 3

The support rods must be exactly 3" apart and square with the bath. The baths are mounted in a special fixture, which will allow the medical researchers to lower the bath's protruding lower 13mm o.d. tube into a 14mm i.d. hole in a parabolic mirror for a fluorescent study. In order to seal the rods on to the cylinder jacket, I had our machine shop build two special fixtures.

The first fixture holds the jacket cylinder of the bath at a right angle to the 1/2" rod which is then attached to the jacket cylinder. (Figure 4)

Since I make this seal using a graphite rod, it is quite convenient to have the lathe stop with the jacket cylinder in the vertical position. (Figure 5)

Figure 4

Figure 5

I usually make eight or more of these baths at a time. After the first rods are sealed on to the jacket cylinders, the cylinders are annealed. The first rod is now squarely in place.

The second fixture which I had constructed uses the first rod for reference. (Figure 6) The second rod can now be sealed on to the jacket cylinder both parallel and square to the first rod.

Figure 6

Figure 7

This procedure is just one example of the many ways in which I have found this indexing modification to be useful.

In order to make this modification, it was necessary to install a foot switch in parallel with the existing hand switch, which is standard on the Litton lathe. (Figure 7) Either switch can be used. The foot switch replaces the "ON" switch in the circuitry. It (the foot switch) turns on relay MS1 which turns on the armature motor which, in turn, drives the lathe. S2 is the "ON" switch. When S2 is in the center position (off position), the field winding in the motor is activated. The Litton two position switch was probably designed to give the motor both direction and a smooth start. Since both switches are in parallel, they will both perform the same function. Once either of the switches is activated, power is provided to a transformer which, in turn, provides power to an optical interrupter which activates a solid state relay. (Figure 8)

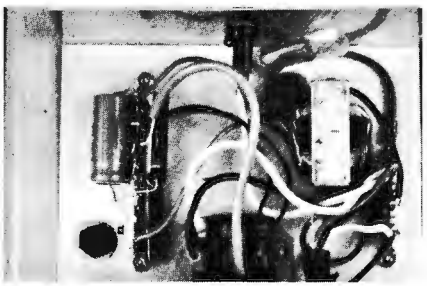

Figure 8

Figure 9

The solid state relay then parallels both S2 (the on switch) and the foot switch. When the foot switch is deactivated, the power to the motor is directed through the solid state relay until the optical interrupter is interrupted. All power is then turned off to the motor, which causes the lathe to stop at the index point. (Figure 9)

The optical interrupter was installed on a bracket which uses the existing mounting holes on the head stock housing. The optical breaker is attached to a 1/4" stand off which is inserted into one of the holes in the spindle nut. We have included a mode switch and red LED which will indicate if the lathe is in standard or indexing mode. All modifications and mountings were done without drilling any holes in the lathe castings.

Conclusion

I have been using this device for about five months and the best way I can describe it is that it is like a microwave oven or garage door opener. Once you have used it, you will find it difficult to be without it. I have not gone into any detail whatsoever regarding the electronic design of this device. However, I have copies of the parts list and schematic for anyone who is interested. (Figure 10)

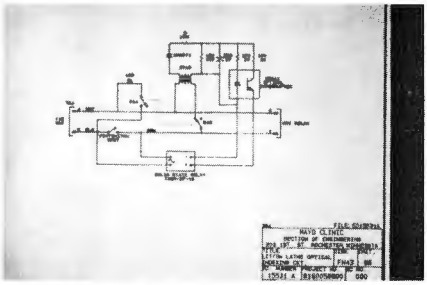

Figure 10

Reference

Litton — registered trade mark of Litton Engineering Laboratories.

Acknowledgement

I would like to thank Don Olson of Mayo Clinic, Section of Engineering, for all of his help on this project.

Parts List for Lathe Indexing Modification

(most parts are in Newark catalog #110)

1	Magnetek Triad Transformer tyupe F-16X	$12.17
1	Off On Toggle Switch	(approx) 3.00
1	LED Light	(approx) 3.00
1	Linemaster #632 Clipper Foot Switch	29.00
1	Guardian Solid State Relay TSSR-2F-10	29.83
1	Diode 1 N 2071	(approx) 2.00
1	Optical interrupter H2 1A1	(approx) 4.00
1	5 ohm 10w resister	(approx) 1.00
1	100 ohm 10w resister	(approx) 1.00
2	100 olh 1w resisters	(approx $1.00 ea) 2.00
1	500 UF (Microfaroid) capacitor	(approx) 3.00
1	Bud Box	(approx) 7.00
	Approximate total:	$98.00

INTRODUCTORY SCIENTIFIC GLASSBLOWING COURSE AT SOUTHWEST STATE UNIVERSITY

Edward Carberry, Professor of Chemistry
Southwest State University
Marshall, Minnesota 56258

In the mid 1970's, a few students approached me about the possibility of teaching them some glassblowing. These were chemistry students, and I was both delighted and challenged by their request. I had learned a little about glassblowing from Joe Wheeler at the University of Wisconsin in Madison during my days as a graduate student. But I didn't know all that much about glassblowing, so I was forced to do a lot of learning in a very short period of time. Fortunately, I knew about E. L. Wheeler's book. Eventually, we did set up a three-station lab area in one corner of the physical chemistry laboratory. I developed some instruction sheets which I mimeographed out for my students, and all things considered, everything really went pretty well.

This was a period of building at Southwest State University, a new institution, opening its doors to its first students in 1967. The temporary greenhouse rooms across the hall from the physical chem lab were left vacant as the biologists moved into their permanent facility. I was close behind, noting that the long narrow room with high ceiling and skylights sure looked like a great place to establish a permanent glassblowing facility. The head of the Division of Science and Math was impressed with my interest in glass and gave me the go-ahead. We built a five station laboratory and scraped up enough money to buy a small annealing oven and a wet cutting saw. I filled out hoards of papers, did a lot of fast talking, and soon glassblowing became an approved course at SSU. By this time, non-chemistry students had heard of our adventure, and they persuaded me to develop a "general" or "artistic" glass course as well. Thus, I took time to learn as much as I could about artistic glassworking, and eventually, I designed some teaching materials for this new class. Along the way I talked to as many glassblowers as possible (including Gordon Smith and others in the three state region). Also, about this time, I noted that the room adjoining our five station lab remained unused, and I needed more space. After taking care of the necessary campus politics, the room was mine, and it became a thirteen station addition to the glass lab (Picture 1).

Picture 1: Part of the SSU Glassblowing Laboratory

I'm not sure that I ever expected to use all eighteen stations at once, but eventually I did. As the course progressed, I managed to develop methods to teach large classes the rudiments of general glassblowing. Anyhow, I found out that it could be done, and I found that the results were surprisingly good.

By this time, the mimeographed notes became a book, and Mr. John Carruthers (then a distributor of glassblowing supplies) convinced me to take a chance and distribute the book nationally. Today (twelve years,

Picture
NOT
AVAILABLE
by Dr. Carberry

Picture 2: *The Second Edition of Glassblowing: An Introduction to Artistic and Scientific Flameworking*

six printings and two editions later) the book is still widely and favorably received (Picture 2). This was reviewed in the May, 1989 issue of *Fusion*."

The philosophy of both of my courses, and thus also of my book, was to expose as many people as possible to glassblowing. Chemistry students would obviously find the scientific glassblowing course useful. It is of some immediate satisfaction for them to find that they can repair that piece of glassware they broke in lab last week or to construct that piece of equipment they need for their research but which is missing from the stockroom. These are the obvious payoffs for taking such a course. But, in my opinion, there are a number of other less obvious benefits. I think it is important for these chemistry students to learn to recognize which things can be repaired and which things cannot. Also, it is just as important to appreciate what would have to be done to make or repair a complicated piece of glassware, even if they lacked the skills to do the work themselves. Perhaps the greatest benefit of the scientic glassblowing course has been to train some of our future scientists to communicate more effectively with the professional glassblowers and to learn to appreciate their point of view. From personal experience, I have seen that people without any background in glass work sometimes come to expect impossible operations from glassblowers. At least those with some training will recognize that the "impossible" jobs should always be scheduled well in advance of when the glassware is needed! The point is that there are many good things which come from such a course, even to those who will never light a torch again, once they leave our campus.

