PROCEEDINGS

THE FIRST SYMPOSIUM ON THE ART OF GLASSBLOWING

1956

THE AMERICAN SCIENTIFIC GLASSBLOWERS SOCIETY

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FIRST SYMPOSIUM ON THE ART OF GLASSBLOWING

TECHNOLOGY AND
MANIPULATION OF GLASS

SPONSORED BY
The American Scientific
Glassblowers Society
IN COOPERATION WITH
Corning Glass Works

CORNING, NEW YORK
Friday, June 8, 1956
Saturday, June 9, 1956

FOREWORD

This, the First Symposium on the Art of Glassblowing, sponsored by The American Scientific Glassblowers Society, in cooperation with the Corning Glass Works, was a success beyond our fondest hopes.

To the Corning Glass Works, for their fine facilities and generosity, and to the members of their company who assisted our Symposium Committee, I extend sincere thanks, not only for The American Scientific Glassblowers Society, but for all those that were fortunate enough to attend.

To our own Mr. William Wilt, Chairman of the Symposium Committee, and the able members of his Committee, thanks for a job well done. Everyone should be grateful to the Committee for the smoothness with which the program was carried out especially when they were confronted with the problem of finding accommodations for an attendance that was 300% greater than originally estimated.

As President of the A.S.G.S., I would have liked to have met personally everyone that ättended the Symposium. However, the close schedule and insufficient time pervented this. Of those I did meet, the foremost question asked was, "How, where, why, when and by whom was this Glassblowers Society started?", and I think the "Foreword" to these proceedings is an appropriate vehicle to give a resume of its formation and growth.

In the latter part of 1950, I visited some of the glassblowing shops supplying scientific glass apparatus for research or experimental work, in and around the Philadelphia, Wilmington, and South New Jersey areas, in order to obtain information as to how my own shop compared in size, equipment, production and personnel with others doing similar work.

At each of these shops visited it was suggested that, as we all have so much in common, and because research generates many glassblowing problems, it would be to our mutual benefit to get together and discuss the many facets of glassblowing, a meeting where we all could "talk shop."

The first meeting of the "Glassblowers Discussion Group" As the Society was first named, was held on Friday evening, March 14, 1952 in Wilmington, Delaware and was called by Frank J. Reese of Hercules Powder Co., who acted as its Chairman. About thirty-one glassblowers and others associated with the production of scientific glass apparatus, attended this meeting, and from this small beginning we have grown steadily, primarily because there was a real need for such an organization. We have become incorporated as a non-profit Society and have, we feel, contributed immeasurably to the advancement and up-grading of our profession.

The major obstacle we had to hurdle was to convince glassblowers that they would eventually be better off if they could and would discard the long standing policy of secrecy, and pool their knowledge for the betterment of all. I think the proof that we have largely overcome this obstacle was definitely shown by the number attending this Symposium and particularly in the discussion session where there was standing room only and where information was exchanged so freely.

What the future holds for our Society, time alone will tell, but as long as those chosen to guide its destiny cling to the original concept of free and willing interchange of information and help to one another, it should continue to grow and take its rightful place among the technical societies of the world.

The publication of these proceedings is another step of the Society in its effort to gather and disperse knowledge concerning scientific glassblowing. We are indebted to Mr. Robert O. Looms of The Corning Glass Works for supplying the texts of the speakers and to Mr. George A. Sites, the Executive Secretary and Director in charge of publications of the A.S.G.S., to whom fell the job of transcribing and editing the discussion, and having the complete proceedings assembled, printed, and distributed.

This has been a long and arduous task, and on behalf of the Society I would like to make a special commendation for the effort and time that Mr. Sites has given toward its completion. No one knows better than I the amount of time that has been necessary for not only this project, but the other items of administration that are so important to the functioning and improvement of the A.S.G.S., and for which he has so unselfishly contributed.

