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Glassblowing

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THE
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Toledo, Ohio

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A Glassblower's View of Soviet Union

Robert J. Ponton
University of Wisconsin , Milwaukee, WI
and
Gordon A. Smith
Mayo Clinic, Rochester, MN

In November of 1989, we received letters and invitations from Dr. Edward Carberry who is the chairman of the chemistry department at Southwest State University in western Minnesota. Dr. Carberry, a member of the A.S.G.S., had been invited by Professor P. Sarkisov, Rector of the Mendelev Institute in Moscow, to lead a small delegation of U. S. chemists and glassblowers to the Soviet Union. An educational exchange and tour was planned.

On July 4, 1990, thirteen chemists, four glassblowers, and seven wives of chemists and glassblowers traveled to Moscow for an eleven day visit to the U.S.S.R. The glassblowers were:

> Hans Florell and his wife, Mary Anne
> Kenneth Opsahl and his wife, Nancy
> Robert Ponton
> Gordon Smith and his wife, Linda

On our flight to Moscow, we discussed our rare opportunity of being the first scientific glassblowers to participate in an educational exchange with our counterparts in the Soviet Union. Our exchanges and tours were at the Mendelev Institute in Moscow, the Kiev Polytechnical Institute in Kiev, and the Leningrad Technical Institute in Leningrad.

We soon discovered that the "best made plans" do not always work the way they are supposed to in the U.S.S.R. After arriving at the Mendelev Institute, where we were greeted by a small group of professors, we surprisingly learned that our hosts had not made arrangements for us to visit their glassblowing shop. However, one of the professors who spoke English agreed to take us on an unannounced tour of their shop. We soon found that scientific glassblowing in the Soviet Union is at a level which is considerably lower than that of the free world. The glassblowers had no air conditioning, no lathes, no annealing ovens, and no standard taper joints or stopcocks. In other words, everything was made by hand at the bench.

At the Kiev Polytechnical Institute, the glassblower and all but two of the professors were gone on vacation. Their one man glass shop was as ill equipped as the one in Moscow. Asbestos was in abundant supply and didymium glasses were unheard of.

At the Leningrad Technical Institute, we were met by Russian glassblowers who were actually prepared for an "educational exchange"; but, unfortunately, they would not show us their glassblowing shop. We were never given a satisfactory reason for that refusal.

We found it difficult to understand how a country which has a highly sophisticated space program can seem to be so far behind in some areas of technology such as glassblowing. Our tour of these cities proved to be a fascinating look at this schizophrenic nation. The two longest lines in Moscow were for Lenin's tomb and the new McDonalds. To have had the opportunity to visit so recently as last summer was not just to engage in ordinary tourism, but to witness history in the making.

Soviet Glassblowers at Mendelev Institute in Moscow

Gordon Smith presenting ASGS certificate to Soviet Glassblowers in Leningrad.

Soviet and American Glassblowers at Leningrad.

Building a Nebulizer that Really, Really Works

By Laura Thacker

University of Virginia Charlottesville, Virginia

There are many designs for nebulizers; in this paper I will explain the step-by-step procedure to create a self-priming nebulizer which is simple to make and use, and works every time.

Begin with 3/8" heavy wall tubing. Attach a short length of 3mm standard wall tubing. Form a maria on the 3/8" heavy wall about 1/2" from the juncture. Attach a small piece of rod on the 3/8" heavy wall halfway between the maria and the juncture. The length of the remaining stud should be 1/4". This will act as a strut to support the remaining piece of the nebulizer. Leaving 1", cut the 3mm tubing. IT IS VERY IMPORTANT TO SQUARE THE END OF THE 3MM TUBING. Very lightly fire polish, and set this piece aside.

Join a piece of 4mm standard wall and 2mm standard wall tubing. Bend the 2mm about 95 degrees, 1/2" from the juncture. Leaving 1/4" of tubing, cut the 2mm standard wall. SQUARE THE END SO THAT THE FLAT IS PARALLEL TO THE 4MM STANDARD WALL (See Figure 1). Very lightly fire polish the tip.

Hold the two pieces together so that the end of the 2mm tubing is directly over the 3mm tubing. Mark the 4mm tubing at the point where the strut on the 3/8" heavy wall intersects the 4mm tubing. (See Figure 2) Attach a very small bit of rod to the 4mm at the mark, but below the angled tip. This stud will connect to the strut on the 3/8" heavy wall, allowing you to position the parts so that the ends will line up properly. Holding the studs together, mark the 4mm tubing just above the maria. Cut the 4mm tubing on this mark, and fire polish.

To connect the two pieces, position them so that the end of the 2mm bent tubing is directly over the 3mm tubing. Hold these pieces at the end, and, with a very small flame, fuse the two struts. Once the pieces are fused, heat the strut only to reposition the parts to achieve the proper alignment. The final configuration should be so that the end of the 2mm tubing covers a width of the 3mm opening equal to the wall thickness of the 3mm tubing. IT IS VERY IMPORTANT TO HAVE THE ENDS PERPENDICULAR AND CLOSE TO ONE AN-OTHER. (See Figure 3) If these pieces are not accurately aligned, the success and efficiency of the nebulizer are compromised. However, if the ends are aligned in this fashion, the nebulizer will work every time.

Once you have achieved the correct alignment, you are ready to insert this piece into the body. Use the maria formed on the 3/8" heavy wall to attach the piece to the body, thereby avoiding the problems encountered if the smaller tubing were heated.

There are many applications for this type of apparatus. It can be used for spraying indicator onto TLC plates, humidifying, testing water-dissolved samples, or even fine mist painting. Two advantages to this type of design are the fact that since it is self-priming, you are able to use the least amount of substance to be atomized, and, if you take the time to align the inside pieces properly, the nebulizer will work every time, thus avoiding the necessity of testing each one prior to assembling it into the body.
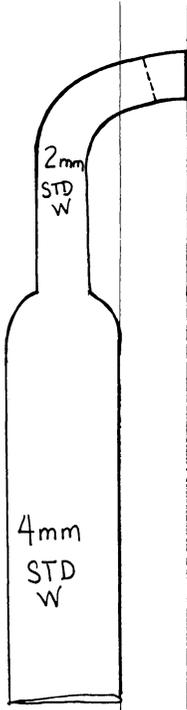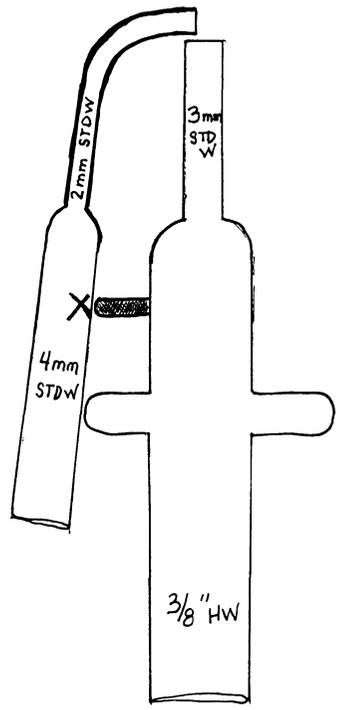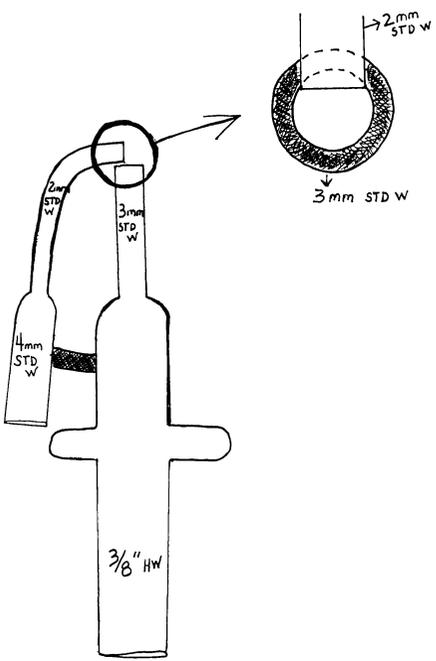
Figure 1.

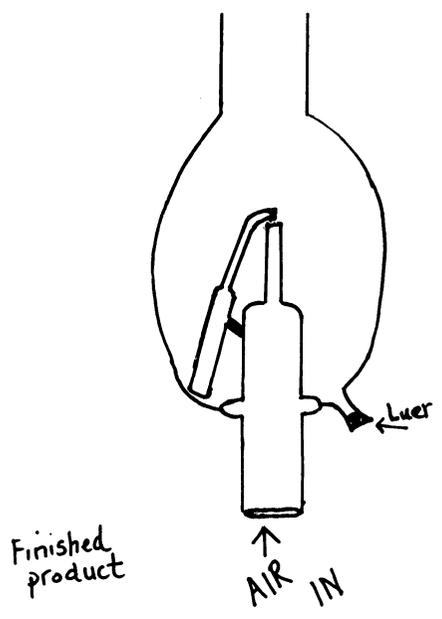

Figure 2.

Figure 3.

Figure 4.

Connecting Glass Components for the Modern Lab

Dieter Opper, German Society of Scientific Glassblowers, and Schott Glaswerke/Mainz. Translated by J. Brookes, Schott America.

Distillation apparatus were the first known laboratory apparatus. With the beginning of modern chemistry, reaction apparatus and apparatus for analytical purposes were developed, along with the distillation apparatus. End openings were closed with cork stoppers. Tube ends were connected to one another with rubber hoses. With bored-out stoppers, one could accommodate different tube diameters. Squeeze-clamps on the hoses were the predecessors to ground stopcocks.

The insufficient chemical resistance of the connections was the cause to search for new connecting components. With the discovery of borosilicate glass by Otto Schott (then 4.2 co-efficient of exp.) came the capability to produce complicated laboratory glass apparatus. This however also necessitated the development of corresponding connecting components. Important, however, also was that they were easily and conveniently interchangeable. From a variety of solutions evolved four different systems:

1) ground joints

2) spherical (ball and socket) ground joints

3) screw-thread connecting components

4) flanges

1. Ground Joints

Ground joints, also called "Normschliff" are today the most-used connecting components. The first ground joints were produced in 1906 in Stutzerbach in Thueringen. Before the 2nd World War this was the center of Germany's laboratory glass industry. The ground pieces were not yet interchangeable. The diameters were then arbitrarily chosen and used as needed.

In 1927, ground joints were for the first time standardized in DIN DENOG 20. These still were not interchangeable components. In 1939, the first interchangeable ones were produced with the establishment of an angle tolerance of +- 1' (minute). With this the full interchangeability among various producers was achieved.

Today's modern technical manufacturing methods, with improved quality control and international standardization, guarantee full interchangeability of ground joints world wide. The diameters and tolerances have been established in ISO 383 and DIN 12 242 as well as other national standards, for instance ASTM, BS, etc.

The tapered cones have a taper of 1:10, which means that over 10mm of length, the diameter is reduced by one mm. The designation for a ground joint means, for instance:

NS 29/32

largest cone OD	29.2 mm
cone lengths	32.0 mm

Knowing the taper is1:10, the smalleest cone diameter can be easily reckoned:

largest OD	29.2
less 1/10 cone length 32	3.2
smallest OD	26.0mm

The cone lengths, according to ISO 373, are in different series or designations, which are:

K2, K4, K6, and K8.

The lengths can be derived using the following formula:

$$l = K * \sqrt[1]{d}$$

Example:

> NS 24 according to K6 has a length as follows:
>
> $$l = 6 * \sqrt[1]{24}$$
> $$l = 29mm$$

K6 is what is used predominantly in Europe.

In the US, the primary usage is of the K8. Taking again the NS 24 as an example:

> $$l = 8 * \sqrt[1]{24}$$
> $$l = 40 \text{ mm}$$

Stoppers, for instance for reagent bottles, are reckoned according to the K4 formula.

The advantages of ground joints are quick and easy assembly of apparatus, good seal, ease of cleaning, and that they are self-supporting. They are relatively economical and interchangeable.

The disadvantages are their obvious rigidity. This makes it difficult to construct safely and without stress apparatus with lattice rod extension clamps. The larger the joints, the harder they are to take apart. They tend to stick, or freeze, and only with certain tricks can one separate frozen joints, without breakage. Cones and sockets cannot be turned when they are dry. They can become scratched and thereby lose the integrity of the seal. In spite of these disadvantages the ground joint is and remains the most important and most-used component for connecting glass apparatus and maintaining an excellent seal. Dry joints have a leakage rate of less than $1 \times 10\text{-}3$ mbar x l/s. For vacuum work joints are sealed with a special grease, or PTFE sleeves.

2. Spherical Joints

Spherical joints are used where the rigidity of apparatus made with standard joints needs to be diminished. These consist of a ground ball and ground socket. The dimensions and tolerances are laid down in ISO 641 and DIN 12 224, and are thereby also interchangeable. Spherical joints serve only as complement to standard ground joint connections - whole apparatus with spherical joints are only constructed with difficultly, because they are not self-supporting.

The leakage rate of dry spherical connections is less than $1 \times 10 - 2$ mbar x 1/s. for vacuum work, again, one can seal them with grease and thereby attain a seal as tight as with greased standard joints.

3. Screw-thread Connecting Systems (SCS)

To complement the ground joint there are also screwthreads, and caps with apertures and the corresponding elastic seals with PTFE-protective coatings. Screw thread joints of 3.3 expan-

sion borosilicate glass are utilized when joint-grease cannot come into contact with the product. Thermometers, boiling capillaries etc. can be constructed without problems. Care must be taken in construction that the PTFE-coated side is facing the reaction area. The temperature limits are approximately between - 40 degrees C. and + 200 degrees C. The leakage rate is less than 1 . 10 -4 mbar x 1/s.

To further complement the screwthread, there are also screw-cap couplings. With these flexible couplings one can join two components with screw-threads. Apparatus and tubulature can be constructed with lattice rod extension clamps, with these flexible joints and integrated seal, free of stress. This also eliminates the need for extra grease for a tight seal. Assembly and disassembly of the components is easy, because the system is composed of one common unit (like connections).

The leakage rate is less than 1.10-4 mbar.l/s and has a temperature resistance of between - 40 degrees C to + 180 degrees C. The medium only comes into contact with glass and PTFE, thereby guaranteeing the best chemical resistance.

4) Flanges

All of the connecting components discussed up to now are for the most part used only up to a certain maximum diameter, for instance for ground joints up to 45/40, and screw threads up to 45mm.

Flanges are utilized where large openings on vessels are required. High-viscosity substances can be effectively stirred with wide, stable stirrers. Both high viscosity and solid substances can be easily removed from the vessels with flanges and cleaning is made considerably easier due to the wide opening. There is also no "dead space", which is important for machine and manual rinsing.

These are the main reasons why flanges are being increasingly utilized in the laboratory. But another is that, in spite of its considerable strength and large diameter, the flat flange is easy and safe to use in the construction of apparatus. It is of course important that the corresponding components are at hand.

Flanges distinguish themselves through the following advantages:

- stable glass flange construction with an optimal flange angle of 45 degrees.

- the material-appropriate design gives the flange its optimal stability.

- different flange executions, ground flat, with and without groove, accommodate a variety of seal requirements.

- different lid executions with a bead for safe attachment to supports allows the changing of vessels without disassembly of the apparatus.

- stainless steel quick-release clamps with for instance, 2 or 3 retaining clips, allow for simple and safe closure.

- through the precisely appropriate angle of the flange and the support, simple and safe assembly.

- tight seals through two different seal possibilities,:

1) Flat flange with groove and with O-ring seal for work in vacuum and pressure, up to 200 degrees C. This allows no sticking or freezing of the components, even after long work under vacuum and high temperatures. No greasing of the sealing surfaces is required.

Or with grease (without O-ring) for work under pressure and vacuum, over 200 degrees C. The groove works here as the ideal space for the grease, without the grease contaminating the substances being used.

2) Flat flange without groove for sealing with PTFE-sleeve/collar - for work with slight vacuum and ease of opening and no contamination of the substances being used.

Or sealing with grease for use under pressure and vacuum, over 200 degrees C. This provides the best seal, but with danger of contamination. The leakage rate with the O-ring seal is for all nominal dimensions less than 1 x 10 - 7 mbar x 1/ s. With greased seals the leakage rate is considerably less.

Vessels for Flat Flanges and Corresponding Lids

There are also round bottom flasks with a flange in the nominal dimension DN 100, sizes 2 to 20-Liter, and cylindrical vessels from 100 ml to 10 Liter having a flange from DN 60 to DN 200. and for these there are also flange lids with a variety of ground socket configurations.

Round-bottom flasks with DN 100 flanges can be heated, for instance in a mantel, or in a fluid bath, just as is typically done with multiple neck flasks. The flat flange with ground sockets permits the connection to various matching components, again, just as with multiple-neck flasks. The flange allows for easy and quick assembly and disassembly of the apparatus.

Cylindrical vessels, as opposed to round bottom flasks, have the following advantages:

The optimal stirring is achieved because the most appropriate nominal dimension of the flange has been chosen for the particular size vessel, and therefore the largest possible stirrer can be used. For instance, wide so-called anchor stirrers rotate optimally just inside the wall of vessel. This is important with highly viscous substances. The top surface-area of the contents of the vessel remains constant even as the volume is decreased, as with evaporation processes. Also, the surface area to be heated is larger compared to round bottom flasks, allowing for more careful, even heating of the contents.

All flanges and vessels discussed here are vacuum-tight, and may be so utilized to the working pressures as indicated in the table. It is of course important for the glassblower to reduce this pressure whenever making adaptations to a reaction vessel blank, for instance any reduction in the wall thickness, the addition of sidearms, etc.

Ground joints still represent today the most used components for connecting laboratory glass apparatus. This is likely to remain so, because of their ease of handling, their ability to seal wall, and cost. However, where ground joints for reasons discussed are inconvenient, or cannot be used, the other types of connecting elements find their place.

The flange allows the creation of comparable vessel which then can also be used in constructing technical apparatus. So it is possible to utilize the achieved results of laboratory work as the foundation for scale-up to production capacities. The flanged vessels are in direct measured proportion to the corresponding technical apparatus. The flange with its corresponding joining elements is the key intermediate step to technical apparatus construction. The screwthread system and spherical joints round out the program.