Just a few words along the same lines about our "general" or "artistic" glassblowing course. I have been convinced for some time that glass is a very exciting substance. There is really nothing else quite like it. I wanted to let as many students as possible discover this for themselves. Numerous students learn to work with pottery or wood or metal, yet hardly anyone was given a chance to learn to work with glass. In some small way, I wanted to begin to change this.

It's no secret, nor is it a surprise, that the greatest number of my students turned out to be these general glassblowing students, not scientific students. In the seven years I have been able to offer glassblowing courses on our campus, 80% of the students (an average of 31 each year) have enrolled in general glassblowing. (This was over a period of eleven years, as in some years my duties and responsibilities prevented me from offering either course.) Twenty percent (an average of 7 each year) have enrolled in scientific glassblowing. You will note that while I do not reach a tremendous number of students each year, the number is nonetheless significant. If I had the time to offer the courses more often, I am sure that I could double the yearly enrollments without any trouble whatsoever. This isn't bad considering that the total enrollment at our university is only about 2600. I should also mention that I have taught a wide range of ages of students (high school to retired) in my classes. To the best of my knowledge, none of my scientific students have gone on to become professional glassblowers, although a few have considered it. But keep in mind that most of these students were already rather committed, being junior or senior chemistry majors, when they enrolled in the course. Thus, it is obvious that my class serves an entirely different purpose than do those more thorough courses offered at schools such as Salem Community College. In this paper, I will limit most of the rest of my remarks to my scientific classes.

The scientific glassblowing class at Southwest State University is a one quarter course, offered for two credits. The course involves approximately four hours of actual class and laboratory work each week. Each student is furnished with his own torch and a full set of tools, and each student is given a locker in which to keep his tools and his work. A list of the items included in each set of tools is given below:

National hand torch with metal stand

#2 OX, #3 OX and #5 OX tips for torch

Didymium glasses (either regular or clip-on)

Glass knife

Forceps (insulated, seven inch)

Carbon rod (1/4 inch diameter, six inches long)

Needle nose pliers (five inch size, insulated handles)

Blow-pipe assemblies with swivel (two furnished)

Rubber septa with hole (for blow-pipe insertion)

Graphite plate

Matches or flint tip burner lighter

Wooden box for tools and items to be graded

Locker Key

Because glassblowing is a rather expensive course and not a chemistry course in the usual sense, a $15 lab fee is charged to cover some of the costs of the supplies used. In addition, a $5 breakage deposit is held until after the final class period. Each student is also required to purchase his own textbook.

Picture 3: Class Demonstration by Dr. Carberry

Usually the first hour of class each week is highly structured and well planned and is devoted to a brief lecture and lots of actual glassblowing demonstrations (Picture 3).

The second hour is usually devoted to close supervision of each student as he or she attempts the new techniques and the assigned exercises (Picture 4).

Picture 4: Students Working on Class Exercise

The third and fourth hours are normally scheduled on another day and provide for more individual practice by the student. Usually the students choose to work more than four hours each week in an attempt to become even more proficient (Picture 5).

On each day of class, a reading as well as a lab exercise is assigned for the next class meeting. Students are required to familiarize themselves thoroughly with each exercise before attempting it in class. Practice pieces from the exercises are handed in when completed. Each student is provided with a second small wooden box in which the completed pieces are placed, along with an evaluation card.

Picture 5: A Summer Workshop for High School Chemistry Teachers

I then evaluate and grade the work, noting the grade on the card along with some con-

structive comments. Some exercises are graded "check-plus", "check" or "check-minus" whereas the more involved ones are graded "A-F". At the next class, I make it a point to make individual comments to each student about his work.

This method of teaching has allowed me (after some experience) to supervise a surprisingly large number of students. There is no doubt that smaller classes may be better, but I have had scientific classes as large as 14 and as small as 3. Seven seems to be an ideal number for these scientific classes, as this is small enough to be manageable and yet large enough so that the students have a good opportunity to learn from watching one another. In my opinion, this is an important aspect of their learning.

Final class grades are "A-F". We do allow students to keep any completed item as long as it has been checked for safety, but we require that each student leave at least one finished item representing his best work, for our display case in the hallway outside the lab.

A typical outline for our scientific glassblowing course is given below:

Class #1	Introduction to the course
	Tour of glass lab
	Operation of hand torch
	Check out of tools
Class #2	Cutting techniques
	Fire polishing
	Rotation of the glass
	Joining rod
	Flame cuts
	Initial demonstration of joining tubing (butt seals)
Class #3	Review of tubing butt seals
	Initial demonstration of T-seals
	Discuss repairing cracks
	Operation of polariscope and annealing oven
Class #4	Review T-seals
	Initial demonstration of round-bottoms
Class #5	Review round-bottoms
	Initial demonstration of through-seals
	Short quiz on borosilicate glass and glassblowing terms
Class #6	Review through-seals
	Initial demonstration of vacuum trap construction
	Short lecture on scientific glassware, standard tapered joints, stopcocks
	Discussion on the use of catalogs, other books and *Fusion* as reference materials
Class #7	Review vacuum trap construction
	Initial demonstration of condenser construction

Class #8	Review condenser construction
	Demonstrate constrictions, rims, hose connectors, flares, and use of wet saw
Class #9	Analysis of complex scientific glassware
	Repair of glassware
	Making bends in tubing
Class #10	Review of various difficult techniques
	Analysis of other laboratory glassware
	Discussion of various glassware repair techniques
	Analysis of glassware in need of repairs
Class #11	Final Examination:
	Simple questions about borosilicate glass
	Construct a vacuum trap
	Analyze a piece of scientific glassware listing probable construction steps
	Check in tools.

In years when I have had especially talented students, I sometimes direct the last third of the course to the design and construction of some one more complex piece of scientific glassware of the student's choosing. Conceivably, this could take up most of the time in one quarter, especially if all of the steps I would like to see done are required. In a couple of cases, I have reserved this work for a second course. Generally, I feel that such projects should not be assigned in an ordinary beginning class. But, if one does choose to do so, it is important to go out of your way to select projects which are not overly difficult. Each should be chosen carefully so as to fit the ability of the individual student. There should always be a very high probability that the student will, indeed, be able to complete the project successfully (Picture 6).

Picture 6: Student Completing his Lab Project

By and large, I am very pleased with this course and also the general glassblowing course we offer at SSU. Each year, I learn a great deal about glassblowing, and each year I want to share the things I have learned with others. I am convinced that there is, indeed, a place for these courses, and in fact, I hope to see more and more similar courses offered at other universities. It is my belief that the major purpose of these courses is not so much to train glassblowers, as it is to give our science students an "extra edge" and to give all students from all areas a feel for the utility and the excitement and the beauty of glass.

NATURALLY OCCURRING GLASSES

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The glasses found in nature generally fall into two broad classifications regarding their origin. These are liquid-state and solid-state transformation glasses. The most common is liquid-state transformation, which results in a 'normal' glass. Normal glasses are formed by natural processes corresponding to the conventional hot-melt technology used by man to compound 'artificial' glasses. As a result of heating a crystalline material to above its solid-liquid phase transition temperature the material melts, and by rapid cooling the recrystallization of the originally crystalline parent material is avoided and the result is an amorphous superviscous liquid: glass. Typical examples of naturally occurring normal glasses include the volcanic glasses obsidian and pumice. A more unusual example is fulgurite, which results when lightning strikes the earth. Fulgurites can be very extensive and delicate, composed of numerous tiny, hollow branches. They are very glassy on their inner surfaces and have unfused sand adhering to their outer surfaces.