J. ALLEN ALEXANDER, *President*

The American Scientific Glassblowing Society

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MR. S. D. BURDICK

Mr. Burdick received his BS from Alfred University and his MS from Rochester University. He has been associated with Corning Glass Works since 1936 and is now Assistant Manager of the Works Control Laboratory. Mr. Burdick has done considerable work in the measurement of stress, and the design of polariscopes. He is also a member of The American Ceramic Society and The Society of Glass Technology.

MR. E. B. SHAND

Mr. Shand was born in Nova Scotia. He graduated from McGill University in Electrical Engineering. After working for Westinghouse on the design of electrical machines, he later joined the Corning Glass Works where he is presently active in general product design, the application of fibrous glass for electrical insulation, the application of glass for engineering applications (particularly structural purposes), and is now Staff Research Engineer. Mr. Shand has written several books concerning glass. He is a member of the A.I.E.E., A.S.M.E., The American Ceramic Society and The Society of Glass Technology.

DR. S. D. STOOKEY

Dr. Stookey received his BA from Coe College in 1936 and was awarded a fellowship at Lafayette where he received his MS in Chemistry in 1937. He was awarded a scholarship and teaching fellowship at M.I.T., where he received his PhD in physical chemistry in 1940.

From 1940 until now, he has been in the Research and Development Laboratory at Corning Glass Works, and at present is Manager of Fundamental Chemical Research. His main fields of research have been in developing new glass compositions and processes, including opal and photosensitive glasses. To date he has been awarded about 25 patents.

Dr. Stookey has received several awards from professional societies and institutions, and is a member of Sigma Xi, American Chemical Society, The American Ceramic Society, and The Society of Glass Technology.

DR. R. H. DALTON

Dr. Dalton did his undergraduate studies at UCLA and the California Institute of Technology. He received his BS in 1925, his MS in 1926, and his PhD in 1928 from California Institute of Technology. He was a Ramsey fellow at Oxford in 1929-30.

Dr. Dalton joined the Corning Glass Works in 1930 as a Research Chemist. His main fields of research have been qualitative analysis, rare elements, activation of molecules by electron impact, chain reactions in glasses, glass composition, gases in glasses, photosensitive glasses, and glass to metal seals.

DR. C. A. BRADLEY

Dr. Bradley received his BS from the California Institute of Technology and his AM and PhD from Columbia in 1929 and 1932. He joined the Corning Glass Works in 1936 where he has been engaged as a physicist, glass technologist, superintendent of mixing and melting and at present is Director of Glass Melting Operations.

DR. M. E. NORDBERG

Dr. Nordberg attended Iowa State College where he received his BS in 1924 and his MS in 1925. He received his PhD from California Institute of Technology in 1928, and joined the Corning Glass Works in 1929 as Research Chemist.

He has done extensive work on the chemical durability of glass, alkali resistant glasses, gauge glasses, and general glass composition research. With H. P. Hood, he is the co-inventor of high silica "Vycor Brand" glasses.

MR. HERMAN SCHRICKEL, SR.

Mr. Schrickel received his early glassblowing training in Germany, but has been ih this country for nearly 50 years. He joined the Corning Glass Works in 1920 and was instrumental in establishing the Apparatus Department where he acted as Supervisor and Manager from 1923 to 1955. Mr. Schrickel is presently engaged as

Special Assistant to the Divisional Manager of Manufacturing—Technical Products. Besides contributing to the development of glassblowing techniques, he has also contributed to improvements in design of glassblowing equipment.

Mr. Schrickel's desire has been to make this country independent of imported Laboratory and Scientific glassware.

Welcome American Scientific Glass Blowers Society

June 8, 1956

O. M. LOYTTY

As I look out upon you, I am amazed, and have been ever since we started receiving reservations for this meeting. If someone had told me three or four weeks ago that this number of people were so keenly interested in their work, I would have told them they were out of their minds. And, you must be interested or you wouldn't have travelled so far as some of you have in order to get here. If I am not mistaken, we have people here from California, Texas, Louisiana, South Carolina, Oregon, Nebraska, Canada, Michigan, Illinois, and a heavy registration from the Eastern states. We, in Corning, think it is wonderful and we want to thank you all for coming to Corning Glass Works for this meeting. WELCOME TO YOU ALL.