No one type of connecting component can stand alone; it is only in the practical combination of the four systems the solutions to any problems can be found. There have been in the past many other component-connecting systems which have come and gone from the market, and there will likely be others to follow suit, but the four types of component systems described in this paper will likely long maintain their position in the laboratory.
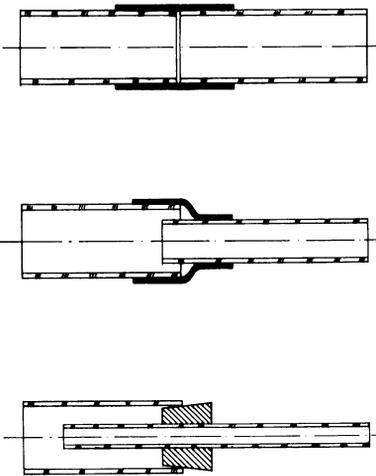
Thank you.
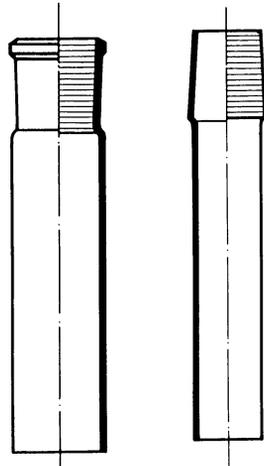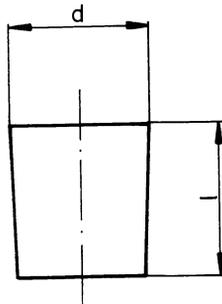
German Institution for Standardization

Figure 1   Figure 2A

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Taper - All taper-ground
joints shall have a taper
of 1 ± 0,006 mm of diameter
per 10 mm of length (1 to 10)
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Figure 2B

Laboratory glassware - Interchangeable conical ground joints

0 Introduction

The purpose of this International Standard is to ensure interchangeability between standard conical ground glass joints, irrespective of where they are manufactured. In order to achieve interchangeability, it is necessary that each of the following requirements be adequately specified, including appropriate tolerances:

a)   taper;

b)   large end diameter;

c)   length of ground zone;

d)   surface finish.

The nominal dimensions listed below are based on the the series of joints already widely used in many countries; in particular, the series of large end diameters represents the nearest acceptable compromise the R 40/3 series of preferred numbers (5, 3, ...,100) laid down in ISO 3. *Preferred numbers - Series of preferred numbers.*

From the practical point of view, and especially because of the difficulty of carrying out precise measurements on the ground portions of the finished joints, it is desirable to apply a gauging system which allows rapid checking of the essential dimensions. The definition of these dimensions in clause 6 is an integral part of this International Standard, but the system of gauging described in annex A, while it has been proved in practice as fully satisfactory, is not the only once which can be applied for the purpose.

The leakage test described in annex B is one which is commonly used for testing joints, but its inclusion in this International Standard is not intended to preclude the use of other tests which may be found more convenient for particular purposes. Attention is specifically drawn to the method of pneumatic gauging.[1]

1.   Scope and Field of Application

This International Standard specifies the essential geometric requirements for interchangeability in relation to four series of conical ground glass joints for laboratory use.

2.   Reference

ISO/R 468, *Surface roughness*

3.   Taper

The taper of the joints shall be such as to give one increment on diameter for ten increments on axial length, with a tolerance of $\pm$ 0,006 on the diameter increment, i.e. a taper of $(1,00 \pm 0,006)/10$.

Note - Actual manufacturing techniques normally result in a tighter tolerance than that given above, but owing to the lack of experimental evidence it is not yet possible to reduce the specified value.

4   Large end diameters

The following series of large end diameters shall be adopted:

5 - 7,5 - 10 - 12,5 - 14,5 - 18,8 - 21,5 - 24 - 29,2 - 34,5 - 40 - 45 - 50 - 60 - 71 - 85 - 100mm

5   Length of Ground Zone

The length of ground zone l, in millimetres, is calculated using the formula

$$l = k \sqrt{d}$$

where

k is a constant;

d is the large end diameter, in millimetres.

[1]   This method is described in *Laboratory practice*, March 1958, Vol. 7, No. 3 "Pneumatic gauging applied to standard ground glass joints" by I.C.P. Smith.

The calculated length is rounded off to the nearest whole number.

The four series of joints listed in table 1 are obtained by using the values, 2, 4, 6 and 8 for the constant k.

$k6$ is the preferred series.

TABLE 1 — Series of joints

Dimensions in millimetres

Large end diameter	Length of ground zone			
	$k2$ series	$k4$ series	$k6$ series	$k8$ series
5		9	13	18
7,5		11	16	22
10		13	19	25
12,5		14	21	28
14,5		15	23	30
18,8	9	17	26	35
21,5		19	28	37
24	10	20	29	39
29,2	11	22	32	43
34,5	12	23	35	47
40	13		38	
45	13		40	
50	14		42	
60			46	
71			51	
85			55	
100			60	

Figure 3B

External diameter of adjacent tubing

Nominal spherical diameter

Bore diameter

Inner component (ball)

Diameter at narrow end
of ground zone

Diameter at wide end of ground zone

Nominal spherical diameter

Diameter at narrow end
of ground zone
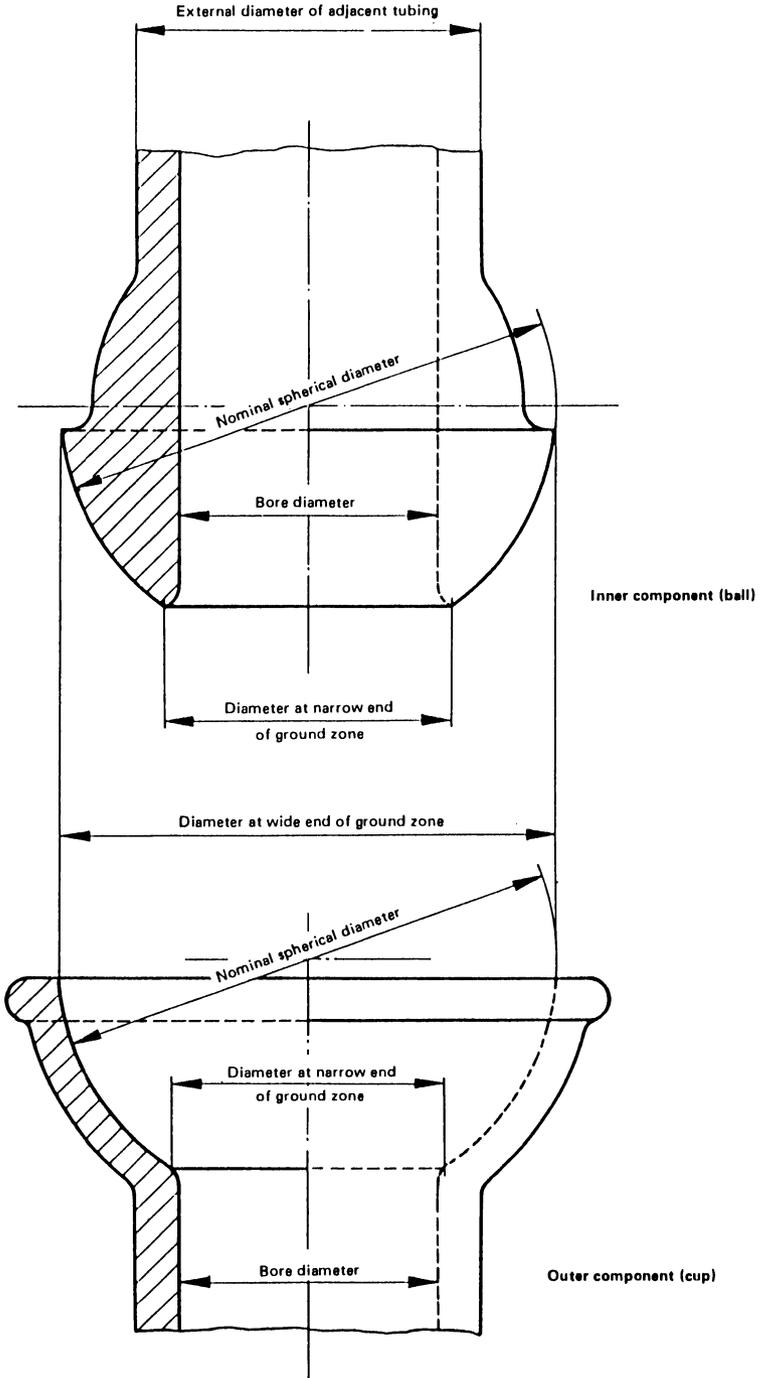
Bore diameter

Outer component (cup)

FIGURE 1 — Dimensions of spherical joints

Figure 4

TABLE 1 — Dimensions and tolerances of spherical ground joints

Dimensions in millimetres

1	2	3	4	5	6	7
	Spherical diameter			Minimum diameter at wide end of ground zone	Maximum diameter at narrow end of ground zone	Maximum external diameter of adjacent tubing
Size designation	Nominal dimension	Tolerance on inner component (ball)	Tolerance on outer component (cup)			
S7	7,144	0 − 0,025	+ 0,025 0	6,9	2,0	4,5
S13	12,700	0 − 0,025	+ 0,025 0	12,5	7,0	9
S19	19,050	0 − 0,025	+ 0,025 0	18,7	12,5	14
S29	28,575	0 − 0,025	+ 0,025 0	28,0	19,0	22
S35	34,925	0 − 0,025	+ 0,025 0	34,3	27,5	30
S41	41,275	0 − 0,025	+ 0,025 0	40,5	30,0	34
S51	50,800	0 − 0,025	+ 0,025 0	50,0	36,0	43
S64	63,500	0 − 0,035	+ 0,035 0	62,5	47,0	53
S76	76,200	0 − 0,040	+ 0,040 0	75,0	58,0	64
S102	101,600	0 − 0,050	+ 0,050 0	100,0	84,0	85

Figure 5

13

GL14

φ12
NS14/23
NS19/26
NS24/29
NS29/32
φ6
φ6

GL18

φ16
NS14/23
NS14/26
NS24/29
NS29/32
φ6
φ8
φ10
φ6
φ8
φ10

GL25

φ22
NS19/26
NS24/29
NS29/32
φ8
φ10
φ12
φ8
φ10
φ12

Figure 6

GL 32

GL 45

Figure 7

15

Bead

Optimum 45°
flange angle

3 segment,
stainless steel
quick release
clamp
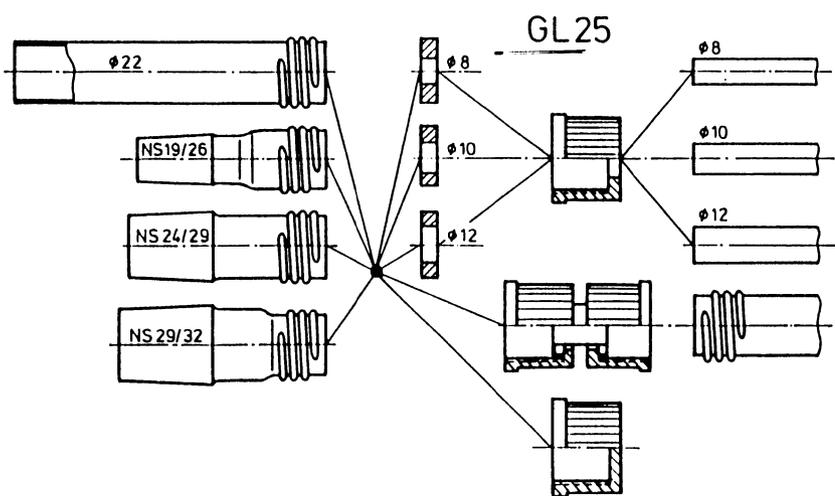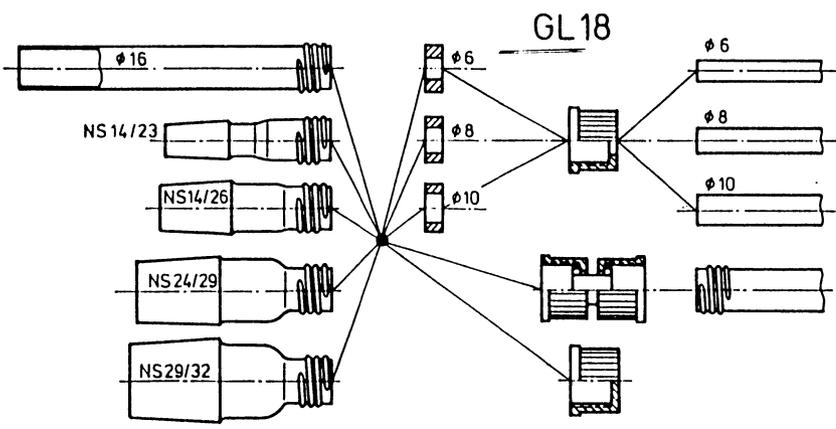
O-Ring

Flange,
with or without
groove

Figure 8

Accessories

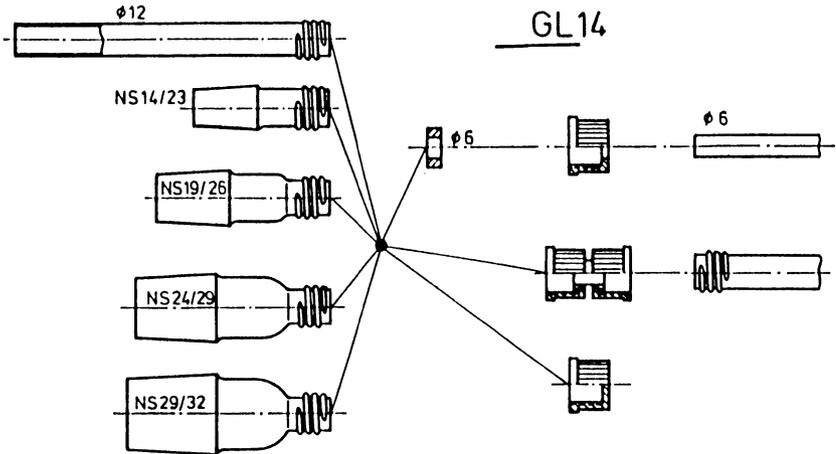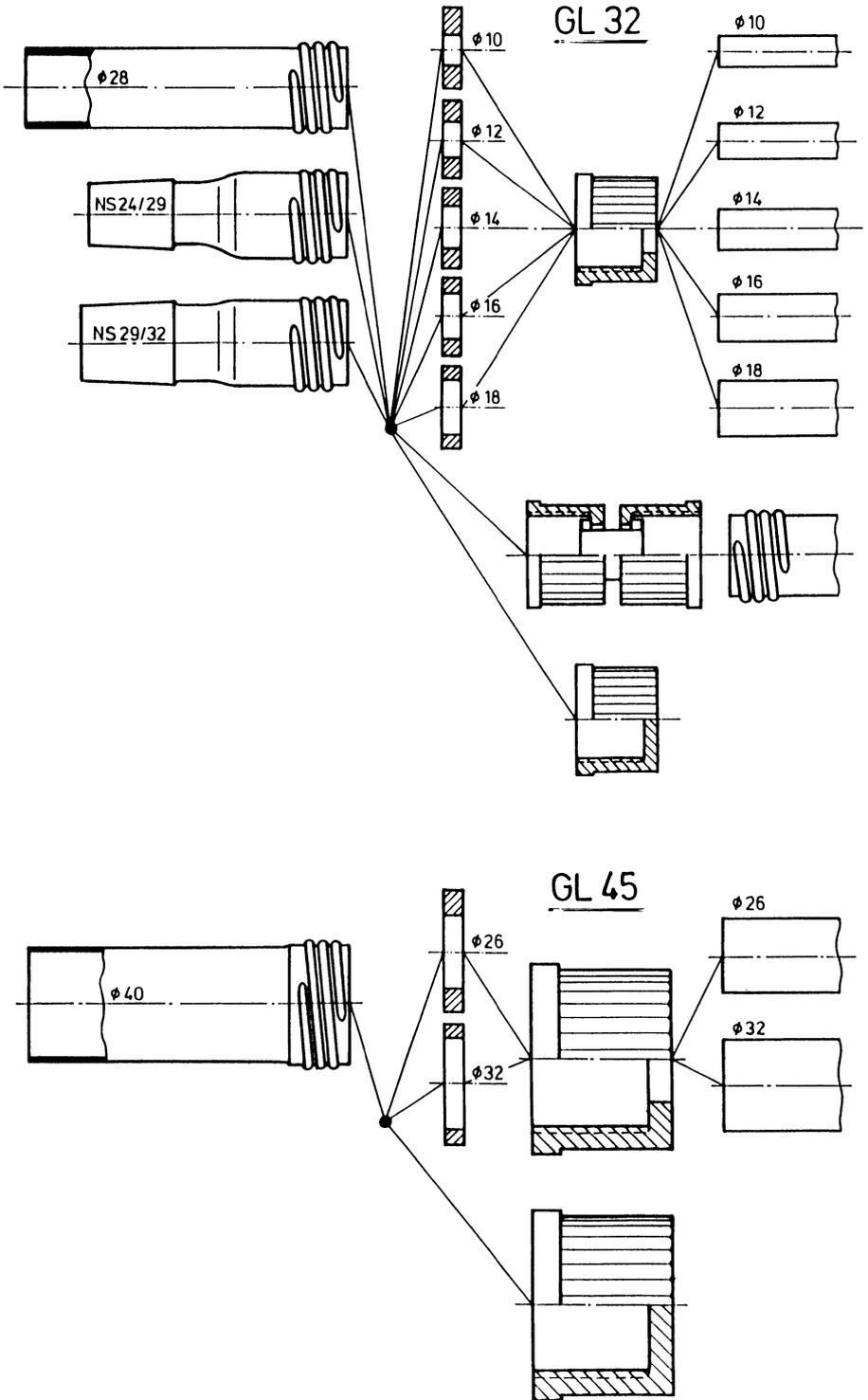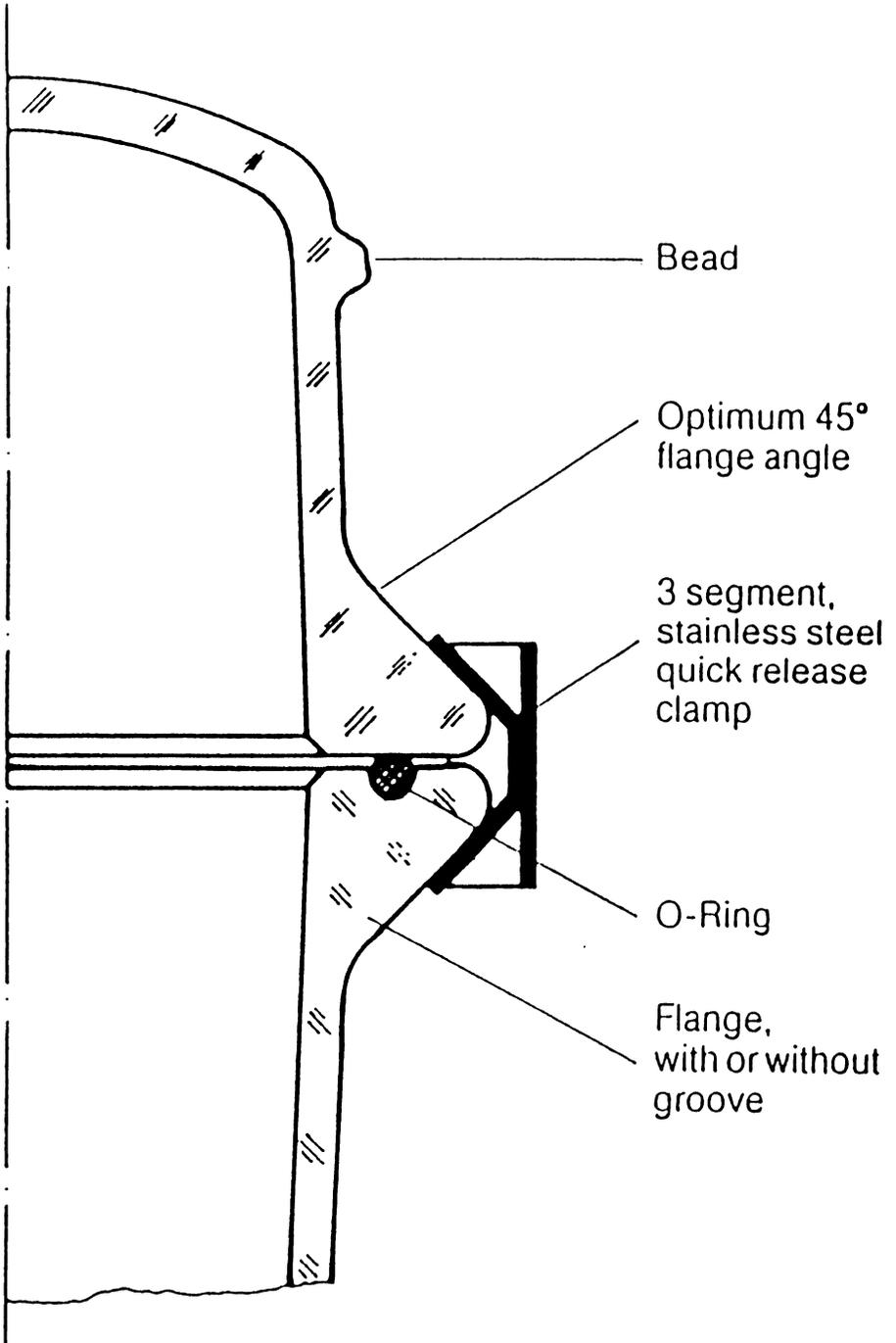There are two possible ways of sealing flat flange reaction vessels which have to operate with minimum leakage:

1. O-Rings for working under overpressure and vacuum up to 200 °C
   - easy to open
   - the lid does not stick even after long periods under vacuum and higher temperatures
   - no greasing of the buttress surfaces.

2. Grease for operation under overpressure and vacuum over 200 °C
   - here the groove works as an ideal greased groove
   - no contamination of substances.

The new stainless steel quick release clamps with 3 retaining clips ensure uniform distribution of joint pressure combined with optimum fit.

The nichrome support device with its 2 support rods provides a means of fixing the reaction vessel or lid in support walls or similar fittings.

Should the lid or the vessel have to be changed, there is no need to dismantle the whole apparatus.

Product range

Silicone O-Ring	Stainless steel quick release clamp with 3 retaining clips	Nichrome reaction vessel support device with 2 support rods
29 225 . .	**29 071 . .**	**29 073 . .**

Cat. No.	Suitable for flange DN
29 225 34	60
29 225 46	100
29 225 51	120
29 225 57	150
29 225 61	200
29 071 34	60
29 071 46	100
29 071 51	120
29 071 57	150
29 071 61	200
29 072 51*	120
29 073 46	100
29 073 57	150

* metal with 2 retaining rods, discontinued, available until stocks exhausted

 SCHOTT

Figure 8A

50010 e 05914.0 we Printed in the Federal Republic of Germany
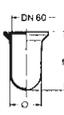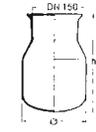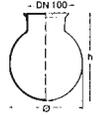
Product range

| Optimum agitation | Uniform product surface area | Maximum possible heating surface | Easy removal of contents, even highly viscous and solid substances | Easy to clean, no inaccessible corners, suitable for washing machines |

Flat flange reaction vessels, beakers, round bottom flasks and lids

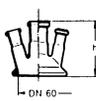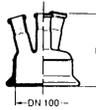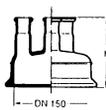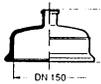| Flat flange reaction vessels Flange with groove		Flat flange beaker** Flange with groove	Round bottom flat flange Flange with groove
24 390 24 24 390 36	24 390 44* 24 390 54* 24 390 63	24 390 71 24 390 76 24 390 86	24 391.. 24 394..	24 395..

Cat. No.	Capacity ml	Nominal diameter DN	Flange O. D. mm	Vessel O. D. mm	Height h mm	Full capacity ca. ml	Max. operating pressure at 250 °C[1] max.
24 390 24	100	60	100	70	85	195	2.5 bar
24 390 36	250	60	100	70	125	315	2.5 bar
24 390 44*	500	100	138	106	120	740	1.5 bar
24 390 54*	1000	100	138	106	205	1395	1.5 bar
24 390 63	2000	100	138	140	270	2620	1.5 bar
24 390 71	4000	150	184	200	290	5765	1.0 bar
24 390 76	6000	150	184	215	320	7320	1.0 bar
24 390 86	10000	150	184	240	410	11935	0.5 bar
24 391 54	1000	150	184	154	120	1915	0.5 bar
24 391 63	2000	150	184	154	200	3070	0.5 bar
24 391 68	3000	150	184	154	265	4090	0.5 bar
24 201 54[2,3]	1000	120	155	130	120	–	–
24 201 63[2,3]	2000	120	155	130	200	–	–
24 201 68[2,3]	3000	120	155	130	290	–	–
24 394 54	1000	120	158	130	125	1360	0.5 bar
24 394 63	2000	120	158	130	200	2200	0.5 bar
24 394 68	3000	120	158	130	290	3220	0.5 bar
24 395 63	2000	100	138	165	215	2610	1.0 bar
24 395 71	4000	100	138	206	265	4660	1.0 bar
24 395 76	6000	100	138	236	295	6675	1.0 bar
24 395 86	10000	100	138	280	340	11720	0.5 bar
24 395 91	20000	100	138	350	410	21415	0.5 bar

* Vessel cylindrical for full length
** Heating must be by water or oil bath. Suitable for vacuum desiccators.

[1] Designs suitable for higher pressure available on request.
[2] Flat flange beaker, flange without groove.
[3] Discontinued, available until stocks exhausted.

Figure 9

Flat flange lids*

Flat flange lid 4 standardised necks				Flat flange lid** with centre socket only
24 396 46	24 392 34	24 392 46 24 392 47	24 392 57 24 392 58 24 392 59 24 392 60	24 398 57

Cat. No.	Nominal diameter DN	Flange O. D. mm	Height h mm	Centre socket sizes	Side sockets sizes	Max. operating pressure at 250 °C max.
24 396 46	100	138	105	29/32	2 x 29/32 angled 1 x 14/23 parallel	1 bar
24 392 34	60	100	90	29/32	2 x 19/26 angled 1 x 14/23 angled	2 bar
24 392 46	100	138	125	29/32	3 x 29/32 angled	1 bar
24 392 47	100	138	125	29/32	2 x 29/32 angled 1 x 14/23 parallel	1 bar
24 392 51	120	158	130	29/32	2 x 29/32 angled 1 x 14/23 parallel	1 bar
24 202 51[3]	120	155	55	29/32	3 x 19/26 parallel	–
24 204 51[2,3]	120	155	105	29/32	–	–
24 392 57	150	184	130	29/32	3 x 29/32 parallel	1 bar
24 392 58	150	184	130	29/32	3 x 29/32 angled	1 bar
24 392 59	150	184	130	29/32	2 x 29/32 angled 1 x 14/23 parallel	1 bar
24 392 60	150	184	135	45/40	3 x 29/32 angled	1 bar
24 398 51	120	158	102	29/32	–	1 bar
24 398 57	150	184	102	29/32	–	1 bar

* Versions suitable for higher pressure available on request.
** Suitable for vacuum desiccators.

[1] Flat flange lid, 4 standardised necks.
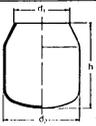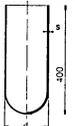[2] Flat flange bell lid, with centre socket only.
[3] Discontinued, available until stocks exhausted.

Figure 10

Cylindrical vessels,
flat flange and reaction vessels and vessel blanks with lids

Tips for apparatus makers

1. The figures given in the operating pressure tables are only valid for Schott's original vessel blanks, on condition that no subsequent reduction in wall thickness occurs.

2. In accordance with technical codes of practice and regulations, the permissible operating/load data shall be determined for glass products which deviate from the original shape as a result of further processing.

Blanks for reaction vessels	Buttress, end ground, without groove	Flat flange, ground without groove	Flat flange, ground without groove	Blanks for lids, flat flange, ground	Blanks for lids, flat flange, unground	Round bottom cylinder for cylindrical vessels Rim cracked off
21 020..	21 033 57	21 034..	21 035..	21 036..	21 037..	21 027..

Blanks for flat flange reaction vessels

Cat. No.	Capacity ml	for nom. diameter DN	Height h mm	Neck d_1 mm	Vessel d_2 mm	Max. operating pressure at 250 °C max.
21 020 54	1000	100	145	–	106	1.5 bar
21 020 63	2000	100	210	106	140	1.5 bar
21 020 71	4000	150	210	155	200	1.0 bar
21 020 76	6000	150	240	155	215	1.0 bar
21 020 86	10000	150	330	155	240	0.5 bar

Buttresses, flat flanges and flat flange lids

Cat. No.	Nominal diameter DN	Flange O. D. mm	Height h mm	Dia. d_1 mm	Max. operating pressure at 250 °C max.
21 033 57	150	184	120	–	–
21 034 34*	60	100	50	68	2.5 bar
21 034 46*	100	138	60	106	1.5 bar
21 034 51*	120	158	60	130	1.3 bar
21 034 57*	150	184	75	155	1.0 bar
21 034 61*	200	242	75	215	1.0 bar
21 035 34	60	100	50	68	2.5 bar
21 035 46	100	138	60	106	1.5 bar
21 035 51	120	158	60	130	1.3 bar
21 035 57	150	184	75	155	1.0 bar
21 035 61	200	242	75	215	1.0 bar
21 036 46	100	138	65	–	1.5 bar
21 036 51	120	158	70	–	1.3 bar
21 036 57	150	184	70	–	1.0 bar
21 036 61	200	242	95	–	1.0 bar
21 037 34	60	100	42	–	2.5 bar
21 037 46	100	138	44	–	1.5 bar

* with groove

Blanks for jacketed vessels (round bottom cylinders)

Cat. No.	Height h mm	Cylinder Dia. d_1 mm	Wall thickness s mm	Max. operating pressure at 250 °C max.
21 027 377	400	65	3.5	3.0 bar
21 027 427	400	85	3.5	2.5 bar
21 027 477	400	105	4.0	2.5 bar
21 027 537	400	130	4.0	2.0 bar
21 027 557	400	160	4.5	1.5 bar
21 027 587	400	185	4.5	1.5 bar
21 027 627	400	215	5.5	1.0 bar
21 027 667	400	250	5.5	1.0 bar

Figure 11

Safety Precautions Concerning Gases and Equipment

by Gerald Davignon

Merriam-Graves Corporation, West Springfield, MA

I. Safety of oxygen - fuel equipment
   A. Protective equipment
      1. Wear safety goggles with shielded lense #4 or #5
      2. Protective clothing
   B. Location
      1. Operate in a well ventilated area - exhaust fans or windows
      2. Keep oxygen - fuel gas cylinders away from work area
      3. Protect cement or wooden floor with sand or fire proof materials
      4. Remove all combustible materials
   C. Cylinders in general
      1. Store oxy-acetylene cylinders at least 20 ft. apart or a 5 ft. fire resistant partition between cylinders
      2. Never lay fuel gas cylinder on its side (To be explained shortly)
      3. Never use a cylinder full or empty for a roller
      4. Close cylinder lightly when not in use and cap it
      5. Always tie down or secure cylinders full or empty
      6. Never open acetylene cylinders more than 1/2 to 1 1/2 turns always have the wrench in place on valve in case of emergency.
   D. Acetylene cylinders
      1. Heavy walls filled with porous materials (vary) corn pith, portlonel cement, balsa wood, etc.
      2. Filled 40% acetone colorless non-flammable which is absorbed by porous material
      3. Remainder of cylinders is filled with acetylene carbide and water mixture extremely dangerous, and explodes at 29-4PSI in pure state acetylene is absorbed by acetone which stabilizes it up to 250 PSI
      4. Cylinder has various safety fuse plugs which melt at 212 in case of fire
      5. Never use acetylene at higher than 15PSI at 50 cu. ft./hour
      6. Fuel gases such as propane chem-o-lene propalene are liquid and can be used at higher pressures. They are heavier than air and settle to the floor
      7. Hydrogen is a high pressure gas and should be handled safely.
   E. Oxygen cylinders
      1. High pressure usually 2100 PSI avoid dropping and breaking valve (balloon effect)
      2. Keep oxygen away from oil grease (spontaneous combustion)
      3. Keep oxygen away from burning materials
   F. Safety equipment
      1. Fire extinguisher CO/2/ and water
      2. Wet blanket
      3. Oxygen kit with mask

II. Description of Equipment
   A. Oxygen cylinder 2100 PSI various sizes up to 247 cu. ft.
   B. Acetylene and fuel gases low pressure, various sizes
   C. Oxygen - fuel gas regulators
   D. Hoses - oxygen right hand thread fuel gas left hand thread
   E. Check valves and flash arresters
   F. Torches and tips

III. Attaching Equipment
   A. Always attach equipment to appropriate gases CGA connection are different
   B. Open fuel gas first then oxygen
   C. Close fuel gas first then oxygen

The Reference and Abstract Section of the ASGS
(on a computer)

by Gary Coyne
University of Southern California, Los Angeles, California

Information can be lost if people are unaware of it and do not have an effective way to find out about it. Therefore, with the intention of passing on information, in 1962 the Reference and Abstract section of Fusion was begun. It had the simple intention to make fellow glassblowers aware of potentially interesting articles from a variety of journals. Articles have ranged from practical to theoretical, artistic to scientific, and from old to new. The Reference and Abstract section has proved to be such a success, that for the last 29 years it has continued with almost no interruptions.

Unfortunately, from the onset there were several limitations with the setup for the Reference and Abstract section. One limitation has required glassblowers to go to a library to obtain the cited articles. This is mostly due to copyright limitations with many journals that prevent the ASGS from distributing copies without payment or permission. Fortunately, most university level libraries have many of the cited journals, and the journals they don't have can be obtained by inter-library loan. All university libraries allow non-university people to use their facilities, and many allow some level of membership.

Another limitation with the Reference and Abstract section is usage. If you see something in a current issue that is of importance or interest to you–it stands out–it is found! Similarly, if you saw an article in the recent past that may currently be of interest to you, you are likely to re-find it. However, the further back in time you saw the article, the less likely it will be found. Furthermore, if you never saw a potentially helpful article, you'd never even know to look for it.

The only viable way for someone to examine past articles on a specific subjects is to collect them into a Cumulative Index. This has been done for articles in Fusion and the ASGS Proceedings. Unfortunately, a Cumulative Index has never been assembled for many cited articles in the Reference and Abstract section. Over the years the number of articles cited has grown so large as to make manual collection of them prohibitive.

In 1984, I became Chair of the Reference and Abstract section, and in 1985 I obtained a computer. The following year I saw the possibility of creating a Cumulative Index of the Reference and Abstracts with the computer.

The biggest challenge was entering into the computer all the past citations from 1962 to present. The data entry took about four years, and could not have been accomplished without the aid of a project called Educational Participation in Communities, or EPIC, at California State University, Los Angeles. Through this program, I was able to obtain high school students during the summer (at no charge to the ASGS) to enter vast quantity of data.

Currently, the Cumulative Index is a compilation of some 4,300 different citations that have been recorded in Fusion. For some time now we have been trying to find an economical manner in which to print and distribute a hard copy version of the index to all members. Its size, almost 600 printed pages, has made this task quite a challenge. At this point in time, all I can say is I hope we have it soon.

Despite the fact that the printed index will contain all the cited references, there is still a limitation on finding information in the hard copy of the Cumulative Index due to the lack of cross referencing. This is because cross referencing could have doubled or tripled the printed size of the index. The reason for cross referencing articles is because some of them contain more than one subject and when it came time to place an article in the index, an executive decision needed to be made how it would be catagorized. For example, an article that talked about (vacuum) traps is easy to place under the subject: **Vacuum - Traps**. However, if an article talked about vacuum systems in general, it would be placed under the subject: **Vacuum**. If an article under the **Vacuum** listing contained an excellent discussion of vacuum traps, it is likely to be missed. Searching through all the articles in **Vacuum - Traps** and **Vacuum** may seem like a lot of work. Regardless, it is still better than having to go through each and every listing in each and every issue of Fusion you may have to obtain the same information.

The Cumulative Index, like any collection of information, can also be called a data base. Phone books, indices in books, and menus are examples of data bases in a printed form. You find information by following the alphabetical order of the subjects, or listing of food types, to obtain the information you need. In these examples the search led to a phone number, a page number, and a price. Notice however, that only part of the information within these data bases is in some order. The phone numbers are not in numerical order, as neither are the page numbers. Within menus, the only order is the type of meat or entree.

The term data base is more typically associated with computers and, for a number of people, computers are an expensive door stop. However, those who use computers know that they are wonderful for doing tedious-grunt type work. Obviously, computers are not required for straight forward demands such as phone books, indices, or menus. On the other hand, as searches become more complex, or the amount of material is significantly large, computers become a major tool.