Less common among the natural glasses are those which result from the solid-state transformation of an initially crystalline parent material by means of intense physical shock. The regularly ordered chemical bonds of a crystal are broken by the shock and then rapidly reform into a random network. Although the outlines of the crystal boundaries of the originally crystalline parent material may remain, the resultant material is amorphous. Note that this process is instantaneous and does not require the external application of heat. Ultramylonite and pitchstone are solid-state glasses which were transformed deep in the earth by seismic shock waves originating from tectonic movements (earthquakes).

A relatively insignificant classification of terrestrial glasses comprises those formed by vapor-phase transformation whereby parent material is vaporized and then condenses upon a cooler substrate to deposit a glass. Such a process may be responsible for the highly glassy coating on the inner surface of fulgurite. Artificial (man-made) vapor-phase glasses include those resulting from the chemical vapor deposition (CVD) process used to fabricate fiber optic cables, and the fusion of the earth's crust resulting from nuclear explosions. Trinitite is the fusion crust which can be collected at the site of the Trinity experiment near Alamogordo, New Mexico.

All of the glasses discussed thus far have resulted from geophysical forces; the terestrial 'glory hole'. The generative forces of all the glasses to follow are either extraterrestrial or entirely unknown.

Virtually all stony meteorites evidence a thin and brittle, vitreous fusion crust. Fusion crust is found intact only on freshly gathered or well preserved meteorites. The fusion crust results from frictional heating of the outer surface of the meteorite during its fall through the atmosphere.

Upon impact, a large nickel-iron meteorite will create an immense shock wave radiating through the crust from the impact point, and will launch surface material (ejecta) in the process of cratering. The shock wave can create solid-phase transformed glass such as the shock-metamorphosed sandstone found at the Canyon Diablo site (the great 'Meteor Crater') in Arizona. Largely resembling the surrounding surface material, the shock-metamorphosed sandstone still retains the granular appearance of sandstone, yet it is a glass. The ejecta from cratering can be both shock-metamorphosed and then heated by friction within the atmosphere when launched from the crater.

The majority of meteorites have come from the asteroid belt located between Mars and Jupiter. This material is most likely the remains of a planet which was crushed by impact. The orbits of asteroid belt material are extremely unusual, bringing some asteroids into the region of the inner planets (including the Earth). The gravitational pull of Jupiter undoubtedly plays a major role in this.

Meteorites have engaged the imaginations of mankind in all cultures for millennia. Meteorites and their associated debris have been considered as objects worthy of worship or destroyed as feared omens of ill will. Perhaps the most widely revered is the holy black stone located in the most sacred Moslem mosque, Kaaba in Mecca, Saudi Arabia. The ancient worship of this black stone predates modern Islam.

> "Today that stone if the most sacred jewel of Islam. Toward it each devout Moslem is bidden to look five times a day as he prays. It is called the Right Hand of God on Earth. It is reputed to have been a stone of Paradise, to have dropped from heaven together with Adam. It was originally transparent hyacinth, but became black by reason of being kissed by a sinner. In the day of judgment it will witness in favor of all who have touched it with sincere hearts, and will be endowed with sight and speech." (Newton, 1897)

In addition to these amazing properties, the Kaaba is also reputed to be able to float in water.

> "The black stone is not a single stone, but is today apparently composed of eight minor pieces of varying sizes made of the same rock. The pieces are cemented together and surrounded by a silver frame, which leaves an area of 20 x 16cm exposed. The largest piece is said to be the size of a date." (Thomsen, 1980)

What is it?

> "In Saudi Arabia, approximately 1100 km from Mecca, meteorite craters were found." (ibid)

This place is called Wabar, and there can be found an impactite glass called Wabar glass which matches the physical description of the black stone of Kaaba. The numerous bubbles and hollow spots incorporated into Wabar glass do, in fact, allow some pieces of it to float in water. Fission track dating assigns an age of from 3900 to 8900 years, which is within a period of known habitation of the area, and is consistent with its having been observed as coming from 'heaven' (note that although the meteorite fell to earth, the glass did not).

There are some unusual meteorites whose origins have been deduced by mass spectrographic analysis. A few meteorites appear to be impact ejecta from the surface of Mars. Another eight appear to have similarly been launched to the earth from the moon. The asserted origins of these particular stones are consistent with the analysis of lunar material from the Apollo missions, and from data returned from Mars by the Viking lander. Similar to other stony meteorites, these stones have glassy fusion crusts.

Some other glasses found on earth are of unknown origin. Tektites are small objects composed entirely of glass which are found in several distinct 'strewn fields' covering thousands of square kilometers. They range in shape from spherical, to lenticular, to long and thin strips. Their colors vary from nearly clear to brownish-green to coal black. Most have pitted, weathered surfaces, and all have shapes and features indicating aerodynamic ablation. They have been proposed to originate from lunar volcanoes or as ejecta from lunar meteorite impacts, but recently a terrrestrial

origin has been confirmed due to similarities of their chemical composition to terrestrial materials.

One final glass of unknown origin is Libyan Desert Glass (LDG), which is found in western Egypt. LDG is a 98% silica glass which is chemically similar to the Nubia sandstone underlying the nearly 6500 square kilometer region where it is found. It ranges in color from transparent to pale yellow and golden-orange to greenish-brown. Depending upon the inclusion of bubbles, it may have an opaque milky appearance. The surfaces of pieces are typically pitted and frosted due to weathering and sand-blasting. Fission-track dating assigns an age of approximately 28.5 million years since its formation. At present there is estimated to be 1.4 million kilograms of LDG remaining from an original mass of 14 billion kilograms, the difference being accounted for by erosional processes. No fragment of LDG has ever been examined which evidences a transition zone with the parent material. Two meteorite craters have been found 150 km west of the glass site, but no LDG is found adjacent to the craters, and no explanation has been presented to explain the transport of the LDG to its present site. Additionally, a small iron meteorite was found within the southern end of the glass site in 1979, however it is considered a very recent fall, for its intact fusion crust would have weathered away in a few hundred years. Considering the thickness (in excess of 10cm), range, and high silica content (therefore high fusion temperature), the origin of LDG is truly one of the great mysteries of the world.

The naturally occurring glasses provide a surprising variety of materials from unexpected sources. It would indeed be a shame if the glassmaking talents of nature were ignored by man. In particular, the solid-state transformed glasses may be a hitherto unrecognized means of achieving vitreous materials on a low energy budget.

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THE EXHIBITS: KEYSTONE OF THE ASGS FORUM

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The Exhibits: Keystone of the ASGS Forum?

Why may The Exhibits be viewed as a keystone opportunity?

How may they be utilized to optimum advantage by all?

This paper is preliminary to the report on the survey-based attempt to discern and foster the effectiveness of THE EXHIBITS PROGRAM OF THE ASGS in fulfilling the Society objectives of equipping, educating, strengthening the scientific glassblowing community. Statistically and through recounted experiences and opinions of our membership, that report will reflect the circumstances, aims and recommendations of glassblowers, of their families, and of our exhibitors whose efforts make available for us the wealth of opportunity provided through The Exhibits. The following reflects survey responses to date and an editorialized account of historic and contemporary background of the event and its participants.

> "In general, I disagree with your premise that the exhibits are the keystone of the ASGS forum. In planning our meetings, very careful attention is paid to providing our members education and information on technique and innovation in the art of glassblowing. While the exhibits do give glassblowers the opportunity to receive information on the latest equipment available, the technical program is where we learn glassblowing. Attendance at the seminars, papers, workshop demos and posters is very important to the glassblower's employer who expects this event to improve his/her skill.
>
> . . . while I view the exhibits as a VERY important portion of our meetings, I also view them as secondary to the technical program. Hence the title, Symposium and Exposition.
>
> . . . I hope this is of some value . . ."