Your committee on this Symposium, Bill Wilt as General Chairman, Joseph Baum, Ass't. General Chairman, Vincent DeMaria, in charge of Publicity, and George Sites, in charge of Distribution & Printing, and their respective committees, have done an excellent job in lining up the program. Bob Looms and Pete Kelly of our staff have worked closely with these people and we feel that you will enjoy their arrangements. You will hear more about the program from Bob Looms who is moderator of the speakers' group.

Just a few announcements — Luncheon will be served in this auditorium — the size of this group was greater than any restaurant facilities of Corning Glass Works. Cocktails at 6:00 P.M. this evening in the Club Rooms upstairs, entrance to the Club Rooms is just outside the building and up the metal stairs. Dinner will be in this room at 7:00 P.M. Luncheon tomorrow, Saturday, will be in the main ballroom of the Baron Steuben Hotel. Transportation to take you on plant tours will be outside this building when the general meeting breaks up.

One extra — not on the program — Some of you, no doubt, have seen the Corning Glass Works travelling van. You'll remember it as being a pipe display only. This year we have had it refurbished to include the Laboratory & Pharmaceutical line, pipe and CGW in general. It is now sitting outside this auditorium and we would like very much to have you visit it during your stay here. We plan to put it on the road in the fall, and if you desire to have the van scheduled into your area, drop us a note, we'll try to get it to you as soon as possible.

If at any time during your stay you have any questions, please feel free to call on any of our staff who are present. We want you to feel at home and hope you will.

Now, I'll turn the meeting over to Bob Looms of our Product Engineering staff, Technical Products Division.

Again a hearty welcome. GOOD LUCK AND A GOOD MEETING.

Glass to Metal Seals

R. H. DALTON

Corning Glass Works

Introduction

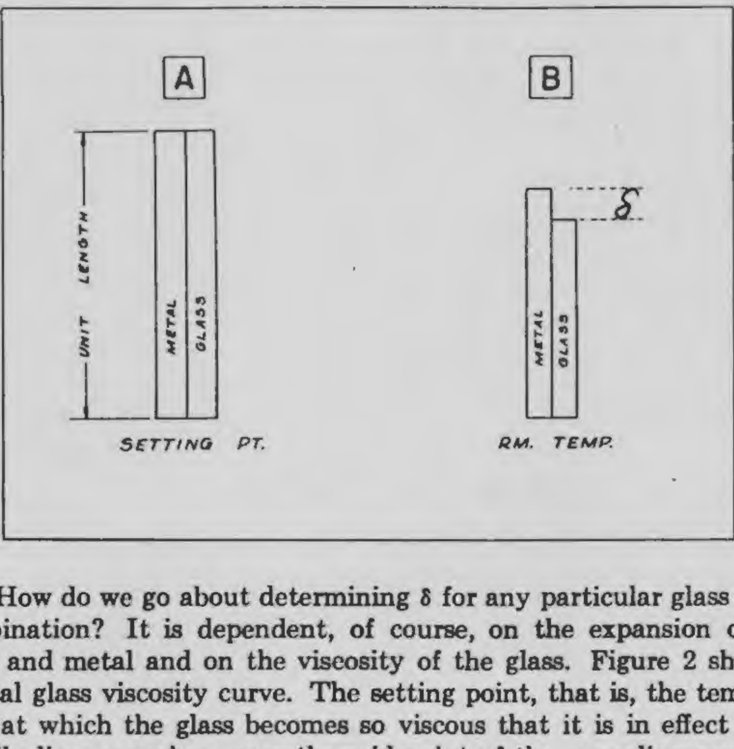
The subject of "Glass-to-Metal Seals" is a very broad one and it is obviously out of the question to cover all phases of it in a short article. It is only possible to touch on some of the main points that I feel will be of particular interest. Accordingly some of the basic principles that apply to all types of seals will first be reviewed and then some of the specific combinations that are of most practical importance will be discussed. The metalized solder type seals are not included.