To use a data base on a computer, it is handy to understand certain terms such as *field* and *record*. Simply, a field contains information, and a record contains fields, for example, one field can contain a name and another field can contain a phone number. These two fields together are a record. With a second name and phone number, you have two records, and so on. If you searched all the records for a specific name, the other field in that record would be shown displaying the phone number. If you added a third field, such as the zip code, you could then start doing some fancy tricks such as finding all the people who had the same zip code and telephone them.

To use the Cumulative Index data base on a computer most efficiently, you need to use Boolean logic. All Boolean logic does is to set the conditions for a search by the use of three words': **and**, **or**, and **not**. The full significance of these three words is very apparent when showing how they can modify a search. Remember that the modifier **and** will always decrease the number of potential finds, and the modifier **or** will always increase the number of potential finds. There will be far fewer articles that talk about traps **and** pumps than talk about traps **or** pumps. Thus, by establishing the proper modifiers for a search, the computer can examine all 4,300 records and display just the ones you are interested in, or provide all possible records that may be of interest for you to select from.

When using the Cumulative Index on a computer, the choice of fields in which you search for words can be critical. The **Subject** field we already know is limiting, and intended primarily for the hard copy. The **Title** field is an excellent location to search because any critical word mentioned in the title implies that the article will devote considerable time to that subject. On

the other hand, information in the **Citation** often details what may not have been specified in the title. Unfortunately, a number of references over the years have had no citation information entered. Thus, searches limited to the citation field will not bring up citation-empty references despite that article covering the desired subject. Computer searches of a single word can be significantly affected by examining the word in the Title **and** citation fields, or in the Title **or** Citation Field.

To demonstrate how a search is affected by where you search, consider a search for the word trap in three different fields'.

Searching for the word **trap** exclusively in the **Subject** field   16 articles

Searching for the word **trap** exclusively in the **Title** field   39 articles

Searching for the word **trap** exclusively in the **Citation** field   55 articles

Now consider how a search in the same fields can be affected by the modifiers **and** and **or**:
Searching for the word trap in the **Title** *or* **Citation** field   76 articles

Searching for the word trap in the **Title** *and* the **Citation** field   18 articles

Lastly, consider a two-word search looking for the words **cold trap** in the **Title** field or the **Citation** field, the **Title** *or* the **Citation** field, and finally the **Title** *and/* **Citation** field:

Searching for the words *cold trap* in the **Title** field   6 articles

Searching for the words *cold trap* in the **Citation** field   6 articles

Searching for the words *cold trap* in the **Title** *or* the **Citation** field   11 articles

Searching for the words *cold trap* in the **Title** *and/* the **Citation** field   1 article

Obviously, searching only for the words *cold trap*, means that you will miss discussions of cold traps in articles that didn't state cold trap. I repeat, when you compare this against the number of articles, or time, you would have missed by looking through past issued of Fusion, the Reference and Abstracts on a computer becomes a very adequate compromise.

As previously stated, the ASGS has a Cumulative Index of articles from Fusion and the Proceedings. This Cumulative Index has been updated, and will soon be sent to all members. In addition, I plan to reformat this information for inclusion into the Reference and Abstract data base. Currently, no Fusion, or Proceedings articles, are included in this index. In that regard, the Reference and Abstract Cumulative Index contains only those articles that have been submitted to this section. That means that this is not the sum and substance of all articles that could be of interest to members of the ASGS. If you ever find articles that could be of interest to other members, regardless of the age of the article, please get in touch with me so that it may be included in the Reference and Abstracts listings.

Before I begin several demonstration-searches in the Cumulative Index, I want to state that I'm using the data base program Filemaker Pro on a Macintosh. With that in mind, remember that the techniques that I'm going to demonstrate are peculiar to Filemaker Pro. Other data bases will have different techniques for searches, sorts, and other manipulation of the data. If you have any specific questions, please see me at any time.

(Live demonstration of specific searches)

When it comes to thank yous, I must first thank the previous editors:

The Axial Stress: The One That Bites, But is Usually Unmeasured in Tubular Sections

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Glass fractures in tubular sections occur most frequently as "ring-offs" (circumferential cracks), which are due to axial tension. Photoelastic observations in air, with optical path along a diameter, will generally not reveal the presence of axial tension. Detection is thwarted by either or both phenomena: (a) stresses are biaxial, of the same sense and near-equal magnitude; (b) optical retardations through the tubing wall sum algebraically to zero.

Oil immersion is reviewed as a reliable and simple means to detect and measure axial stresses photoelastically. Simple formulas and case studies are presented. Glassblowers are urged to set up a mineral oil immersion cell in conjunction with their polariscope or polarimeter.

I. Introduction

Most individuals that work with glass have experienced "ring-off" fracture with tubular geometries. Associated with this phenomenon, as observed in polariscopes or polarimeters, is the stress that is commonly called "ring strain".

The purpose of this paper is to shed some light on residual stress systems in tubular glass bodies, near the ends, especially after flame working. Particular attention is given to the axial stress which is seldom measured, but which is frequently the stress that causes fracture.

II. The Tubular Stress System

A section of glass tubing is shown in Figure 1, which shows the principal stresses that can exist within the glass: circumferential, axial, and radial. Since the stresses of interest are residual, we can ignore the radial stress. This is justified by the fact that fracturewill originate from the glass surface and laws of mechanics demand that the radial stress is zero at the surface.

Accordingly, concern must be focused on the circumferential and axial stresses as potential fracture-causing agents. Furthermore, tensile stresses of significant magnitude are of major concern.

Because fracture propagation is normal to the tensile stress direction, "ring-off" must be due to the axial stress. Therefore, the axial stress must be given major attention.

III. Photoelastic Observations

Photoelastic measurements are, by far, the best way to determine residual stresses in tubular sections. As described in ASTM Designation F218, either a polarimeter or a polariscope can be used satisfactorily to provide quantitative or semi-quantitative data. For best precision and accuracy, the polarimeter is recommended.

Consult Figure 2a, in which the light path is assumed normal to the printed page. If one uses the light path A the optical retardation observed is due to the difference between the mean circumferential and axial stresses, $\sigma_C - \sigma_A$. Therefore, it is difficult to resolve either one accurately. On the other hand, sighting along light path B eliminates the circumferential stress

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since its direction is parallel to the light path. The radial stress does play a part in path B, but it is small in magnitude and zero at the surface Therefore, path B is the preferable choice.

There are two problems with path B, but they are solvable. The first problem is that the refractive indices of air and glass differ substantially making observations in air impossible. This is why most observations and measurements are made at point A, with unsatisfactory information. This problem is easily solved by immersing the glass in oil that has an index of refraction close to that of the glass.

Most glassblowers work with low expansion borosilicate glasses, for which ordinary mineral oil is ideal. It is inexpensive, as well. For other glasses, oils can be purchased from R.P. Cargille Laboratories, Inc., Cedar Grove, N.J., at higher cost, however. The container for the oil must be transparent, and have flat and parallel sides. Tropical fish tanks, available in many sizes, are ideal and reasonable in price. One should check the stress retardation of the tank before using it. Most are fabricated with well-annealed glass and present no problem with background retardation. The center of the glass panel in the tank certainly should give no background.

The second problem is that the optical path increases as observations proceed inward towards the center of the tubing, as shown in Figure 2b. Furthermore, it is obvious from Figure 2b that the axial stress function through the wall becomes progressively integrated into the resulting retardation as observations proceed inward. Fortunately, Ritland (1) and Sutton (2) have developed the mathematical solutions for these considerations.

IV. Axial Bending - A Common Occurrence

Firepolishing the ends of tubing is frequently done and the purpose is to smooth the geometry of a jagged, irregular cut. Sometimes this firepolishing is left unannealed, frequently based upon polariscopic or polarimetric stress measurement made in air. A disastrous stress situation can result.

Consider what occurs at the end of a piece of tubing during firepolishing. Only the end of the tubing gets hot, exceeding the annealing point so that complete stress release takes place as it is heated. However, on cooling the hot end now contracts and, upon reaching room temperature, wants to be at a smaller diameter than the rest of the tubing. This forces an elastic adjustment shown in exaggerated form in Figure 3. This adjustment produces pure bending at two places in the transition zone above the heated portion of the end. The detrimental bending is at the point that produces tension on the outside surface where surface damage is more probable.

Axial bending is easily recognizable from the retardation function through the wall with oil immersion. As shown in Figure 4, for simple linear bending stress, the resultant optical retardation peaks at one-fourth a wall thickness in from the outside surface, then declines to zero at three-fourths wall thickness, and finally at the inside surface, reaches the same magnitude of retardation attained at the initial peak, but opposite in sign.

Once recognizing and establishing that this function exists, the stress is calculated from the equation given below:

$$\sigma = \frac{1.5 \, Rp}{K\sqrt{Da}} \qquad (1)$$

where: σ = Stress at the surface, psi,

Rp = Optical retardation, nm,

K = Stress -optical constant of glass, nm,/cm/psi,

D = Tubing diameter, cm. and

a = Wall thickness, cm.

For white light source measurements of a laboratory apparatus borosilicate glass (Corning Code 7740), using a Friedel polarimeter, Formula 1 reduces to:

$$\sigma = \frac{17.1A}{\sqrt[2]{Da}} \qquad (2)$$

where: A is the analyzer rotation in degrees.

One can recognize the bending stress retardation function using a polariscope. After observing the peak colors in one orientation, rotate the piece (or polariscope) 90°. The colors will reverse, and if they appear to be equal to those in the original orientation, bending has been verified. Approximate retardation magnitudes can even be determined by color comparisons with strain discs or other standards.

Results of a field problem with a tubular product demonstrate that measurements in air may not reveal the peak tension. Measurements of a flame polished end are shown in Figure 5. Measurements in air showed tension (circumferential) to be present at a magnitude of only 600 psi. Oil immersion measurements indicated that bending was present at a level of 1600 psi. These articles failed when thermal process stresses added to these residual stresses.

V. More Complicated Axial Stresses

Ritland (1) and Sutton(2) instruct how to determine axial stresses with any function. To elaborate in detail on this procedure is outside the purpose of this paper. Briefly, it involves measuring the retardation function in detail through the tubular wall and processing the data into stress by numerical integration.

A recent serious breakage problem with a tubular product demonstrated again that retardation measurements made in air only are inadequate. In air, circumferential tensions appeared to be much less than 1000 psi. In oil, tension on the outside surface exceeded 6000 psi! The glass tubing was a laboratory apparatus borosilicate with an outside diameter of 1.86cm and an inside diameter of 1.36cm.

This product was flamepolished on the end. After detecting the high tension in oil, the problem was easily diagnosed by observing the flamepolishing process. Occasionally, the high intensity flames would impinge on the outside surface 1/2" to 3/4" from the end, causing severe local heating. At these points temperatures would exceed the annealing point of the glass, releasing the temporary stresses. Then, upon cooling, the hot surface trying to contract relative to its cooler neighbors (interior parts of the wall and surrounding surfaces), is forced into very high tension.

Figure 6 shows plots of both optical retardation and resolved axial stress through the tubing wall. The optical retardation starts at zero on the outside surface because the optical path there is zero. Just inside the outer surface the optical retardation rises rapidly due to the high tensile stress. The impact that this has on stress is shown in the companion plot on Figure 6. The

tensile stress at the outside surface was calculated as 6300 psi, indeed high enough to cause surface checking of the glass. It is logical to conclude that a local circumferential stress of the same magnitude accompanies this high axial stress, but it can not be measured photoelastically because the difference in principal stresses is zero.

A polariscope with oil immersion shows the presence of this high tensile stress as the tubing is rotated. A semi-quantitiative analysis is also possible. The peak colors in the polariscope appear to be either orange or gray-white, depending on the orientation of the tubing with the full wave plate. Consulting Table 2 of ASTM Designation F218, these colors indicate that they are equivalent to a polarimeter analyzer rotation of about 120°, which, when multiplied by 3.15 nm/degree, equals 378nm optical retardation.

The stress therefore is calculated as given below:

$$\sigma = \frac{Rp}{K\sqrt{Dfa}} \qquad (3)$$

where   Rp = Peak retardation, 378 nm,

K = Stress-optical constant, 0.277 nm/cm/psi,

D = Outside diameter, 1.86 cm,

f = Fractional part of tubing wall in from the outer surface where peak retardation is observed, 0.1, and

a = Wall thickness, 0.25 cm.

Substituting values, σ = 6200 psi. This exercise points out that numerical integration is not necessary to get a good stress approximation. However, this is only true if the peak retardation is close to the surface ($f \leq 0.2$).

VI. Conclusions

This discussion alerts those involved with thermal processing of tubular glass sections that photoelastic observations in air can seriously understate the residual stress condition. It instructs how easily and inexpensively an oil immersion tank can be added to a polarimeter or polariscope. Simple bending is discussed and easily recognized. Stresses in some more complicated patterns can also be approximated.

It is hoped that this paper will encourage glassblowers to add oil immersion to their polarimeters or polariscopes.

VII References

1. H. N. Ritland, "Stress Measurement in Cylindrical Vessels", J. Am. Ceram. Soc. 40, (5), 153-158 (1957).

2. P. M. Sutton, "Stress Measurement in Circular Cylinders", J. Am. Ceram. Soc. 41, (3), 103-109 (1958).
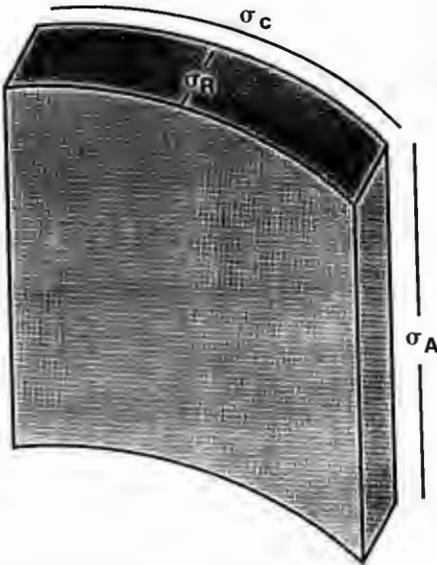
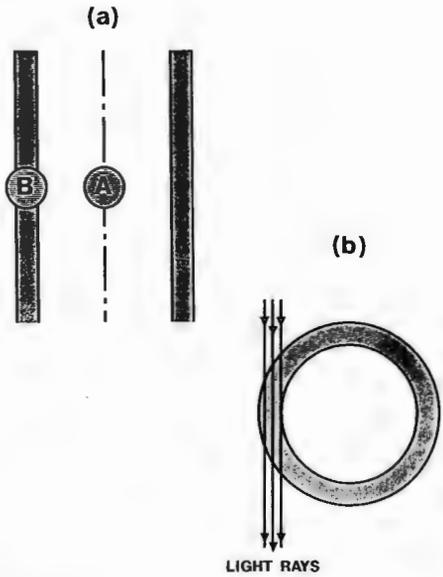Figure 1. Principal Stresses in a Tubular Section

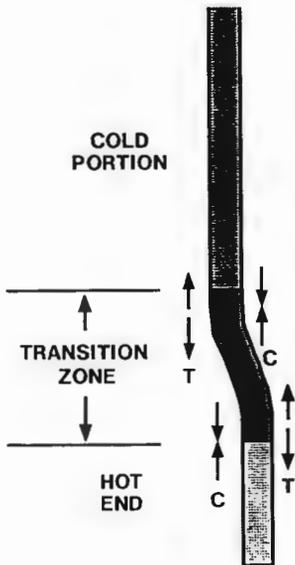

Figure 2. Optional Viewing Paths Through Tubing

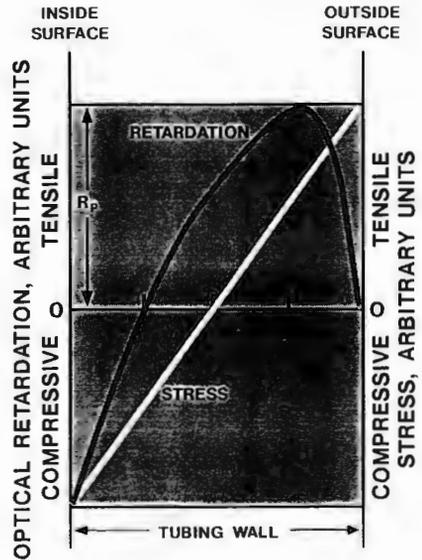Figure 3. Residual Bending Stresses Following Flamepolishing of Tubing End

Figure 4. Stress and Optical Retardation Functions in the Tubing Wall for Pure Bending
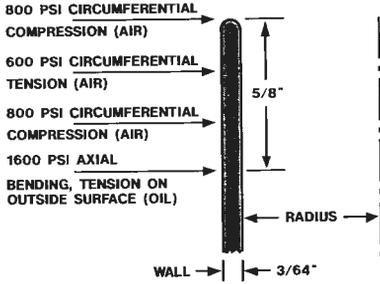
Figure 5. Measured Thermal Residual Stresses in a Firepolished Tubular Glass Article
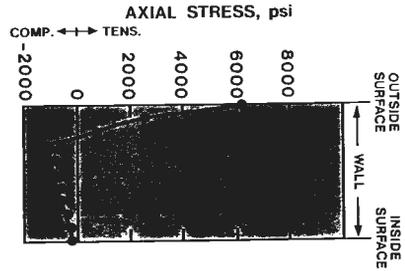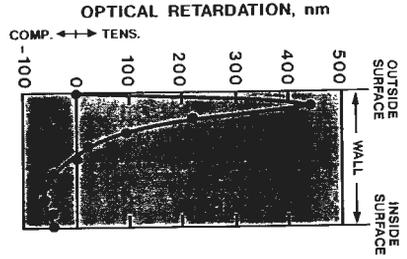

Figure 6. Measured Optical Retardations and Calculated Stresses in a Tubular Glass Article Improperly Flamepolished

A High Efficiency Gas Diffusion

Burner Design
by Scott Hiemstra

I'd like to preface my remarks this morning with a couple of qualifications. First of all, I am not a very good soft glass and Pyrex glassblower. The bulk of my experience is in working quartz and the comments I'll be making this morning will be directed specifically to the torches and burners a quartz glass blower will ordinarily use with Hydrogen gas for a fuel. I have no doubt that the ideas and design considerations we'll be discussing are applicable to the torches soft glass and Pyrex glassblowers commonly use, but are probably, for reasons that will become clear presently, not as significant to efficient glassblowing as for quartz workers. Also, this is not a topic that came to me out of the blue one night. I never had the temerity to imagine that the torches quartz glass blowers use were not very good or even stood in need of minor improvements. On the contrary, even after I had begun to blow glass in the Rocky Mountains, and had discovered that the equipment which worked perfectly well in the San Francisco Bay Area at sea level was completely inadequate at 6000 feet of elevation in Colorado Springs, it only occurred to me after a couple of years that the burners might be at fault. In the meantime I blamed the gas lines, or the regulators, or the gas saver, or even contaminated gas. What I'd like to share with you this morning is what I found out was really going on and what we can do about it.