Having asked each of you to speak your mind in evaluation of our Exhibits Program proffering your observations and suggestions alike, I had hoped you would do just that, speak your mind. Nevertheless, I had been both startled and delighted at what I found in this short letter. While response to our survey in general has been particularly challenging and thought provoking as well as informative, this one especially has given me cause for pause, requiring my double checking definitions of terms as well as recognizing and evaluating my own perspective, my attitudes, observations and experiences.

This person had hesitated to send his view, concerned lest he offend my own. For nearly a quarter of a century my involvement within ASGS has always been oriented about the exhibits; my children have been nurtured in many ways by its provender, and, as they have matured and become more involved in its activity, my own participation has increased as well. Hence, it is quite apparent where my enthusiasm lies. For the sake of our survey and growth, join me in relief and appreciation for his expressing his view afterall, and, if you have as yet to mail your response by letter or questionnaire, be encouraged to be as frank in expressing your own opinions, concerns and recommendations, your support equally appreciated.

Yes, this declaration of viewpoint is of tremendous value, extending well beyond

point of agreement or disagreement. Each of us views the exhibits from our own unique perspectives, those oriented in our own needs and experiences, our perception of Society goals and how those objectives are being served by the exhibits. The exhibits program, as has been said of the symposium, is many different things to many people, according to our interests, ages, etc. Our evaluation of its significance will vary, too, depending upon whether our guidelines are education, economic, social, etc. Today, our thinking accordingly is oriented about educational objectives primarily.

The concept of the exhibits program, the exposition, as I see it, encompasses whatever explanatory audio and visual displays and demonstrations we implement as well as the traditional booth displays of our suppliers. For our delegates and exhibitors alike the vendor exhibition in our unique symposia has always been considerably more than merely a display and source of information focused on equipment, tools and material. Diverse interests and needs are fulfilled there for all attendees, our families and guests as well. While our children "have grown up under the eyes of the A.S.G.S." the Exhibits Program of the society, of the Symposium and of ASGS at large, has grown, developed, matured as well.

Most references to our annual program include the terms Symposium, Forum, Exposition. While specifically unique, by definition (see Webster's "New World Dictionary") they are related by that prime common element, ". . . the discussion and exchange of ideas." Supportive, informative, explanatory and technical exchange is paramount within and around the exhibits as in all other educational components of our symposium. Not in budget alone do our employers feel the considerable impact of the exhibits bounty upon the glassblower and skills he's developed through session attendance. A skilled craftsman is at a considerable advantage in his work, provided adequate and quality tools coupled with the knowledge of the most effective and safe approach to their utilization.

Whether it be in the facilitation of examination and comparison of available tools of the trade, the opportune and fruitful moment of the one-on-one discussion of related "hardware" problems or techniques, or in imminent follow-up resulting from discussion our exhibiting suppliers provide vital support to the glassblowers' production, "holding together" that which is learned in session and the application of that knowledge back home in the glass shop. I've used the term Keystone as I referred to The Exhibits. It is defined as "that one of a number of associated parts or things that supports or holds together the others; . . ". What is communicated and learned while perusing displays and in discussion between suppliers and attendees certainly accomplishes this.

The definition of keystone, however, goes one step more: —". . . main part or principle". Has our forum, the symposium, a main or principle portion? . . . that one upon which we all agree unanimously as THE MAIN ATTRACTION? To rank the elements of the ASGS Symposium one must envision the program without each element in turn, discerning what needs are left unserved in each omission. Considered as we do parts of the body, the exhibits may be no more and no less but equally valuable among the offerings in the program of the ASGS in its endeavor to educate, inform, equip, strengthen, and support the glassblowing community.

Many of us believe since its inception the exhibits have served those ends well, that it is being utilized more effectively as we become more aware of how to use its opportunity to our greatest advantage, and, however, that we have just begun to tap its boundless potential and, with vision, the entire program will supply the sundry needs of the glassblower even more comprehensively. It has been vision at work creating a diversified and balanced program whereby we now accomplish the

objectives of the ASGS. This balance, each part a complement and reinforcement of the remainder, is the strength of the ASGS program.

Back in 1955 at Corning, New York that first venture at a national symposium featured no exhibit such as we know it today. Our board recognized the opportunity an exhibition affords and the need for it in balancing and enriching its program; the subsequent gathering in downtown Philadelphia was provided with an exhibition by ten suppliers, some, themselves glassblowers. Ever since, an exhibition has been a vital part of symposium and section programs. That small group of exhibitors continue yet to be represented in our hall, at least one of them having attended every symposium. Last year, 1988, in Atlantic City 44 companies displayed in record proportions. In the recent decade we have seen approximately 65 different participating companies; a high percentage are regulars, many are locals or repeats as circumstances afford, and newcomers appear each year.

Those statistics are indicators of growth, but the true measure of growth is vested in the activities and the seen and unseen elements with which the exhibits have been imbued. Implicit in those statistics is the increase in the human resources with whom the glassblower has ready access. Our ranks in the exhibit hall include salesmen and company owners alike, their families continuing the representation into the second and possibly third generations. Numerous of them are skilled glassblowers and many are the designers and manufacturers of the equipment, tools and other items displayed; an impressive percentage of the personnel available in the booths of our hall have a solid working knowledge of the materials, tools and equipment available as well as conditions and circumstances under which glassblowers produce.

Our exhibitors are a wellspring of experience and knowledge, providing something for everyone. The glassblower plies the hall seeking and finding solutions and ideas, access to the variety of tools of the trade, often inspiration for innovations and modifications possibly applied to his present equipment and procedures in order to make his efforts more effective and his work easier. He "can compare and get questions answered" as is possible thru no other means. The while, families of attendees and exhibitors alike gain familiarity, understanding and appreciation for the work engaged in by their breadwinners, progress and plant security affording them little if any access to the modern workplace. (For more comprehensive discussion of this benefit refer to *Proceedings 1986*, the paper "Involving Family . . .").

Our children are prime benefactors of the opportunities afforded by the exhibits, a veritable buffet of scientific and occupational resources, materials and well-written and illustrated literature. For some it may well provide the inspiration leading them into glassblowing; but, whether or not they are destined to become active in the trade of their parent, exhibitor and glassblower alike, they glean knowledge, awareness and appreciation of limitless value for the present and the future. In addition, they exercise and develop social and communication skills through exposure herein where adult rules of conduct prevail.

Our exhibitors' benefits are none the less varied. Most mention their learning and their deriving awareness, inspiration and encouragement as well as ideas leading to improvement in specific products or additions in the product lines with which they provide us, an acquaintance with their clients as people and personalities and the establishment of a rapport, more effective communication and the increasing effectiveness of services rendered. Keeping their company name before their market and, of course, sales have been mentioned as both benefits and objectives as has been awareness of the competition and renewal of cooperation and personal acquaintances. It is important we note that in our exhibitors also are users of materials, tools, and equipment exhibited in the hall.

Exhibitors and attendees alike refer to the unique rapport prevailing in our entire group. The friendly, sociable nature and the supportive, encouraging and cooperative spirit is felt strongly by newcomers and established members alike. Even among competitors, camaraderie pervades all activities of the society, and whether or not one can avail himself of the social portions of our program, that welcome is appreciated. I refer to this as a benefit we hold in common, its being the binding tie upon which our success as a society hinges.