Seal Requirements

The basic requirements of a typical glass-metal seal may be reduced to two points. First, the seal must be vacuum tight, that is, it must be absolutely impervious. Second, it must have sufficient mechanical and thermal strength for the intended application. To meet these requirements the seal must be free from any tension stresses that would lead to cracks or checks. This brings up the important question of expansion match between the glass and the metal.

Let us suppose that we have a particular metal and glass that we wish to seal together. The combination is heated until the glass fuses and adheres well to the metal, and then cooled. As this cooling takes place both members will, of course, contract and in general by different amounts. At high temperatures, where the glass is still fluid, this is of no particular concern but when the glass becomes rigid such differential contractions will result in stresses. If these are excessive the seal will fail. Referring to Figure 1, let us assume that (A) depicts unit lengths of the metal and glass at the setting point, that is, the temperature at which the glass in effect becomes rigid. If the combination is cooled to room temperature, and assuming the glass has contracted more than the metal, we would have the situation shown at (B) where the differences in contraction of the two members is represented by δ. The stresses which would develop in such a seal are proportional to δ. If δ were zero there would be no stress at room temperature and we would have a perfect match. If δ lies anywhere between zero and 100 parts per million we still have a very good match. Even values of 100 to 500 are usually satisfactory. Values much above 500 are questionable and values above 1000 are a very poor match and permissible only in special cases.