This is a cross section of a Litton or Carlisle n-Jet ring burner tip. They come in three sizes with the number of jets varying from 1 for the smallest size to 14 for the largest size. I have shown here a cross section for the intermediate size with three jets in the median section. When the fuel is turned on to this burner it passes through the burner along the outer annular region up towards the cap and out the major orifice. If the fuel is ignited at this point it will burn with a very diffuse flame, the oxygen necessary for combustion being supplied by the ambient air diffusing into the plume of fuel gas. We might also add that while air is diffusing into the fuel gas plume the fuel gas is also diffusing into the ambient air. This type of flame is not much good for anything of course, except perhaps for preheating and taking the moisture chill off the glass. If we want to get any work done we need to turn on the oxygen. When oxygen is supplied to this burner it passes to the center and proceeds up the core to a set of small diameter orifices. There it is injected into the fuel gas stream and combusts with the fuel to give the flame some punch. In fact the oxygen injected into the center of the fuel stream completely combusts and gives the flame shape, directionality, momentum, heat, and intensity—all the things that make the flame worth having around. Oxygen injected into a fuel stream typically raises the flame temperature some 30-35% and increases the speed of the flame particles some 300 to 1000%. That gives us a lot of energy to concentrate on the surface of the glass to melt it, soften it, shape it, mold it, blow it, or whatever we're interested in doing to it. The fast flame particle speed induced by the oxygen also draws—entrains—into the flame surrounding air to help combust the fuel gas that diffuses away from the central oxygen jet. It is a mistake to suppose that when we put oxygen into a fuel plume all the fuel molecules are overjoyed and say: Look fellas! All them oxygen molecules. Let's go over and make some hot water vapor! They'd much rather continue in the any which way they were already going.

This was the first surprise to me on learning how these flames work. One cannot inject into the center of the flame enough oxygen to completely combust the fuel. If one tries all that is accomplished is a lean, cool, flame center that lifts off the burner from the oxygen running in too fast. Unfortunately, the air that carries oxygen into the outer portion of the flame to finish combusting the fuel, adding heat to the flame, also carries in nitrogen which acts as a heat sink, diluting the flame and cooling it off.

These natural design limitations of the Litton/Carlisle n-Jet Burner tips are exacerbated by the choice of hydrogen for the fuel gas and by operating them at high altitudes where the arr ·ent air is thin. These burners rely on the ambient air for some 25-30% of the oxygen consu.. the flame. Operating them at high altitude is subject to the same constraints a fighter p. experiences at high altitude: if his body requires a given amount of oxygen, and his lungs can only draw in a given volume, all of that volume better be oxygen. These burners would do well to have an oxygen mask at high altitude.

Secondly, compared to well behaved fuels like methane or propane, hydrogen is ill-mannered and unruly. The usual hydrocarbon fuel molecules are roughly the same size as oxygen, travel at about the same speed as oxygen, and diffuse at about the same rate. They generally, when directed into a plume, will stay there for awhile and give the oxygen an opportunity to show up and make some hot water vapor. In contrast hydrogen is a very small molecule compared to oxygen, moves a lot faster, and diffuses rapidly. If a molecule of hydrogen isn't heading in the direction of some oxygen, the oxygen simply will never catch up with it. In comparison with methane and propane about four times as much fuel is wasted, that is, combusted by the nitrogen cooled ambient air, when hydrogen is chosen as the fuel.

In sum then, the Litton/Carlisle n-jet burner tips have a design limitation that derives from an inadequate diffusion of oxygen into the gas plume.

One way quartz glassblowers get around oxygen limits of the Litton/Carlisle burners is to use AGF style burners. It isn't readily appreciated that one can push just as much hydrogen through a Litton/Carlisle burner as one can through an AGF burner. The difference in heat obtained is the emphasis the AGF burner places on oxygenating the gas plume. For those of you familiar with AGF burners I should point out a couple of discrepancies in the drawing form what you may be used to. First, I have labeled the gas ports in accordance with common usage, that is, oxygen into the back and up the jets and injected into a field of hydrogen. This is equivalent to the Litton/Carlisle scheme with the exception that the flame is generally broader and softer with more jets involved. This labeling is contrary to the factory label which suggests that the burner should be operated with fuel coming into the back, up the jets, and injected into a field of oxygen. This scheme has the virtue of completely combusting the fuel as the fuel has nowhere to go but diffuse into the oxygen. Unfortunately, with hydrogen as the fuel, because hydrogen diffuses about four times faster than oxygen the characteristic conical flame front has a tendency to expand beyond stability. Also, because the oxygen is larger and heavier than the hydrogen, it tends to carry the venturi entrainment and so pull the flame front apart as well. The result is a poorly shaped, diffuse flame, lacking momentum and not very good at transferring heat from flame to glass. The reason, I think, why the parts are misla-beled is that when these burners were built to the original specification in the mid 1960's when they were first developed, the labeling was correct.

Figure 2A shows the original orifice geometry. The large annular region about the gas jet originally was not drilled completely through the face. Rather a pilot hole just large enough to pass the jet was bored through the face, that kept the jet centered, three small holes were broached next to the pilot hole to pass the oxygen to the surface, and finally each jet was given a counterbore relief. When the burner is constructed to these original specifications, the labeling is correct for the effect is to generate three small oxygen jets into a field of hydrogen. That way the gas flow scheme is identical to that of the Litton/Carlisle burners except that the fuel is super oxygenated.

Incidentally, the whole point of the original specification was to prevent flashback and "pop-ping". I suspect that the burners got too expensive to machine given the rising labor costs of

the sixties and seventies. Unfortunately, drilling the final counterbore completely through the face plate vitiated the most attractive features of this burner. What is left is a burner that has the same gas flow scheme as the Litton/Carlisle burners and so the same design limitations, although on a lesser scale because the AGF burners tend to have a larger cross section to perimeter ratio.

In assessing these torches, one would like to preserve the level flame of the AGF Burner, the ability to get a sharp strong flame of the Litton/Carlisle burners, and of course eliminate the design limitations of each. Recently Weiss Scientific of Portland, Oregon has developed a hybrid of the Litton/Carlisle and AGF style burner. It is essentially a Litton/Carlisle burner with the top cap closed over and the oxygen jets extended into tubes which bring the gas to the cap surface. While preserving the desirable features of both burners, this hybrid emphasizes the design limitations common to both by reducing the cross section relative to the perimeter.

This is a diagram of an efficient gas range burner developed by William Traub of Chicago in the early 1920's. If this old boy is still around I wouldn't mind taking him out for a few cold ones as what he knows or knew could have saved me a lot of trouble over the years. Traub's idea here is to encapsulate the gas—methane in this case—completely in the supplied oxidant, here air. You can see from the drawing that the gas is supplied to the burner surface through the annular regions 4a which are surrounded by an envelope of air supplied to the surface by the regions 10a. The central core of the flame is supplied with air through the jets 9. The effect is, thinking in terms of the Litton/Carlisle burner, to place an envelope of oxygen about each minor jet within the flame. Or alternately, to inject the fuel into a field of pure oxidant.

Traub's idea was applied in just such a way in the late 1970's by Meinen Herren Leinberger and Golke working in Germany to improve burners for slag melting in steel mills. Here the oxygen flow from chamber 34 is split into two components. Part is directed up jet 50 to form a flame with the fuel, a liquid hydrocarbon aspirated down passage 22 by the oxygen. The other part is directed through passageway 40 into an upper chamber 36 and thence into the orifice 28 to supplement the flame. Leinberger and Golke found that the thus enriched flame was not only good for melting slag but also had no trouble melting off the end of their burner! They had to go to quite a bit of trouble to cool the end of their burner and so preserve the intense flame intact.

This is an enlarged schema for the idea of Traub as applied by Leinberger and Golke. I have labeled the gases Hydrogen and Oxygen as I would like to apply the idea to the Litton/Carlisle and AGF combination burners we've been discussing. Again, here oxygen is supplied in a central jet to establish in a field of hydrogen a well defined energetic flame. About that flame an envelope of oxygen is directed through the outer annular region of the orifice to complete the combustion of the hydrogen diffusing away from the major flame front. Since the oxygen in the envelope carries no nitrogen the flame is neither diluted nor cooled. Since the bulk of the oxygen is supplied to the center of the flame, the flame dynamics are well established and the flame remains stable.

I have built some burner tips for use on a Litton ring burner that employ this gas flow scheme of Traub's. They are equivalent to the standard 7-jet tips normally used for working quartz tubing of moderate diameters. At high altitude with hydrogen fuel they perform the way such burners ought to perform anywhere. The improved performance is indicated by flame temperatures elevated by about 10% and by efficiencies improved by about 25%. The efficiencies were measured by the given amount of hydrogen required to perform a standard seal and pull down.

I have also tested these burner tips at sea level, where they work equally well. We have developed a rule of thumb for the number of tips required to work standard wall quartz in various diameters. Basically one tip is required for every inch of diameter although this tends to push it. So while a 6-Fire can work 150mm quartz tubing, it is more easily done with an 8-Fire. Also while 220mm tubing can be worked with an 8-Fire it is more comfortably done so with a 10-Fire. I'd like to invite you to compare that performance with your experience of the standard burners.

References:

1. U.S. Patent #1,723,667; William F. Traub; 6 August 1929

2. U.S. Patent #4,320,874; Klaus Leinberger and Heinz Golke; 23 March 1982.
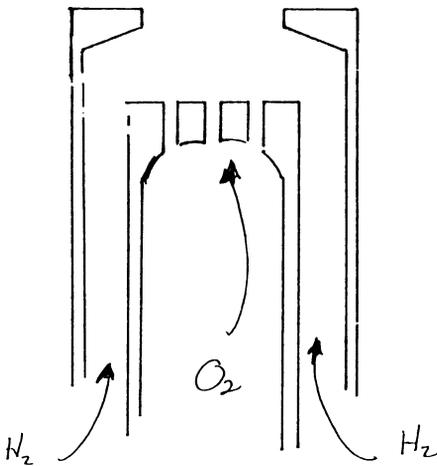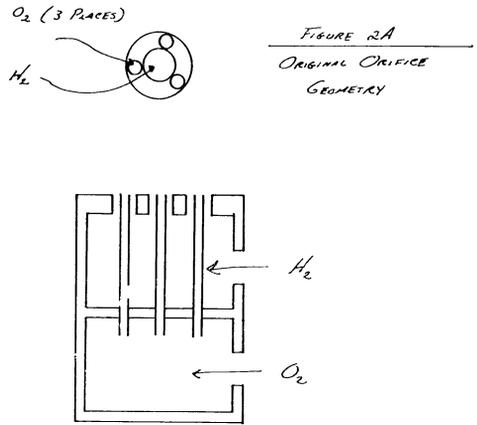
Figure 1. Litton/Carlisle N-Jet Burner Tip

Figure 2. AGF Style Surface Mix "Teleshefsky - Korzeb" Blow Pipe.

Filed June 19, 1922
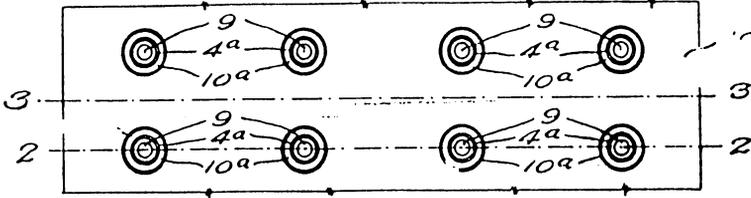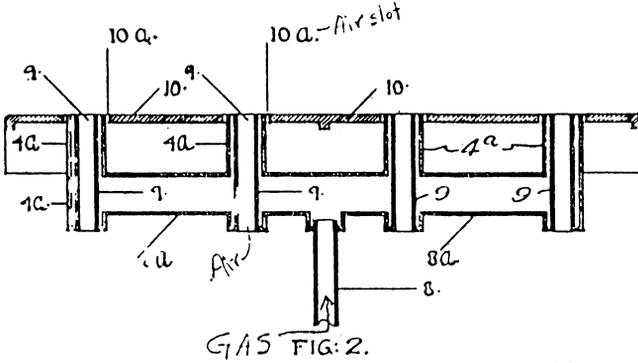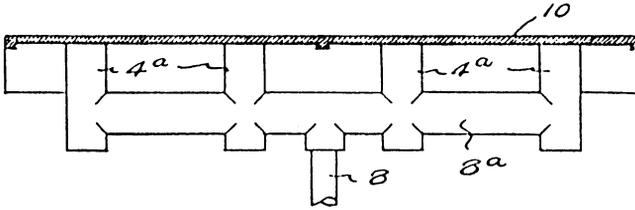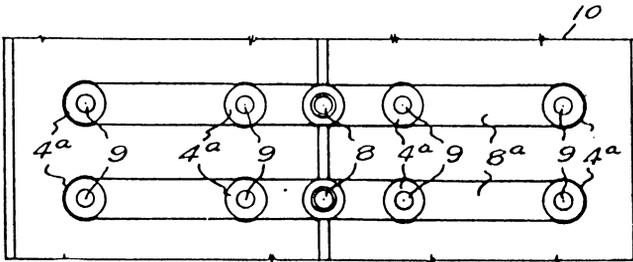

FIG: 1.

GAS FIG: 2.

FIG: 3.

FIG: 4.

INVENTOR:
William F. Traub

BY: Parker & Carter

ATTORNEYS.

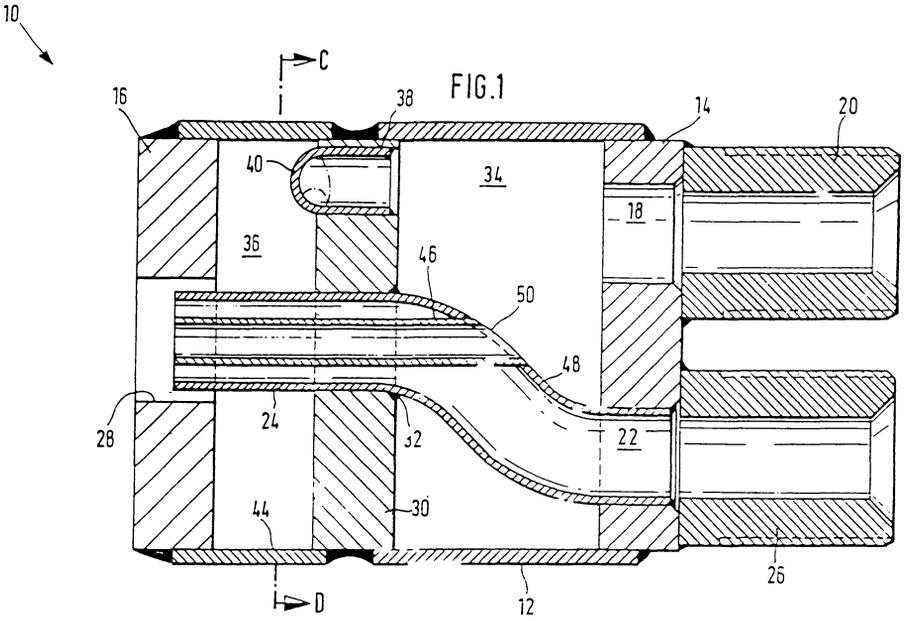Figure 3. "Traub" - Gas Range Burner
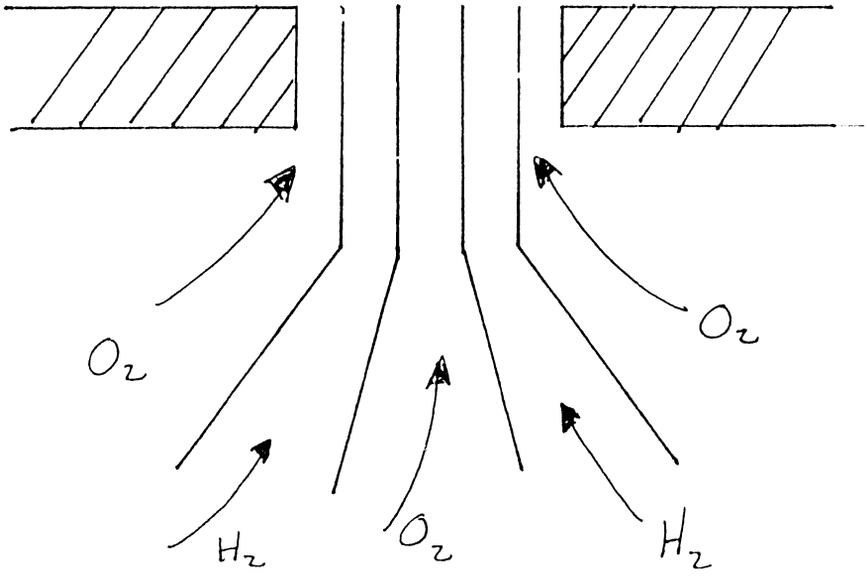
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Figure 4. "Leinberger-Golke" Slag Melt Burner

Figure 5. Double - Diffusion Orifice Detail

Construction of the Dewar
for the First 112-Element Flir Detector Array

by Royce Carter

Man has desired to see at night since the beginning of time. Militarily, the need for night vision was never more evident than during the Korean War when the Chinese infiltrated thousands of troops at night, while the U.S. military leaders were debating whether or not China would enter the war.

Initial efforts to devise a method of night vision resulted in the image intensifier tube, a rifle scope that intensified existing starlight or moonlight many times to obtain a clear picture at night. That method is still used today for rifle scopes and for goggles worn by helicopter pilots at night for military operations. The major drawback in the system is that it is dependent on existing light. If there is no moon or starlight, the system will not work.

Another more sophisticated and reliable system, patented in the mid 1960's by Texas Instruments Incorporated, is the forward-looking infrared (FLIR) system.

This method, using an infrared detector array, uses the radiation emitted from objects to generate minute electrical signals that can be directed into a small television screen (CRT) or visible light-emitting diode (VLED) array to generate a live picture. Of course, still pictures can also be generated.

The uses of this system are numerous. In daylight, the FLIR system has advantages over visual systems. By detecting minute differences in heat, it renders camouflage techniques ineffective.