Accommodations within the exhibit hall have changed through the years. The scheduling of refreshment breaks, oriented around sessions and provided within the hall, affords opportunity for exhibits access to those persons whose sessions interests fill their day; it tends also to sustain the exhibitors whose circumstances have not afforded relief from hall responsibilities. Live demonstrations, which in earlier times had been within the exhibit hall itself, as scheduled events in the symposium program and as an illustrative approach by individual exhibitors, have been a "mixed bag" while fulfilling a wide range of objectives. Not only had the purveyor opportunity to demonstrate the potential of his products and the glassblower illuminate a particular technique for fellow glassblowers, but fellow exhibitors, our families and whoever else were attracted at the time gained awarenesses and appreciation vastly beyond enumeration here. Answers to our questions were profluent in their critical moment under those circumstances. Possibly, too, it had afforded a more clear and effective communication of the human resources available to us in our exhibitors.

Today the nature and orientation of live demonstrations has been tempered by a number of factors, among them fire and safety codes, hook-up expenses, labor considerations, available space, liability, etc. We've had to utilize differently advantageous accommodations and audio-visual aids. In adapting to the limitations set upon exhibitors and ASGS we have turned them to our advantage, expanding on the possibilities available to us for maintaining and promoting our objectives. Whether or not the new innovation in the program, Poster Sessions, may in part be attributed to this adaptive thinking, it is most advantageous; it has been received enthusiastically and promises to become even more effective. And today, with more and more of the technologically modern innovations in audio-visual aids available for use by the general public, the possibilities are boundless for our sharing and exhibiting, maintaining and perpetuating the skills we foster.

Literature, photos, posters, slides and videos are used in ever increasing effectiveness to demonstrate and preserve techniques, exhibit products and promote concepts, ideas. However, according to survey returns to date, in our exhibit hall, the actual items which can be held, examined, manipulated continue to be the greatest in importance. Attendees and exhibitors alike ranked these equally with the dialogue between exhibitor and attendee. (Interesting, there had been an absence of audio-visual equipment in use in the exhibit booths this year in Milwaukee.) The most impressive and effective means for illuminating a skill or a technique remains the live opportunity where dialogue and questioning are possible, today conducted apart from the main flow of traffic.

Those tempering factors have considerable impact on the exhibitors. Not only have they determined how he may present his products to the gathering, they make the exhibitors' efforts in general an interesting challenge, one often requiring a sense of humor. They determine what he chooses to exhibit and how he displays it, the measures with which he protects his products as well as the means by which he transports them to the symposium and handles them enroute to and from the booth. It is the details of this handling and the before and after activities "behind the exhibit door" of which most non-exhibitors and some exhibitors mentioned being more or less

unaware. A "cook's tour", a "bird's eye view", if you will.

At present, survey returns from among the exhibitors reflect that as many of them usually ship their entire display as personally have been transporting and handling their own in entirety. The greater bulk of exhibitors carry in only their most delicate or small and lightweight packages, sending the bulk of their exhibit by common carrier, including UPS, to be hauled into and out from the hall by the drayage firm or exhibit company. The determinant of this percentage most usually is distance, cost, and reputation of "the town".

Because the draymen are "general handlers", those with equipment requiring special handling, rather than risk loss and damage, elect the alternative headaches and hassles of customarily hauling and wrestling their own entirely. Even here there are limitations, rules which at times have required compromise, perhaps, at considerable additional charge, allowing those exhibitors only their presence during their product's passage about the premises. These are the men and women who are among the first to arrive. By the time the "second string" appears, those of us with large crates to unpack and we who only occasionally self-transport, they already have located the reasonable and convenient eateries, reconnoitered the hotel facilities, and plotted the best access routes and most efficient procedure for getting equipment unloaded and into the hall, sparing the rest of us many a problem.

More often than not "getting in" is no less than a formidable task. First worry is jockeying their trucks into position at the door minutes ahead of the exhibit company, or between its loads. Their timing slightly off, they risk at the least a long interminable wait, at perhaps the worst, intimidation and threat of slashed tires and other damages.

Rarely are there loading docks of standard useful elevation. Some of our men still chuckle about one of those rare times when the hotel did have a proper loading dock, but the route to the exhibit hall from there was circuitously involved. More often than not, getting heavier equipment in has required dragging and shoving crates and gear through the parking garages, hotel kitchens, and service corridors onto notoriously inadequate and poorly maintained freight elevators which, at their best, are scarcely designed for the weight or volume of trade show loads such as ours. At best they grunt and groan and jerk spasmodically, but more usually doors work too hastily or not at all, or the elevators simply break down, and at that repeatedly, some makes more notoriously than others; and some recover miraculously when "grease" is adequately applied to furtively outstretched palms, or possibly "more than meets the eye" in the delayed return of service, . . .

Occasionally service elevators have simply not been spacious enough to accommodate the dimensions of our pieces. In another hotel, while an elevator had been sufficient, the corridor between it and the exhibit hall had a kink in it, making off-loading some longer items impossible. At times such as this, if alternate access is not possible, the item never does reach the hall, a predicament not unusual in the trade show experience. While numerous of our larger suppliers display in two to four other shows annually, most of our exhibitors who have thus far responded to the survey cite ASGS as their primary if not their only showing. As our own exhibitors and committees have benefitted from experience, they've learned what to notice and what questions to ask, what detailed information must be received by the exhibitors well enough in advance for their planning their displays around accommodations, preventing many a hangup . . . until, in compliance with Murphy's Law, we discover a new wrinkle, or more!

While incoming boxes and bulky wooden crates of sundry dimensions and weight

are shuffled about the hotel, the decorating crew of the exhibit company saunter about screwing pipes and poles into bases, erecting the framework of the booths, draping the dividing curtains, stapling table-tops with paper covers and re-usable taffeta skirts. They've barely begun as, mid the cacophany and breath-robbing belches of diesel exhaust, draymen astride monstrous forklift trucks and exhibitors with their muscle-powered dollies heavy-laden, descend upon the hall like stage hands or circus roustabouts, clogging the aisles and every open space with their cargo. Our crews, usually the same folk who later man the booths, uncrate and attempt to render order to the chaos within their own booth, lending tools and a helping hand to fellow exhibitors, dodging crates and scurrying mates, the while making-way the draymen who ply those clogged passageways intent and unyielding as Pharoah's pyramid builders. Exhibits company vendors circulate, making one last pitch to "sell", at formidable rental fees, fixtures they install to light the dark corners and operate displays, and distributing the forms that spell release at the other end of the week.

This is a time requiring alert security. Hired security guards man the doors; symposium committee people circulate, lending a hand and additional eyes as they provide for the many needs and uncertainties of the operation; and our own crews exercise necessary precautions. Despite all this, occasionally tools, wares, and wallets walk, accidents have happened. Excitement, organized confusion and distraction fill the air as when the circus came to town or Brigadoon had waked for another day. Exhibitors busily make ready while helping out and enthusiastically greeting exhibits mates, new and old. Emptied crates are prepared for hauling to storage much as they'd been brought in and will again be returned in a few days for repacking and dispatching; a moment to visit and catch a breath before doing the sights of the town or a needed rest before the doors open for Hours . . .

In advance of Symposium, the exhibitor plans the contents and layout of his booth; he also plans how to "idiot proof" his goods for shipment; padding, fastening or "hanging loose" as materials warrant, packaging his goods lest the worst befall his boxes and crates. Usually our exhibits arrive intact; occasionally rough handling in shipment or mid the confusion before Hours takes its toll. Most of us plan our packing so that, upon the closing of the exhibit hall, that wait til our crates are returned can be used in padding and boxing our items for re-crating. The rush and pressure is different at this time, as often personally imposed as it is affected by schedules for subsequent use of the hall.

For a "gofor" such as I, this is a time of astonishment, having more opportunity to notice the handling of the packages left behind as the fleetest packers have departed. In general, so I'm told, the draymen are duly careful. However, there is always that one or two (and more) who in ignorance, immaturity, nonchalance, bullish playfulness, or simply rotten brutish meanness don't give a hoot about the well-being of the contents let alone the time, painstaking effort and considerable investment involved in building the equipment and producing the tools and materials packed inside.

Seeing a heavy wooden crateful rolled end-over-end across the floor, forklift tines dashed forthrightly at palletted precision machinery, cartons of fragile glassware shot-put onto a heap of like packages as one tosses a basketball through a net sets the heart of the relatively uninitiated in outraged anguish, but the veterans just shake their heads and finish packing. No sense letting it spoil the good feelings of another satisfying symposium. But back home, they too wait with baited breath til our crates arrive and they can check things over, repair the damage, pay the bills, hope for a return on their investment, and look forward to next year and its reunion once more with friends and associates and all that we hold special about symposium time.

The satisfactory symposium, "Good Show", is one that has been busy, well attended with both serious and friendly inquiring, questioning, and evaluating dialogue. That essentially justifies the investment of time, materials, risk and cash outlay. On top of hotel and travel expenses, the exhibitors' unique costs only begin with the common fee of approximately $600 per booth and add up from there accordingly. Any return on investment, if noticed as decidedly attributed to any particular symposium, may range from practically immediately to seven and more years. It will be interesting to discern those figures among other statistics and data pertaining to your expectations you provide through the survey for subsequent report.

I appreciate your support. Today I have attempted to convey in minutes what you have given me through years, an enthusiastic viewpoint of The Exhibits Program, a bit prejudiced, but hopefully an objective and comprehensive insight as well. I hope too that I have provided glimpse enough into the exhibitors' experience so that we all will derive that much more in benefit, appreciation, and enjoyment from the valuable opportunity provided through The Exhibits. We have not established The Exhibits as Keystone of The ASGS Forum, but rather we have discovered what is. That most important critical element holding together all aspects of the ASGS endeavor, derived from and pervading the communication functioning throughout, is Support. Support is the Keystone of the ASGS Forum.

There is still time for including your views, expressed through the questionnaire or by letter. A considerable portion of it, I believe, shall be of value to our committees, our exhibitors and to you as preparations are made for subsequent exhibits and symposia. Your suggestions for more effective use of exhibits, your viewpoints, recommendations, experiences, a measure of the affectiveness of the chapter and symposium exhibits in meeting your needs and expectations, etc. will be compiled into a report forwarded to ASGS for its use and publication.

UPJOHN
GLASSBLOWER TRAINING GUIDE

Frank Meints
Upjohn Company

I would like to share with my fellow glassblowers the details of a training guide which was developed at the Upjohn Company Glassblowing Department. After the retirement of the senior glassblower in our two-man shop, a candidate was hired to learn the art of scientific glassblowing. Fortunately, we were able to obtain the services of the retired glassblower on a consultation basis to help with the training. To keep everyone informed as to the status of the training, and to avoid duplication or omission, this guide was created. This guide serves three main purposes.

1. It shows the apprentice what the job requirements are through its detailed list of operations.
2. It serves the trainer(s) as a checklist to see what items are complete and what must be demonstrated or needs further practice.
3. It serves as a status report to management.

Many glassblowers report to someone who has no knowledge of glassblowing or its level of difficulty. This guide can show progress in a more understandable way which will be explained in more detail later in this paper.

Please note that this guide is custom made for our glass shop. You may need to add or subtract parts to fit your particular needs. Also, it does not show how to do an operation. This is done through personal demonstration and/or glassblowing instruction books. It is divided into the following categories:

* General operations (Fig. 1)
* Use of mechanical equipment
* Knowledge of glass
* Working at the bench (Fig. 2)
* Working at the lathes
* Safety

Each operation item has four stages to completion:

1. Verbal description and/or demonstration
2. Used/tried
3. Acceptable
4. Proficient

The actual glassblowing categories are also divided by difficulty Levels I, II and III.

Let's look at an example operation of working at the bench. (Fig. 2)

* Level II, right angle bends. The candidate is shown how to make a right angle bend. The candidate then tries it and the date this is done is entered in the appropriate boxes. After some time and practice, the trainer feels the bends being made are acceptable, and logs in the date. At some future time, the trainer feels the candidate can make a good Level II right angle bend consistently and logs in that date in the appropriate box.

This basic procedure is followed for all listed operations. You may wonder what the differences are between "acceptable" and "proficient". Here we must use our experi-

GLASSBLOWER TRAINING

General Operation A	I Verbal Description & Demo.	II Used/Tried	III Acceptable	IV Proficient
Shipping/receiving				
Packing glassware				
Stocking of glassware & storage				
Phone procedure				
Handling walk-in customers				
Computer use				
Use of catalogs				
Use of library				
Comments:				

cas 3/89
Glass-A\123

Figure 1

GLASSBLOWER TRAINING

Working at Bench D-3: LEVEL 2 (Tubing up to 30 mm O.D.)	I Verbal Description & Demo	II Used/Tried	III Acceptable	IV Proficient
Pulling points				
Right angle bends				
U - tubes				

cas 3/89
Glass-D\123

Figure 2

ence, judgment, tact, and professionalism. What is acceptable to one may be poor or very good to another. I use the following criteria as "acceptable" for glassware:

* Structural integrity (will it hold together?)
* Will it do the job it was intended to do?
* Will the customer accept it?

My definition for "proficient" is all of the above, in addition to:

* Is the item free of flaws (lumpy, out of round, discolored, dirty, too thick or too thin, etc?)
* Was it done in a reasonable amount of time?

Note that we have left a space at the bottom of each page for any comments you may want to add for clarification. The bench and lathe glassblowing categories are divided into three levels, with Level I being the easiest. Here again, judgment is called into play. In general, Level I is an easier type of operation, usually involving smaller diameter items, sawing, sanding, drilling and so forth. Level II represents the medium difficulty items over 15 millimeters, O.D., multiple ring seals, multiple neck flasks, under 12 liters, vacuum seals, etc. Level III involves large diameter tubing, large fritter ware, some micro work and items with several subassemblies. One pitfall to try to avoid is the situation where a difficult operation becomes easy because of repetition. Remember how hard it was in the beginning and how long it took to become easy. Usually, Level II items take longer to learn, and Level III even longer. The point is not to down-grade your experience.

When judging another one's work, try to use tact and constructive criticism. We all make mistakes. We can laugh about it later. Even though the safety category is last in order in this guide, it is of prime importance.

Please note that the various operations are not listed in a specific order for training. Usually, one operation seems to set the stage for the next so that various operations will tend to overlap in a single training session. It also is more interesting for both trainer and apprentice to rotate through a series of operations, sometimes doing "real work" by repairing glassware or filling a customer's order for new glassware.

This guide is adaptable for most glassblowing operations. You may have to add or delete certain parts to fit the particular job. In our shop, most of the work is specialty, one or two of a kind type work which makes it more challenging. This results in a lot of shifting gears, set-up time, planning, and trial and error. This creates a different situation compared to a shop that is more production oriented. In all cases, changes in this guide will be necessary as new advancements in equipment and procedures come along.

One area we are looking at is the repairing of glassware. It's true that many repairs are made using basic operations already listed. However, some repairs can be more challenging than was the original construction, also requiring original ideas in the creation of apparatuses, tools and jigs, and procedures to accomplish the job. The condition of repaired items could also be used for job performance ratings as "acceptable" or "proficient" when looking at the overall average of the repaired items. Repaired items can also be classified as Level I, II or III.

The main purpose of this guide is to insure that all the necessary operations of the training are included, and to keep everyone involved informed of the overall progress. I know there can be many arguments as to whether an item is Level I, II or III difficulty, or where to draw the line on acceptable and proficient. There is also the question of when is a person fully trained. These questions can never be answered the same for everyone. It depends on the job requirements, the talent of the apprentice and the judgment of the person in charge.

At Upjohn we are using an overall percentage scoring to arrive at levels of progress. Using the table included at the back of this guide, we can see what percentage of the various levels are acceptable and proficient. In this guide you will find that the majority of operations are Level I, so there is rapid progress at first.