In 1968, Texas Instruments had extensive knowledge for manufacturing IR detectors to guide heat-seeking missiles and of integrated circuit technology. So it was a natural progression to combine the technologies to acquire a multi-element IR detector array.

In missile guidance systems, only one or two detectors were necessary, but the FLIR system requires a multiple detector array, housed in a single container, to achieve a clear, distinct picture.

This paper details construction of the container, or dewar, used for the first 112-element FLIR detector array.

The materials used for making the array were indium antimonide or mercury cadmium telluride. These materials were operable only at -196°C, hence the need for packaging in a vacuum dewar. This dewar required a special IR transmitting window on one end, 114 Kovar metal leads out the other end, and a precision bore cold finger (±.0005").

Fabricating the dewar presented problems - some obvious, some not so obvious. I will list the problems first, then try to explain how they were resolved.

Problems

1. The first problem was fabricating a reusable dewar with 114 metal leads. If a problem developed after the expensive detector array was sealed inside, we would need to reopen the dewar to resolve the problem.

2. Assuming that 114 Kovar wires could be sealed through the outer wall into the vacuum chamber, the next problem was to attach 114 connecting leads onto the O.D. precision bore cold finger to join the array to the outer leads.

3. As mentioned, a special IR transmitting window (synthetic sapphire or zinc sulfide) must be bonded to the end of the dewar. The outer surface of this window must be held to a specific distance from the detector array surface ($\pm 0.005"$).

4. The not-so-obvious problem was reducing the heat load of the dewar by controlling thermal conduction and radiation in a dewar that could not be baked at over 100°C, sometimes no more than 80°C, depending on the detector array material.

5. The first system had to be shipped within 6 months. This influenced our approach considerably. A workable package had to be developed as soon as possible, then improved as time allowed.

All glass tubing was made by Corning. The Kovar wires, tubes, and disks were deburred with hydrochloric acid and wet fired in a hydrogen furnace at 1000°C for 10 minutes. The Kovar was certified to withstand -196°C without undergoing phase transformation. The sapphire windows sere single crystal, purchased from Adolf Meller Co. or INSACO. The zinc sulfide windows were Kodak's Irtran II material. When using any acids, care must be exercised to prevent serious injury.

Solutions
1. Except for the distance from the detector array to the outer surface of the optical window, the physical dimensions were not difficult to hold.

The dewar had to be made in two parts, the inner flask and outer envelope. Each part would have a Kovar interlocking tube to facilitate soldering together instead of welding, making it easy to disassemble if necessary.

Using proper fixtures when fabricating the parts allowed the dimensional tolerances to be controlled.

The precision bore tubing was readily available from Richland Glass or Wilmad Glass in New Jersey.

For soldering the parts together, we used a 4% silver bearing solder, made by Allstate Solders, which melted at 226°C. This proved to be a good solder for vacuum integrity and could be gold-plated easily.

From past experience, I determined that it would be more feasible to seal the Kovar wires radially instead of through the end of the dewar because of space limitations and ease of fabrication.

A simple fixture was made for bending the 0.030" diameter Kovar wires 90 degrees to a precision length. Two other fixtures, one aluminum and one graphite, held the wires in a spoke configuration. A spot-welded metal ring around the radial ends of the wires served as a lead frame support.

The wires were then removed from the aluminum fixture but still remained in the graphite fixture. The graphite fixture was chucked into the lathe. I then oxidized the circular row of

Kovar wires and fused 7052 glass rod around their circumference. This supported the lead frame at both ends, which was necessary when making the inner flask.

Making the glass/metal seals to the Kovar interlocking tubes required an RF generator because of the short length of Kovar tubes. Also the generator was used to seal the Kovar disk to the cold finger. Both seals required special fixtures to hold the glass and metal concentric and to control the amount of glass fused to the Kovar metal. The shaft in these fixtures is adjustable, using a slip ring with screw to control the amount of glass that is fused to the metal parts. Care must be taken to never touch R. F. coil when using generator. Resulting electrical shock could be fatal.

The 1.5" diameter Kovar ring was loaded into a boron nitride susceptor at the face of the fixture; the 1.6" diameter glass tube was loaded into the holder on the shaft of the fixture; and the slip ring for seal control was adjusted. The glass tube was raised off the ring and the power was turned on. The power was controlled by a variable transformer. Power was increased until the Kovar ring was red hot. The power was lowered to let the oxide form and set on the Kovar ring. Then the glass tube was lowered onto the Kovar ring and power was increased again until the Kovar was so hot that the glass started melting around the edges, housekeeper style. When fully melted, power was reduced and a visual examination of the seal was made. If the seal was good, it was removed - if not, it was reheated until the proper shape and color were obtained. All Kovar seals were made at this time.

The Kovar disk was sealed to the cold finger basically the same way using different holders. The cold finger tubing was prepared by flaring one end approximately 1.5" in diameter. The tube was then precision cut to a specific length to accommodate melting to the Kovar disk. The cut end was cleaned with 10% hydrofluoric acid, rinsed, and dried. Both were loaded into the RF fixture, and the slip ring that controls the meltdown depth was set using an appropriate spacer (around 0.015").

As with the Kovar rings, the glass tube was held above the disk while oxidizing, then it was set down and power increased to make the seal. All parts were annealed at 550°C.

For making precision, large quantity seals, the RF generator can't be beat.

After the parts were annealed, the glass with the interlocking Kovar tubes was cut to a predetermined length, cleaned in 10% hydrofluoric acid on the cut end, rinsed, and dried.

The glass tube with the Kovar tube having the inner step was loaded into a special fixture in the lathe headstock. A 1.6" diameter 7052 glass tube with a stopper in one end was loaded into the lathe tailstock. Both edges were heated and flared approximately 1/8".

The Kovar lead frame was oxidized with a hand torch and placed inside the fixture in the lathe headstock. The tailstock was moved in to press the lead frame between the flared ends of the glass tubing.

The lathe was started, and using a lathe burner connected to a proportional control valve, the parts were heated until a good sodium glare was present. The lathe was stopped and the proportional valve turned off, but it was adjusted so that a small, slightly oxygen-rich flame played on the bottom of the parts.

Using a small Hoke torch (#3 tip), the glass flare was melted on one side of the Kovar lead frame. The melted glass was rolled into the Kovar lead frame with the side of a 1/4" graphite

rod. The glass on the other side of the Kovar lead frame was melted and rolled in the same way. Then both sides were melted thoroughly so they fused together, leaving no pinholes. This first melt was only 3/4" long but was extremely critical. If not fused together thoroughly where you start, eliminating a reentrant seal, the glass will crack before completion.

The lathe and proportional valve were turned on, the part was reheated thoroughly, and the previous technique was repeated except for fusing a distance of approximately 1 1/4" around the circumference.

This procedure was repeated until the seal was completed all around. Rolling the glass in with the side of the graphite rod instead of pushing it in with the end of the rod provided a good smooth shape on the outer diameter of the seal. To ensure a good seal inside the dewar, a hydrogen-oxygen flame was used and the speed of the lathe was increased (to 300 rpm.). The glass was heated at a tangent next to the lead frame until the glass was thoroughly melted.

After removing the flame, I waited a few seconds and blew hard through the blow hose attached to the fixture to radius the inside of the seal. This was repeated on both sides of the lead frame. The reason for waiting before blowing was to move the thicker glass around the Kovar wires. By hesitating, the thinner glass cools and will not move, while the thicker glass retains enough heat to be soft and movable.

By spinning the lathe faster on this operation and keeping the flame next to the lead frame but at a tangent, the Kovar wires do not get hot enough to burn in two.

I flame annealed the part with the lathe burner, then, with the hydrogen-oxygen flame, I fire cut the tubing in the tailstock approximately 1/2" from the lead frame. I melted it back smoothly, inserted the cold finger with the Kovar disk, and melted the two parts together (dewar seal). A long 3/8" diameter graphite rod ensured the Kovar disk was pressed against a stop inside the fixture. This provided the proper length from disk to Kovar interlocking tube.

The part was removed and annealed in an oven. After annealing, it was descaled in hydro- chloric acid and bright dipped. (Bright dip is a solution of acetic acid, nitric acid, and hydro- chloric acid that makes the Kovar metal bright and shiny.) The part was washed thoroughly to remove all acid, rinsed and deionized water, and dried.

2. Once the inner flask was bright dipped and clean, the next problem involved attaching 114 connecting leads down the length of the cold finger. I determined that it was impossible for me to fuse 114 platinum or Kovar wires down that length without shorting out the leads, burning them in two, and distorting the precision inner diameter of the cold finger beyond salvage. Also, the heat load of that many wires would render the array inoperable.

I decided to try evaporating a metal layer onto the outer diameter of the cold finer, then photo etch lines to serve as connecting leads.

To do this, we devised a method of rotating the inner flask in a horizontal position inside a vacuum bell jar that had three electrodes for evaporating material simultaneously or sequen- tially. Also, we added a quartz lamp near the inner flask to heat the cold finger. This outgassed the cold finger, which permitted the metals to adhere much better.

We first tried evaporating just silver onto the cold finger, but this proved unsatisfactory as the silver peeled off when ball bonded or soldered to. Finally, we arrived at the following process which worked very well. We masked off all the inner flask with aluminum foil except the

cold finger. First, while rotating the cold finger, we preheated it with the quartz lamp, and evaporated a thin layer of titanium on the glass surface, then evaporated Kovar metal while titanium was still being evaporated. Once the metals started mixing thoroughly, we turned off the titanium and evaporated a thin layer of Kovar on top of the titanium, then started silver evaporating and mixing with the Kovar, turned the Kovar off, and finished with a thin layer of silver. The resulting layers of metal were only a few micrometers thick, resulting in good electrical conduction and poor thermal conduction.

In a photographic dark-room, we coated the metal-layered cold finger with Kodak negative photoresist and dried it in an oven. After drying, we wrapped a photographic negative film with the desired lead pattern (0.010" lines, 0.010" clear space) around the cold finger end and taped it in place. We then rotated the cold finger around a mandrel and exposed it to light. Where the light penetrated the clear spaces in the film, it exposed and hardened the photoresist so that it adhered to the metal layer. Where the light could not penetrate the dark lines of the film, the photoresist was not exposed. It remained soft and was easily removed by dipping in Kodak developer (solvent) after removing the lead pattern film. The cold finger was then dipped in dilute nitric acid to remove the layer of silver that was not protected by the exposed photoresist. Then it was dipped in a mixture of dilute hydrochloric acid and hydrofluoric acid to remove the Kovar and titanium layers. The exposed photoresist was removed from the remaining metal lines by boiling in a Kodak stripper solution. This left good distinct metal lines that could not be peeled or scraped from the glass.

The inner flask was thoroughly cleaned and dried, then 0.005" diameter gold or silver wires were used to connect the metallized lines to the 0.030" diameter Kovar wires. This was done by soldering with indium solder or by thermalcompression bonding (ball bonding). The detector array substrate was mounted to the Kovar disk on the end of the cold finger with thermal conducting epoxy or soldered with low-temperature indium solder. It was then attached to the metallized leads in the same manner. Note: I refer to "we" frequently in this metallizing procedure. Actually, 90% of this process was developed and performed by a good friend and coworker, Price Wende.

3. The next step was fabricating the outer envelope with the IR transmitting window. The window, either single-crystal synthetic sapphire or zinc sulfide, could not be sealed directly to the 7052 glass because of coefficient of expansion mismatch, so I made a graded seal using 7520 glass that has compatible thermal expansion for both.

I cut the 7520 glass so that only 0.150" remained fused to the 7052 glass and lapped the cut surface with 240 and 400 aluminum oxide powder to get a flat, smooth surface. With a toothbrush, I scrubbed the sawed end clean and used hydrofluoric acid to etch the 7520 glass. When clean and dry, the tube was mounted into the RF generator fixture and the window was placed in the graphite susceptor inside the RF coil. I used a 0.007" spacer to set the meltdown distance. The expansions match, but sometimes, a thick seal will break.

The seal (or bond) is made by touching the glass tube to the window and adjusting the RF generator power until the graphite susceptor is extremely hot (almost white). The heat conducts through the window and melts the glass. I kept pressure on the shaft holding the glass tube for good thermal contact and watched for a shiny reflective line that appears at the interface of the glass and window when the seal starts. The shiny line will propagate around the circumference of the interface. After the line went completely around, I left the power of for another 20 seconds to ensure that the seal was complete. Power was then turned off, and the window remained on the susceptor about 45 seconds as it cooled slightly. The part was removed from the holder using stainless steel tweezers and placed in an oven preheated to

450°C. The oven was maintained at that temperature until all seals were completed, then the part was annealed at 565°C, making sure the glass tubes were standing vertically. After annealing, the 7052 glass tube was sawed to a predetermined length, and the sawed end was cleaned with dilute hydrofluoric acid, rinsed, and dried.

The window was placed in a vacuum chuck in the tailstock of the lathe. The 1.6" diameter glass tube with the 1.5" diameter outer lip Kovar tube was placed in the fixture in the lathe headstock.

After the lathe was turned on, the 1" diameter tubing was flared to approximately 1.25" and the 1.6" diameter tubing was reduced to match. The two were fused together, making sure the lathe tailstock pressed the window against the stop in the headstock fixture. Flame annealing followed, then the part was released and a small hand torch was used to seal a 6mm exhaust tube on the 1" diameter tube at the base of the taper. The part was flame annealed, then two 0.050" diameter Kovar wires were sealed opposite the exhaust tube midway of the taper. These held a refirable getter. After the outer envelope was annealed, the part was bright dipped, cleaned, and dried. Using a Kovar disk to mask off the window, and a magnet to hold it in place, we loaded the envelope into a bell jar. The envelope was placed over a tungsten filament wrapped with aluminum wire, and the bell jar was closed and evacuated. Current applied to the filament at this point melted and evaporated the aluminum onto the inner wall of the envelope. Power was removed, the jar was allowed to cool, the vacuum was released, and the envelope removed.

Next, a refirable getter was spot welded to the 0.050" diameter Kovar pins and the envelope stored in a vacuum oven until ready to use.

4. I have referred to the heat load of the dewar and will try to explain the meaning. The detector array must be cooled to -196°C to operate; however, because of the system design, we could not just pour liquid nitrogen into the cold finger. A cryostat that makes small amounts of liquid nitrogen was precision fit into the cold finger against the Kovar disk on which the detector array was mounted. These coolers are capable of removing only a small amount of heat. If the leads connecting the detector array to the outside leads were too large in diameter or too short, the thermal conduction would be so large that too much heat would be conducted through the wires into the array. The cooler could not remove enough heat to cool the array to -196°C. Hence, the long thin metallized leads on the cold finger were necessary.

The outer envelope was aluminized to prevent light from radiating heat into the cold finger, which would also render the cooler ineffective.

A good vacuum for a minimum of 36 months was also required. Since we could not bake the dewar at more than 100°C, and since there were epoxies inside the vacuum chamber, it was necessary to find a good gettering process to trap the gas molecules that inevitably would be floating around inside the dewar.

Initially, a barium getter was used that required heating to evaporate a coating on the inner walls of the dewar. That worked until it was saturated, then it lost its effectiveness. Also, if too much barium was evaporated, it would deposit on the cold finger, and, being electrically conductive, would short out the connecting leads on the cold finger.

After much searching, a getter made by SAES Getters of Italy was found that did not require evaporating a coating to the getter. It was a 3/16" wide, 1 1/2" long strip of special material that, when activated with 7 amperes of current, would activate the surfaces and trap gases in a

vacuum. Better yet, when it became saturated, a current could be run through it again and the trapped molecules would migrate inside the strip, leaving the surfaces activated. These getters were re-fired four or five times, and there was no trouble maintaining a good vacuum for three to four years.

I know its tiring sometimes to hear what we did in the good old days. This was done in 1968 and has become one of the more successful developments in high-technology industries.

There have been many modifications and refinements since then, but most still require the glass cold finger with metallized leads.

Since 1972, 59,000 FLIR systems have been sold with the common module dewar, of which this dewar was the forerunner. There have been 30,000 FLIR systems using a variation of that common module dewar.

This has been and will continue to be a billion dollar industry and I'm very proud that the glassblowing profession was and continues to be a major contributor.

TEXAS
INSTRUMENTS

INFRARED IMAGING APPLICATIONS

AGRICULTURE

CROP DISEASE
LAND UTILIZATION

LAW ENFORCEMENT

SURVEILLANCE
SECURITY
BORDER PATROL
ILLEGAL D&A SURVEILLANCE

DOMESTIC

ENERGY FLOW
RESOURCE ASSESSMENT
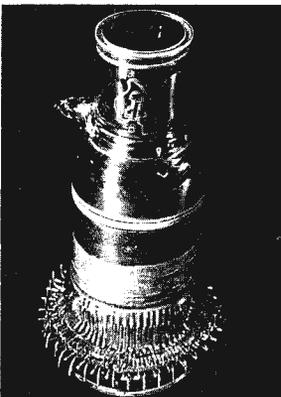ENVIRONMENTAL PROTECTION

INDUSTRIAL

MACHINERY INSPECTION
HEAT FLOW

MEDICAL

SCANNER

MILITARY

NAVIGATION
MISSILE GUIDANCE
STRATEGIC SURVEILLANCE
FIRE CONTROL
THREAT WARNING

Finished Glass Dewar for Joule-Thomson
Cooler or Liquid Nitrogen Transfer System.
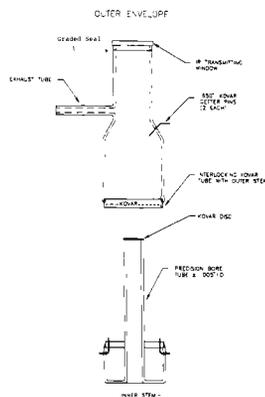
Figure 3. Two part - outer envelope and
inner stem flask.