As time goes by, things get more difficult and progress seems to slow down. The further you go the steeper the hill. Time is not a factor in this guide because it will vary with every person and circumstance. It is up to you to set time limits along with other performance criteria for each particular job to arrive at each step and finally a "fully trained" journeyman glassblower. With this guide you have another tool to help with training and advancement.

You may obtain a copy of this guide by writing to me, Frank Meints, the Upjohn Company, Dept. 7283-25-1, Kalamazoo, MI 49001, or call 616/385-7070. I would like to thank William N. DeWolff and James T. Baker for their help on this project.

THE DESIGN AND FABRICATION OF AN ACETONE PERCOLATION DEVICE FOR ULTRACLEANING OF CELLS AND GLASSWARE

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Introduction

Light scattering is a physical method used to study polymers and colloids. Light, usually from a laser source, is scattered in various directions from these relatively large molecules. From the angular distribution pattern of the scattered light, and also the rapid fluctuations in its intensity, one can determine the molecular weight, size, shape, and degree of aggregation of the polymers or colloidal particles.

Experimentally, one of the most difficult aspects of light scattering techniques is that almost everything scatters. Thus, it may be difficult to distinguish scattering arising from the particles of interest from light scattered by other particles, usually referred to as "dust". In fact, "dust" can come from many sources — pollen, bacteria, viruses, smoke, to name but a few. The size of "dust" extends from about one ten-millionth of a meter to particles large enough to see. Light scattering practitioners use various techniques to remove "dust" from solutions to be measured. These include primarily filtration and centrifugation. However, these techniques are only part of the story. For example, many newcomers to light scattering discover that filtered samples are still dusty, because they collected the filtrate in a dirty vessel. Blaming the filter, they repeat the operation — often many times, an inefficient operation at best and generally a very bad practice since some polymer is lost on the filter each time. There is a need for a device that prepares clean receptacles for filtered samples.

The Design

In Dr. Russo's lab, various methods to make clean vessels are used. These include anti-wetting treatment (silanation) of certain glassware, combined acid-base washing, followed by rinsing with special particulate-free water, and the use of the acetone percolation device (APD), Figures 1A and 1B. In the APD, boiling acetone (I) in the sealed lower chamber is made by a system of water-cooled coils to condense in receptacles (1). The pressure in the lower chamber then drives the condensate upward through a tube insulated with a water-cooled coil (2) ending with teflon tubing (3) until it spurts onto inverted glassware placed in the cleaning chamber (III). The acetone returns (4) to the lower chamber, carrying "dust" from the glassware with it. A constantly circulating pump with an in-line filter keeps the acetone reservoir (5) clean. A system of valves (6) is used to balance the system.

The APD is often the final cleaning step. Thus, only cells that are already free from gross dirt should be placed on the APD. Cleaning time depends on vessel size. Typically, 5-ml measuring cells require between 15 and 60 minutes of cleaning. The four-port design of the APD allows four such cells to be prepared simultlaneously. Usually, cells cleaned by the APD are perfectly adequate for use with nonpolar solvents (e.g., toluene, cyclohexane, benzene). The APD is not always the best choice when the measurements are ultimately to be carried out in polar solvent (water, dimethylformamide, tetrahydrofuran). These solvents sometimes seem to promote release of materials from the glass that the APD left behind. Acid-base washing, with clean water rinse, or silanation procedures are better for these solvents. Even so, the APD is very useful in "precleaning" other glassware in these studies, such as volumetric flasks.

The original design of Dr. Russo's cell washer was as shown in Figure 2. After discussing the concept we came up with a better way, improving the performance qualitatively and quantitatively by introducing coils instead of fingers; adding more ports to wash four cells at once or to wash three cells and have the fourth port spray acetone over the others; using a system of valves to facilitate balancing the flow of liquid; and using a pump to filter the acetone.

The APD at first had only two washing stations and didn't have the balancing system (Figure 3). The connection between the condensing chamber and washing chamber was made through a flat flange and a teflon device. In this configuration, the cleaning procedure would sometimes stop and at other times there were leaks.

The Fabrication

In the fabrication of the second generation APD, the eight inner coils were first made at the bench using classical coiling methods. A system of braces interconnected them to make a rigid yet flexible structure which would not break under stress (Figure 4). Once inserted in the outside envelope of 130 mm OD tubing and mounted on the lathe (Figure 5), the condensers will stay together while the lathe turns. No other support was used. The ends of the coils were positioned tangentially to the flat surface of the top of the condensing chamber. The next step was to seal all eight connections going through the outside wall (Figure 6). Since a great deal of hand annealing had to be done between seals, they were braced to keep them steady. Next the jets going through the top part of the condenser chamber (Figure 1, II) into the cleaning chamber were sealed. There again the tubes sticking out were braced because much hand annealing was required.

The capping process was next. The polished 103-60 female joint held in the right chuck of the lathe was sealed over the jet using a half-moon flame heating the peripheral area of the condensing chamber and the tip of the bottom of the joint (Figure 7). This was probably the most crucial seal since any mistake would result in a complete loss of that part of the apparatus. There are no pictures of this operation since I was anxious to finish and I didn't know I would be here today telling you about the APD.

As soon as this global sealing process was finished, the APD was introduced into a preheated annealing oven. This type of one shot deal reminded me of work I did when I was at SUNY at Stony Brook fifteen years ago when I did sixteen ring seals in a similar global sealing process (Figures 8A and 8B). Interestingly enough, although it is a completely different apparatus for a different purpose, they are both for the field of laser light scattering.

The next operation was easier. It consisted of sealing the valves to be used to balance the system, Figures 9A and 9B). At that time a crew of cameramen from LSU who were in the building for other projects came inadvertently into my shop and, therefore, I have no pictures but a clip of video that will better show the sealing of those valves.

I will not explain the fabrication of the upper condensing chamber nor the boiling flask since most of us are familiar with those operations.

Conclusion

This is a classic example of the mission of the research glassblower. A simple scientific concept, in the present case the APD, was refined and improved to produce a reliable and aesthetically pleasing piece of apparatus for researchers and has become an integral part of the light scattering experimental routine in Dr. Russo's lab at LSU. See Figures 10A, 10B and 10C.

Dedication

I would like to dedicate this paper to the memory of my father who passed away this spring after a long illness and by whose example in life I was introduced to fine workmanship.

Acknowledgements

I would like to express my thanks to Vincent Guerrini, my assistant at the time I worked on the APD, who kept it nice and warm during the final phase of putting it together; to Claire Baron, my present assistant, for the APD drawing; to the College of Basic Sciences at LSU; and especially to Dr. Paul Russo without whom there would be no APD.

This work was supported by a grant from NSF, Division of Materials Research, #8520027.