NOTE: RF FIXTURE IS THE SAME
FOR EACH PART. THE HOLDERS AND
SUSCEPTORS ARE INTERCHANGEABLE
FOR DIFFERENT PARTS

KOVAR
WIRES

SPOT
WELDS

ALUMINUM
FIXTURE

GRAPHITE
SUSCEPTER

SLIP RING
FOR ADJUSTMENT

GLASS HOLDER
INTERCHANGEABLE

SUSCEPTOR FOR KOVAR OR WINDOWS
– INTERCHANGEABLE

RF COIL
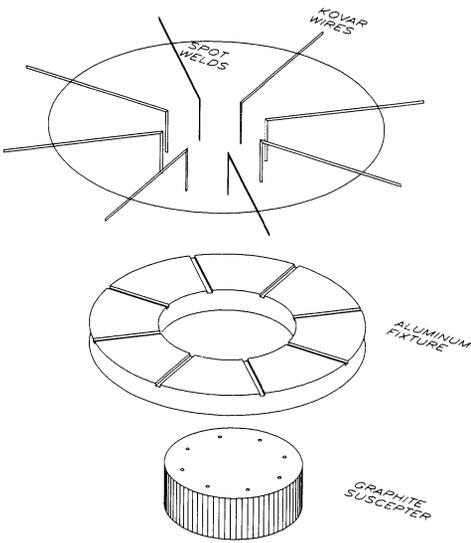
4. Kovar Lead Frame fixture
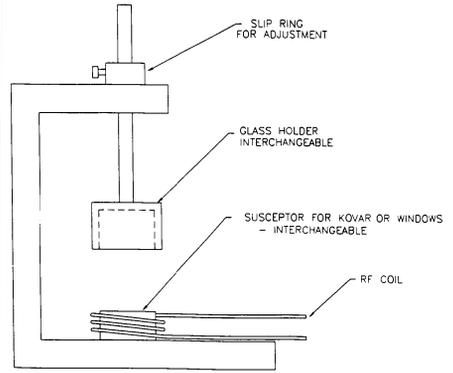
5. RF Sealing Fixture

KOVAR LEAD-FRAME

KOVAR LEADS

SPOT WELDED
LEAD FRAME

7052 GLASS RING

GRAPHITE
SUSCEPTOR
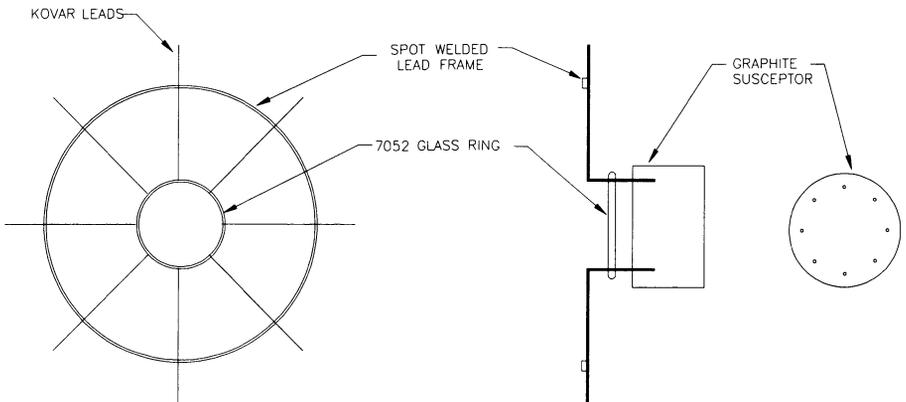
4A. Graphite holder with lead frame.

LATHE HEADSTOCK

STOP FOR KOVAR TUBE

STOP FOR LEAD—FRAME

GRAPHITE ROD

LATHE TAILSTOCK

STOPPER

BLOW

FIXTURE

PRECISION STOP FOR COLD FINGER

LATHE BURNER

GLASS TUBE
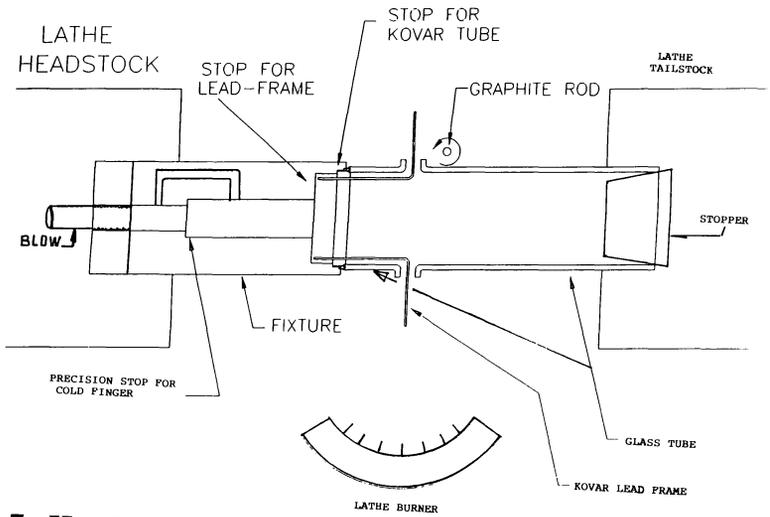
KOVAR LEAD FRAME

7. Headstock fixture for sealing in Kovar lead frame

KOVAR

KOVAR PINS

GOOD SEAL RADIUS

GLASS

BAD SEAL RADIUS

SEAL INTEGRITY CRITERIA

Cold Finger without Kovar Disc

Cold Finger with Kovar Disc

6. Cold finger for inner flask

8. Inner radius for good seal
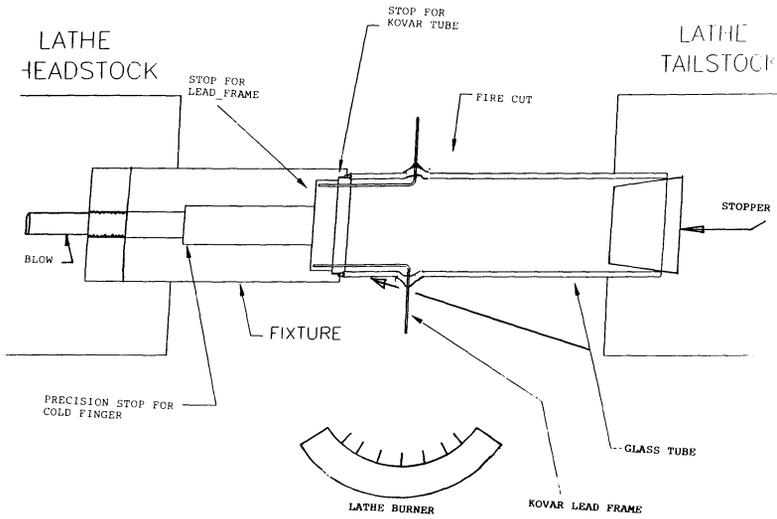
9. Fire cutting
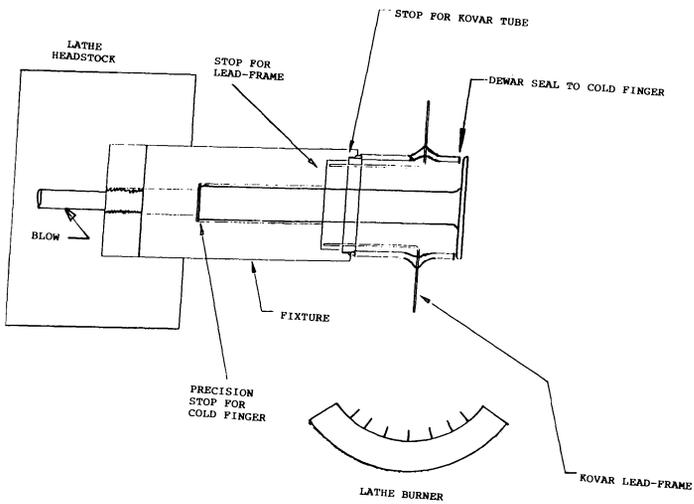
10. Dewar seal, inner flash
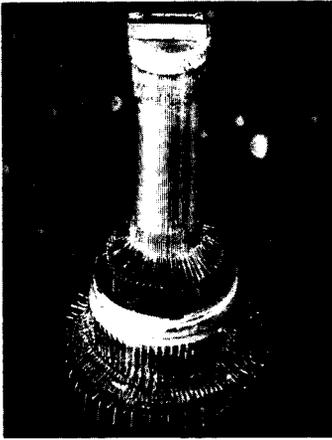
11. Connecting leak with gold wires

BELL JAR

QUARTZ LAMP

ALUMINUM FOIL
AROUND BASE

ROTATABLE
MANDREL

COLD FINGER

TITANIUM KOVAR SILVER
ELECTRODES
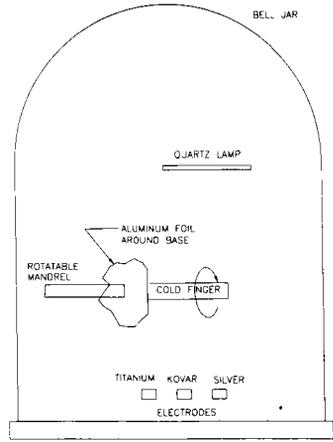
12. Bell jar for metalizing cold finger

KOVAR DISC

Photographic
film

PRECISION BORE
TUBE ± .005" I.D.

INNER STEM —
INTERLOCKING
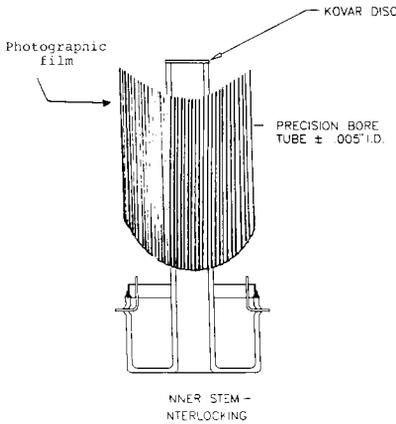
**13. Photographic film for exposing
photo resist on cold finger**

VACUUM CHUCK
HEADSTOCK   TAILSTOCK

ADJUSTABLE STOP   TO
VACUUM PUMP
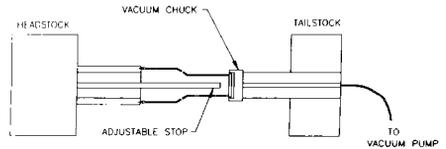
14. Butt seal outer envelope

HEADSTOCK

EXHAUST TUBE

GETTER PINS

ADJUSTABLE STOP
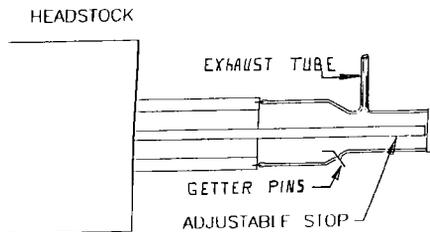
15. Exhibit tube and getter pins

BELL JAR

MAGNET

KOVAR DISC
FOR MASK

EVAPORATION
FILAMENT
ALUMINUM
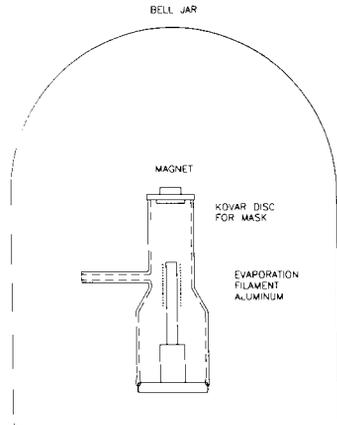
16. Alumining outer envelope

Hydrofluoric Acid
HF Safety and Treatment of Injuries
by Donald E. Woodyard

Hydrofluoric acid is an extremely dangerous chemical that is periodically used in many glass shops to clean and etch glass and quartz. Though general safety procedures for using acids are adequate, HF has particular problems that should be noted. It is probably the most acutely hazardous chemical that is in general use in glass shops. Contact with comparatively small or dilute amount of HF can cause serious injury or death.

HF is one of the most corrosive of inorganic acids. It is often referred to as a very strong acid, this is only true for anhydrous hydrogen fluoride and concentrated aqueous solutions which are strong protonic acids, but weaker solutions are comparatively weak acids. There is strong hydrogen bonding in all forms of HF, it is 1000 times less dissociated than hydrochloric acid (HCl). In this undissociated and particularly hazardous form, it is able to penetrate lipid barriers and into deeper layers of skin and subcutaneous tissue. Here, fluoride ions exert their extremely corrosive affects.

Fluorine, the most electronegative element, bonds tightly with many materials and its dissociated ions attack enzymes, cell membranes, and internal cell structures readily (1). This causes severe destruction, liquefaction necrosis and possible decalcification of underlying bone. Also in this phase, there is tissue depletion of Ca++ and Mg++ in the effected area. It is speculated that this results in cellular release of K+ from local nerve endings, which cause the excruciating pain characteristic HF burns. This depletion can lead to the life-threatening systemic problems of hypocalcemia and hypomagnesemia (1,2,3).

The severity of HF burns is a function of the type of exposure; the duration of contact, the concentration and amount of the material in contact, and the area (or areas) of the body that is in contact. The duration of contact with HF is important, because of HF's ability to readily penetrate the skin and tissue. This is a particular problem with dilute solutions (<50%), since they do not cause immediate pain or inflammation and prolonged exposure many times takes place (1). The initial signs of contact are redness, swelling, severely throbbing pain and, with higher concentrations, a blanched white appearance to the skin.

The initial first aid treatment of HF burns is common to other chemical burns. Stop contact with acid as soon as possible by removing contaminated clothing and materials. Wash with large amounts of cold water for 15 minutes to remove all acid still in contact with the skin (3). At this point, treatment specific to HF, which varies with the type of injury, should be applied as soon as possible.

One of the unfortunate aspects of HF treatment is that little or no anaesthetic can be used. The relief of pain is used as an indicator for the success of the treatment.

Treatment for exposure to <20% solutions of HF should be divided into two groups. Those exposures that there was no delay in decontamination and treatment, and those that there was a delay or undetermined time of exposure. This latter group's burns should be considered more serious than those who involved splashes of dilute HF that were immediately washed.

Initially both groups undergo topical treatment. This may be a 25% magnesium sulfate solution (Epsom salts), an iced quaternary amine compound (Hyamine or Zephiran, aqueous or alcoholic), or a calcium or magnesium paste or gel. There is no clear evidence that any particular topical treatment is superior. But, calcium gluconate gel (made by mixing 3.5 mg of calcium gluconate with 5 oz of K-Y Jelly) has a strong following (1,4). Also, calcium carbonate gel has been shown

to be an easily compounded and effective preparation. It is made by crusing 10-gm tablets of calcium carbonate (e.g., TUMS) and mixing with 20 ml of K-Y Jelly. These gels are noninvasive and easily applied by a patient (7).

If pain is not completely resolved by topical treatment within 45 minutes, injections of 5-10% calcium gluconate are indicated. Any blisters that develop should be cut away, cleansed, and topical treatment reapplied. If tissue around or under a nail is swollen and painful, the nail must be split open or removed to facilitate treatment.

Treatment for burns by intermediate-strength (20-50%) HF must be evaluated and treated on the basis on symptoms and duration of exposure. If there is any redness, discoloration, pain, or if there has been any more than a few minutes delay in decontaminating, it is very likely calcium gluconate injections will be needed in addition to topical treatment. As with dilute HF, blisters must be cut away and involved nails removed.

With serious involvement of hand tissue, intraarterial calcium infusion may be prescribed. The infusion is done be inserting a catheter in the artery of the arm of the injured hand, guiding it into the affected area, and pumping in a dilute calcium salt and dextrose solution. This is generally less invasive than calcium gluconate injections (1,5).

Treatment of injuries from concentrated (>50%) HF is very different. Many injuries are life-threatening and some are fatal. Their treatment invariably requires calcium gluconate injections or infusion in addition to topical treatment. Dead overlying hard tissue should be quickly cut away. Between 16 and 24 hours from exposure, added underlying dead tissue should be cut away. Intravenous lines should be used to maintain serum calcium levels to prevent systemic hypocal-cemia in those patients that have burns from concentrated HF over 1-2% of their body area. Furthermore, patients that have larger burns from more dilute HF should have serum levels maintained.

Inhalation of HF fumes can not only cause severe burns but may also lead to the lungs filling up with fluid to cause respiratory failure. Because concentrated HF is extremely volatile (more volatile than ether), patients with face, neck, and chest burns should be checked for pulmonary injury. Mouth and throat burns may cause swelling to the point that a tracheotomy is required. In these cases, 100% oxygen is administered as a first aid measure. This is followed by 2.5% calcium gluconate nebulized into 100% oxygen, preferably with intermittent positive-pressure breathing. (1,3,6).

Burns to the eyes by HF can result in scarring and blindness if not treated promptly and properly. The first aid treatment is to flush for at least 5 minutes the affected eye (or eyes) with large amounts of water or sterile saline while the eye lid is held open. Minor burns from very dilute acid can be treated effectively by irrigating with 1-2% calcium gluconate in saline. More serious eye burns require using an eye clamp and intravenous infusion set to instill calcium gluconate in saline into the eye (3).

Safety and prevention of HF injuries should be considered as a part of treatment. HF is extremely volatile, corrosive, and dangerous and must be handled with great care. It should be at least handled under a hood, with gloves (that have been checked for leaks), apron, and goggles. When possible, HF should be mixed with barium sulfate to make a paste that reduces fume and splash hazards. Treat it with at least the care you would any other strong acid.

In this paper, an attempt has been made to inform the glassblowing community of the current treatments for HF injuries. This is so an informed choice can be made on the type of treatment to use in a particular situation. It is also to alert the community to the particularly hazardous nature of HF.

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Photoelastic Quality Control Methods for Glassblown Products

Dr. Ropler/Schott-Rohrglas

O. Introduction: Field of Application

The quality of objects made from brittle-elastic materials depends not only on their design, but to a great extent on the presence, type, strength and distribution of mechanical stresses. These have a fundamental influence on the function, durability and workability of such objects.

It is therefore obviously a good idea to make photoelastic quality control tests on glass products both during production and after finishing. For this kind of non-destructive stress test on transparent glass objects the photoelastic method provides an elegant and relatively simple solution. This method primarily provides qualitive and quantitative information regarding stress. As a by-product we also receive data on nonhomogeneities in the glass such as cords, stones and knots which cause stress to be built up as a result of their different level of thermal expansion compared to that of the surrounding glass.

Photoelastic quality control methods are universally used in view of their versatility and corroborative strength.

Typical fields of application are the production and repair of glass instruments, the production of hollow-ware, utility glassware, ampoules and vials, and the production of prestressed glass objects. These are all basically applications in which glass is thermally and/or mechanically subjected to strain, in particular when glass is joined to other materials.

Photoelastic methods can also be used for testing the function of techniques and apparatus used for deliberately producing stress within glass, and of those with which stress is removed from glass by annealing.