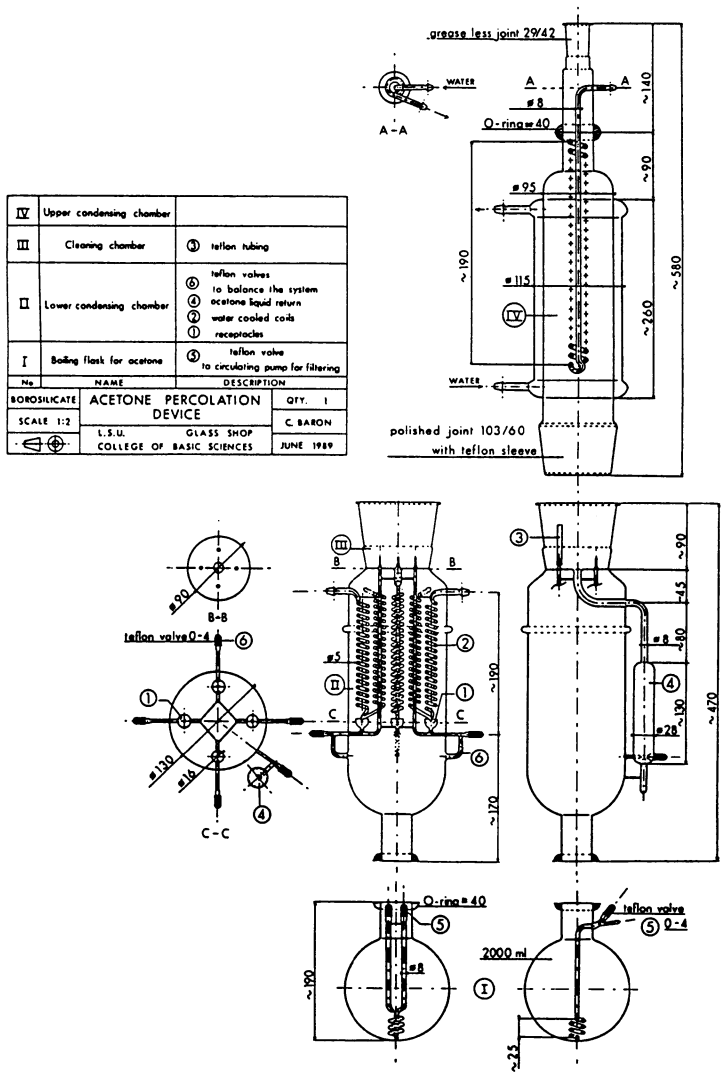
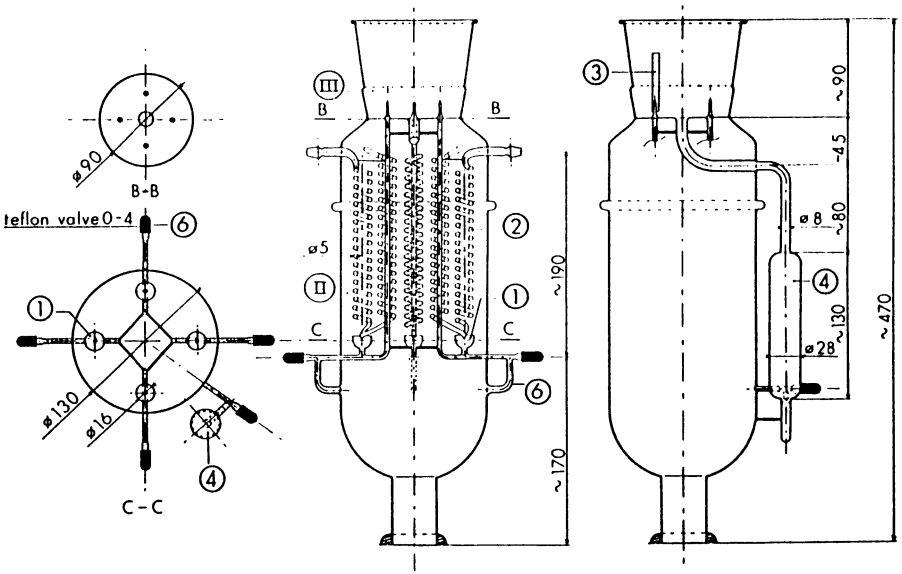


Figure 1A


ø90
B-B
teflon valve 0-4
⑥
①
ø130
ø16
④
C-C
Ⅲ
B
B
ø5
Ⅱ
C
C
②
①
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ø8
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④
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ø28
~470

Figure 1B

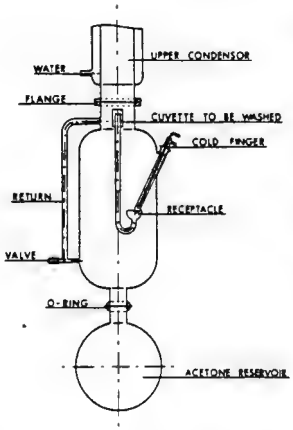

Figure 2

Figure 3

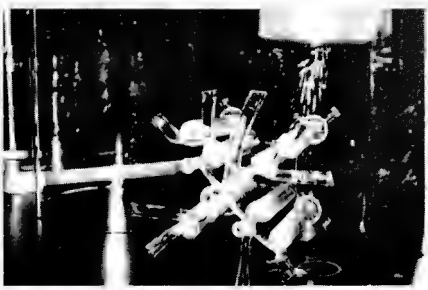

Figure 4

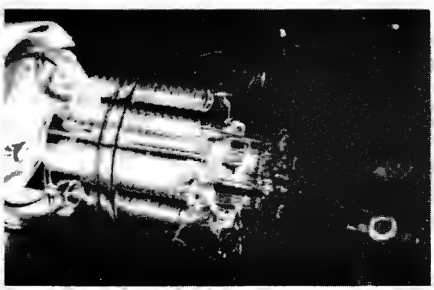

Figure 5

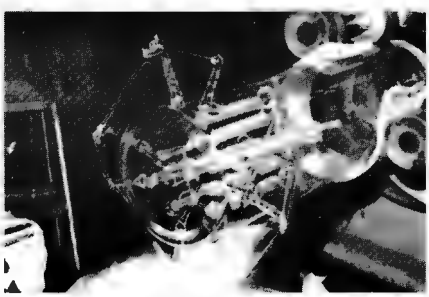

Figure 6

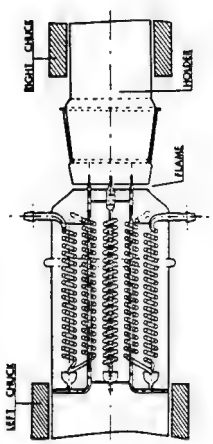

Figure 7

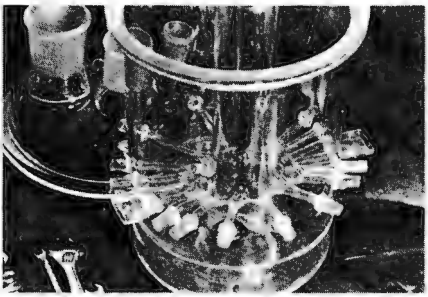

Figure 8A

Figure 8B

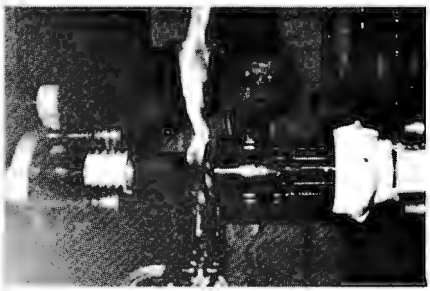

Figure 9A

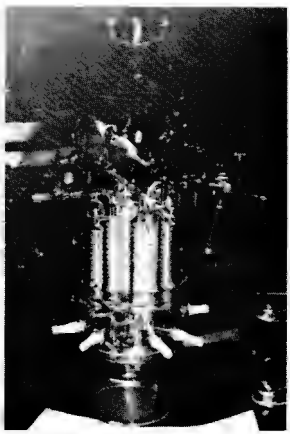

Figure 9B

Figure 10A

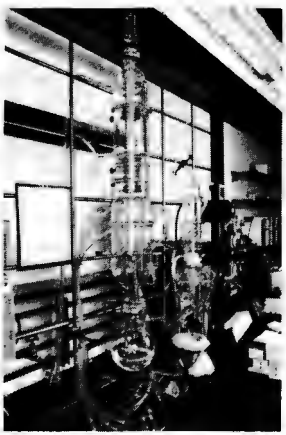

Figure 10B

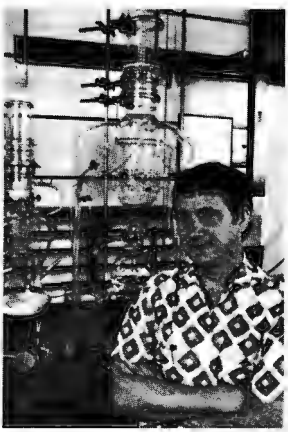

Figure 10C

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