1. Physical Fundamentals

Glass is by nature amorphous and optically isotropic. Its refraction factor is independent of direction. However, as a rule, glass objects are subjected to forces resulting in stress. This leads to the glass becoming optically onisotropic, and to double refraction. In the case of glass objects which were originally optically isotropic, the main axial stress system coincides with the main axes of the optical anisotropy. The standard for stress within a glass body is the extent of double refraction. If linearly polarised light, that is to say, light oscillating in one plane only, impinges on an anistropic glass body, this light is broken down into two components depending on the main direction of refraction. Both components have different speeds and thus different path lengths, that is to say, a phase difference. The partial waves produced after passing through the test body are subjected to interference in an analyser with a polarization direction vertical to that of the impinging beam. If one wave length is extinguished by interference, the residual light has mixed colours. This points to the extent of double refraction and thus to the stress being tested.

This may be expressed by the following formula:

$$\Delta\sigma = \frac{\Delta s}{a \cdot K}$$

The above signs denote:

$\Delta\sigma$ difference between the two main axial stresses

Δs phase difference between the two light components (positive sign for the tensile stress, negative sign for compressive stress)

  a   test body thickness

  K   photoelastic coefficient (dependent on the composition of the glass).

The stress diagram visible on the analyser shows correlated areas of the same colour, so-called isochromates, corresponding to areas of the same level of stress within the test body. Black lines or so-called isoclines characterize areas in which the main stress direction coincides with the polarization direction of the incidental light. In this case the wave passes unchanged through the glass and is completely absorbed by the analyser. Areas with an optical phase difference Δs = 0 (stress-free) or an integral multiple of the average wavelength also appear dark.

The measuring equipment for photoelastic stress testing purposes is basically the following:

- a primary light source with white light

- a polariser and

- an analyser rotated through 90°,

- the glass test object which is placed in the light beam at an angle of 45° to the polarizer and analyser.

2. Application for Glass in General

2.1 With respect to the particular glass type

The photoelastic method is basically suitable for all clear glass types. There are also special methods for darker glass types, which work with a modified technique (light/dark or colour-change method). However, for thicker layers it is only possible to measure stress as an integral over the whole thickness, so that specific maximum values which are decisive for the behaviour of the glass body have to be measured in some other way. However, such thick layers are not the rule in the glassblowing field.

It is important to note that the stress measured is dependent on the above-mentioned photoelastic constants. In the case of borosilicate glass DURAN, for example, the value is 4.0, for sodalime silicate AR-Glas 2.8 (10^{-6} mm^2/N). Digressing somewhat, it may be noted that the photoelastic test method is also used for components made from other materials, such as metal or ceramics. Scale models are made from transparent solid plastics such as acrylic glass and conclusions may then be drawn from the corresponding stress diagrams as the behaviour of the metal or ceramic body. This method often saves complicated calculations.

2.2 Stress in homogeneous bodies

As already mentioned, the strength of glass bodies is essentially dependent on the type, strength and distribution of mechanical stresses. Their function is determined to great extent by the fact that their tensile strength is only approximately 10% of their compressive strength.

We distinguish between permanent and temporary stress. Permanent stress is generated during the production process as a result of different cooling areas within the annealing temperature range. However, for technical reasons it is not usually possible to regulate the temperature of the glass after the processing in such a way that the glass is sufficiently stress-free. A special annealing process is therefore used to reduce stress as far as possible.

This diagram shows the normal temperature curve during the annealing process.

After annealing the glass is tested for residual stress.

On the left side of the slide is a glass cylinder with a high level of stress. The blue areas are fields of compressive stress, the white/yellow areas show high levels of tensile stress. This tensile stress is so strong that this glass tube is in fact under the greatest possible load. Any further mechanical or thermal stress would quickly exceed its strength limit and lead to breakage.

On the right is the same cylinder after annealing, all stress has completely disappeared.

This picture shows a practical example. A "small" repair job was done on this separator by laboratory technicians themselves. Their inexpert handling led to a high level of stress and to the destruction of the whole apparatus. For a glassblower this job would not have taken very long and there would have been no risk to the apparatus.

Both these photographs were taken by a colleague of yours, Klaus Mämpel, who is in charge of the glassblowing shop at the University of Bayreuth.

Here we can see both annealed and unannealed parts of flange joints as used in chemical engineering equipment. These joints are formed from one tube which results in circumferential stress.

Systematically produced stress can also be made visible and measurable, as in the case of this prestressed cylinder for miner's lamps.

Temporary stress is generated by mechanical strain on the glass object, for example by compression, expansion, bending and torsion. Secondary stress is also caused by uneven heating or cooling below the lowest annealing temperature.

Temporary stress disappears after removal of the source of strain, or as soon as temperature compensation has been reached again in the glass (as long as the glass remains undamaged).

In this experimental set-up I have subjected glass capillaries to varying amounts of strain. The different stress values are clearly visible.

It is quite simple to subject a glass body to mechanical and/or thermal strain under a light beam using the photoelastic test method. This then allows us to investigate stress distribution as a function of strain and temperature (plus time).

2.3 Stability of glass bonds

The good qualities of glass particularly come to the fore in connection with other materials.

Fusing, cementing, clamping, bolting, in other words, practically all bonding techniques are used. Even involuntary bonds (inhomogeneities) such as foreign bodies in the glass can be considered part of this picture.

Typical examples of this are electrotechnical applications such as bushings, or optical uses such as cementing and mounting lenses, or, in the mechanical field, coffee-pot handles. One obviously tries to minimize any differences in expansion rates by an appropriate choice of materials. These

problems can be solved by the use of suitable metal alloys, certain ceramics and special seal glasses.

This diagram shows the expansion behaviour of a metal, in this case Vacon 10 compared with glass 8250 which has been specially adapted to this particular metal.

The great similarity of their expansion behaviour means that it is possible to produce stable glass/metal bushings for equipment such as this photomultiplier.

In this particular case, there is a great difference to be bridged between the expansion rates of quartz and of metal. Several types of solder glass have to be used, and in this case were connected manually.

Automation does not stop here either, nowadays such solder glasses are machine-joined.

In the case of frictional bonds, stress within the glass can be made visible by photoelastic means and these results used to judge quality.

This method also provides information as to the detrimental effect of foreign bodies for any given application.

Photoelastic methods for direct quality control of bonds between various glass types or between glass and other materials are of great significance and have even gained part admission to some standards.

I should like to mention one more example of general interest for glass processing which particularly emphasizes the efficiency of photoelastic quality control methods.

Billions of glass ampoules for pharmaceutical products are produced all over the world, one might therefore term these a mass-produced article. Each and every ampoule must never-the-less be of a very high quality as its use may possibly save a life.

Such injection ampoules are thermally processed from borosilicate glass tubing, filled under sterile conditions by the pharmaceutical industry, sealed and labelled etc. All this takes place on high-speed automatic machinery and involves both mechanical and thermal strain.

Certain kinds of ampoule such as the One-Point-Cut and Colour-break types are deliberately weakened at a predetermined breaking point to allow the ampoule to be opened without using a tool. It is therefore particularly important for the ampoule to be tested for stress during all phases of production. Breakage at the time of processing would lead to unwelcome production breakdowns. This is why stress testing is done at various points on the production line.

The acceptable level of stress for ampoules of FIOLAX glass of one wall thickness corresponds to a particular phase difference which is visible as a colour. Using this kind of table, we can determine exactly whether the quality of the ampoule being tested is faulty or not.

3. Customary Apparatus

I have unfortunately not been able to compile a complete survey of all photoelastic testing apparatus presently available on your market. However, all such devices work on the same

principle, many have been modified for particular applications, some are even homegrown constructions.

In our own Quality Control department we use this kind of large-area stress tester:

The test object is placed here.

This is a smaller vertical type for testing small objects such as ampoules.

This is a projection device for stress diagrams which is particularly suitable for research and demonstration purposes. Any kind of apparatus for testing the strain on glass bodies can be added to it without difficulty.

Summary

Ladies and Gentlemen:

The following three points are decisive when judging the quality of technical glass objects:

- the type of glass used, as a function of chemical composition

- design, as a function of geometry

- forces within the glass, as a function of stress

Stress within the glass, more precisely, stress differences, their type, strength and distribution, can be made visible and measurable by non-destructive photoelastic methods. These are based on the phenomena of double refraction and of interference.

The versatility of this elegant method has been emphasized by means of various examples taken from the fields of manual glass apparatus production and industrial mass-production of glass objects.

I do hope you may be able to put some of these ideas into practice in your own work.

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Two photographs illustrating the photoelastic test method by kind permission of K. Mämpel, University of Bayreuth/Germany.

Polarisator   Sample   Analysator   Observer

Annealing of Glass

Chart axes: $dI / I_0 \times 10^{-5}$ (vertical), values 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 600.
Temperatur in C° (horizontal), values 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650.
Labels: VACON 10, Glass 8250
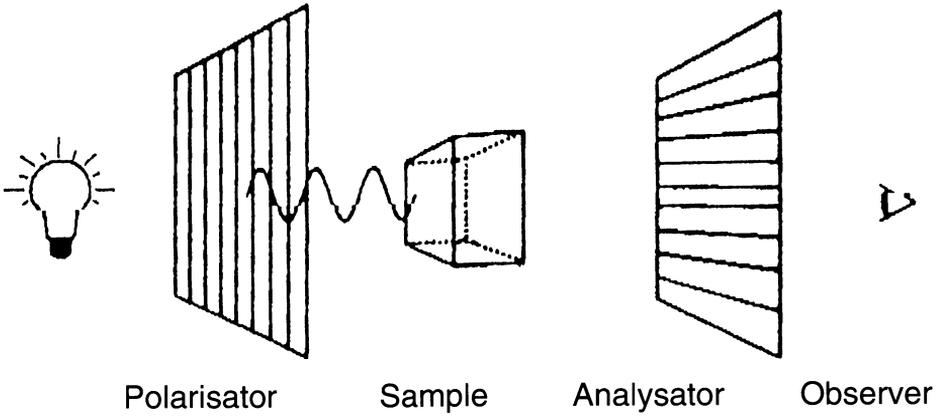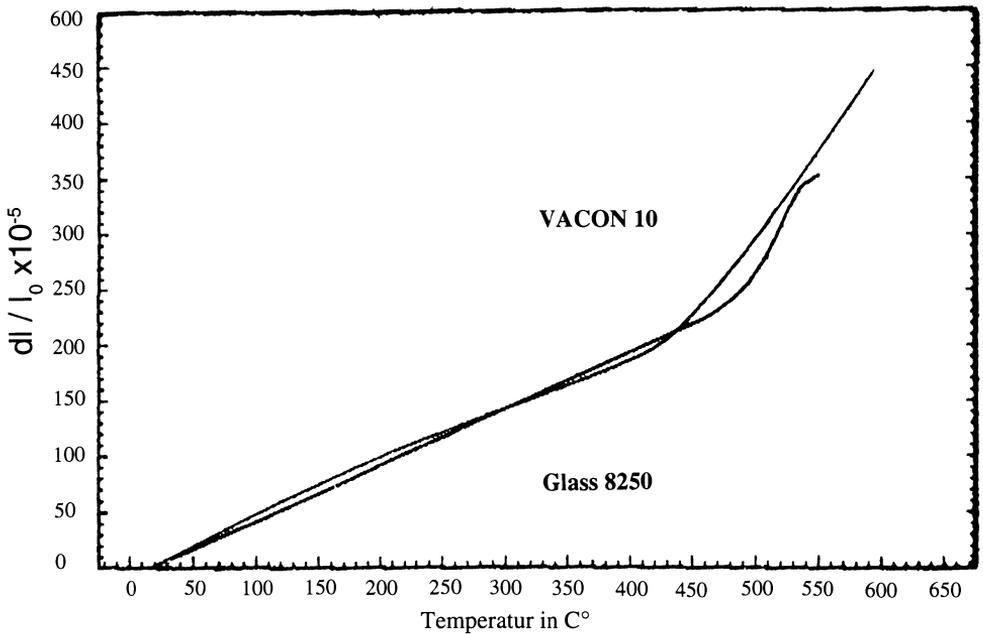
Table of the most usual interferential colours

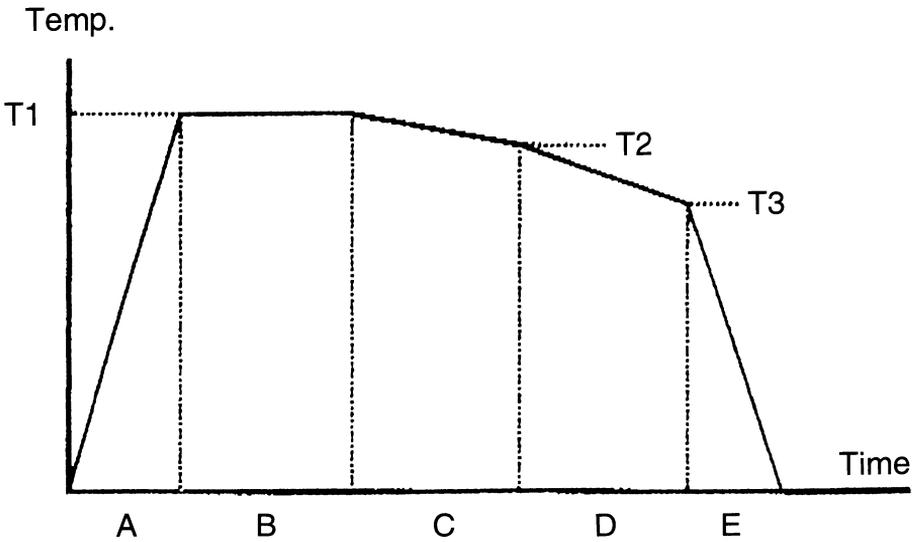| Phase difference	Colour	Phase difference	Colour
0	black	843	yellowish green
40	iron gray	866	greenish yellow
57	lavendar gray	910	pure yellow
158	gray blue	948	orange
218	gray	998	vivid orange-red
234	greenish white	1101	dark violet-red
259	almost pure white	1128	light blueish violet
267	yellowish white	1151	indigo
275	pale straw-yellow	1258	greenish blue
281	straw-yellow	1334	sea-green
308	light yellow	1376	glossy green
332	vivid yellow	1426	greenish yellow
430	brown yellow	1495	flesh-coloured
505	red orange	1534	carmine red
536	red	1621	pale purple
551	deep red	1652	gray violet
565	purple	1682	gray blue
575	violet	1711	pale sea-green
583	indigo	1744	bluish green
664	azure	1811	light green
728	greenish blue	1927	light greenish gray
747	green	2007	whitish green
826	green lighter than	2048	flesh red

Cami Clark, R.N.

First Aid & Care of Injuries Received While Glassblowing

Whitakers, NC

This paper presented the proper procedures to be taken when burns, cuts, or eye injuries are received while glassblowing.

Peter Clarke

Glassware for an Experimental Commercial

Procter & Gamble Co.
5299 Spring Grove Avenue
Cincinnati, OH 45217

Some of the most interesting and challenging jobs that come into our lab are from the advertising department. This paper/video described the glassware that was fabricated for an experimental "shoot" for Pepto Bismol.

Josh Simpson

Planet Making on a Small Scale

Contemporary Glass, Inc.
Frank Williams Road
Shelburne Falls, MA 01370

Artist Josh Simpson presented a slide show on the creation of his glass planets. His lecture illustrated the ancient Italian techniques of overlay and latticino cane making within the context of his work. Josh has exhibited in international galleries and museums including the Royal Ontario Museum, the Corning Museum of Glass and the National Air and Space Museum.

Gunter Kehr

Mosaic Glass Blown Before the Lamp

Mr. Kehr's presentation consisted of approximately 60 color slides depicting glass mosaics utilizing borosilicate glass worked at the bench. This unique approach produced truly extraordinary artistic pieces and illustrates how scientific lampworking technique lends itself to artistic expression.

Technical Posters

Name   Tim Landers
Company   University of Mass
Poster Topic   Tech Posters Chair

Name   Theodore Frasier
Company   Airsep Corp
Poster Topic   Oxygen Generation

Name   James Byrnes
Company   Cannon Instrument Co.
Poster Topic   Freeing a Stuck Joint

Name   John Chabot
Company   Syracuse University
Poster Topic   Vacuum Line for Manipulation of Air Sensitive Gases and Liquids

Name   Ian Duncanson
Company   University of Notre Dame
Poster Topic   A Simple Way to Fabricate Custom Flanges on Lathe

Name   John Hayes
Company   Chevron Oil Field Research
Poster Topic   Safety Considerations & Plumbing for a 200cc Visual Cell with
                   Removeable Fritt Rated at 200psi & 30F

Name   Andrea Kennedy
Company   Manchester Institute
Poster Topic   Pregnant Elephant

Name   Lisa Malchow
Company   G. Finkenbeiner Inc.
Poster Topic   Bends in glass up to 2 Inches

Name   Richard Nagle
Company   General Electric Co.
Poster Topic   Recycling Mercury

Name   Kenneth Weber
Company   United Technologies
Poster Topic   Ultrasonic Machining of Glass

Name   David Wedsworth
Company   Eli Lilly & Co
Poster Topic   Making Jacketed Glassware from Pre-existing Vessels

Name   Joseph West
Company   Eastman Kodak Co
Poster Topic   Vacuum Holders

Technical Workshops

Name   Allan Brown
Company   University of Conn
Workshop Title Workshop Chair

Name   Earl Nagle
Company   St Univ of NY
Workshop Title Workshop Asst Chair

Name   Bob McAnally
Company   AT&T
Workshop Title A Quartz Rotating Fixture

Name   Edward Mitchell
Company   E.I. DuPont Co.
Workshop Title Glass Diaphragms & Break Seals

Name   Jay Rosenbluth
Company   Starlite Industries
Workshop Title Drilling Small Holes

Name   A. Ben Seal
Company   Supelco
Workshop Title Tooling of External Threads

Name   David Searle
Company   University of Victoria
Workshop Title Shapes & Turns for Neon & Scientific Glassware

Name   Tom Schul
Company   Tek-Glass & Inst
Workshop Title Modification of Snyder Columns

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Company   Phillips
Workshop Title Stationary Sealing of 7052 Glass

Name   Wayne Winn
Company   Ace Glass Inc.
Workshop Title Friedrich Condenser

Name   Marvin Molodow
Company   Texas Instruments
Workshop Title Custom Torches

Name   Connie Hause
Company   C.J. Hause Tool Co
Workshop Title Grinding Threads on Glass

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Buffalo NY 14228

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Vineland NJ 08360

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Wettenberg
Germany

Carlisle Machine Works
PO Box 746
Millville NJ 08332

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3861 No Mill Rd
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Christy Machine Tech
1139 W. Haining Unit #1
Prescott AZ 86301

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Corning NY 14831

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