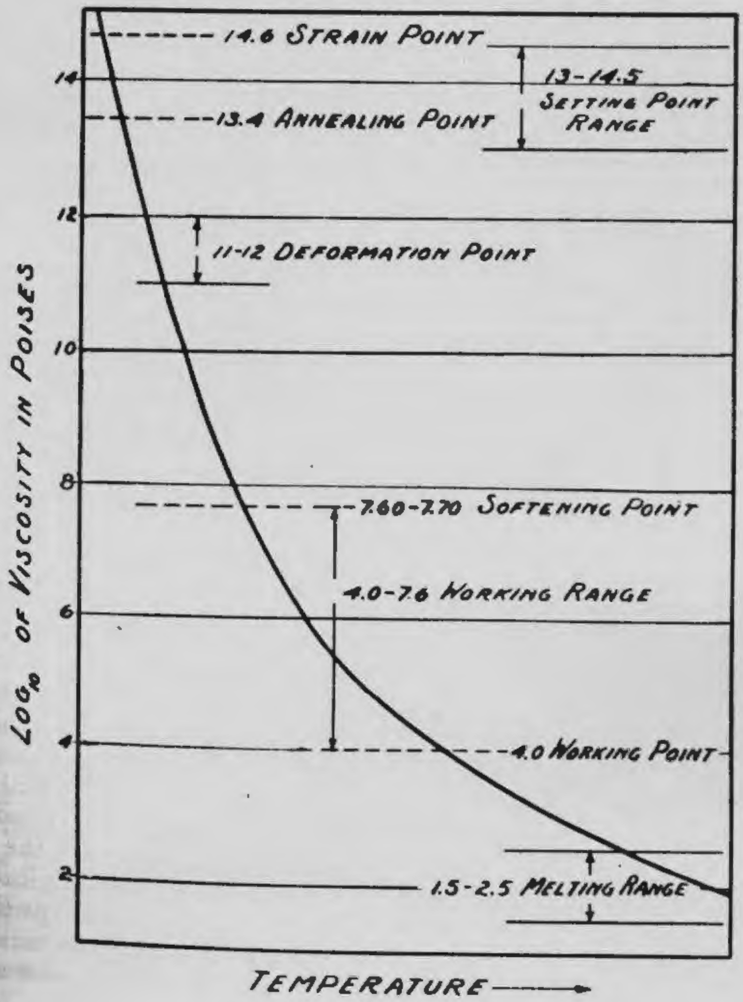
FIGURE 1



How do we go about determining δ for any particular glass metal combination? It is dependent, of course, on the expansion of the glass and metal and on the viscosity of the glass. Figure 2 shows a typical glass viscosity curve. The setting point, that is, the temperature at which the glass becomes so viscous that it is in effect rigid, usually lies somewhere near the mid point of the annealing range, in other words, about half way between the annealing point and the strain point. Actually it is not a fixed point even for a given glass but varies somewhat depending on the geometry of the seal and the rate of cooling. The mid point rule applies for slow cooling. In our work this was around 1°C per minute which corresponds in general to very good annealing. The mid point rule holds for most geometries except those where the glass is confined by the metal.

Turning now to the question of expansion, Figure 3 shows a typical glass "expansion" curve. Actually this should really be called an elongation curve since the quantity plotted against temperature is the specific elongation $\frac{\Delta L}{L}$ and not the expansion coefficient. You will note that the plot is initially linear but swings upward as the annealing zone is approached. The quantity which is normally referred to as "glass expansion" and which is tabulated in most glass property tables is the slope of the initial linear section of this curve. To be more exact it is the average specific elongation per °C between 0° and 300°C and this is the sense in which the term "glass expansion" will be used in this discussion. It is evident, however, that this

FIGURE 2



is not the quantity of interest for sealing purposes since the setting point of the glass is always up around the bend of the curve where the elongation is higher than would be predicted from the low temperature linear section. The quantity of interest for sealing purposes is the average contraction from the setting point of the glass down to room temperature and it is this value which we must know to calculate δ.

FIGURE 3

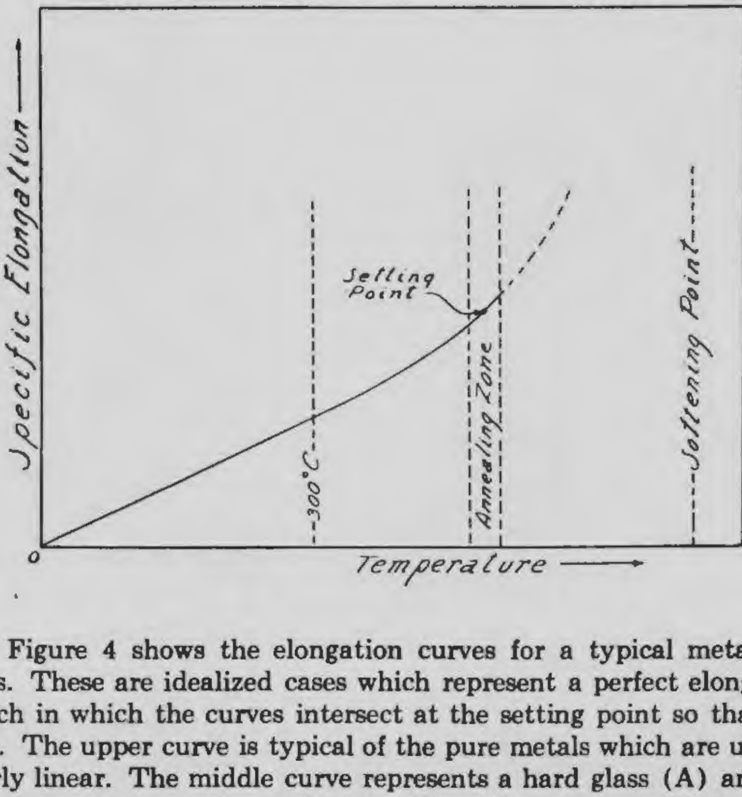
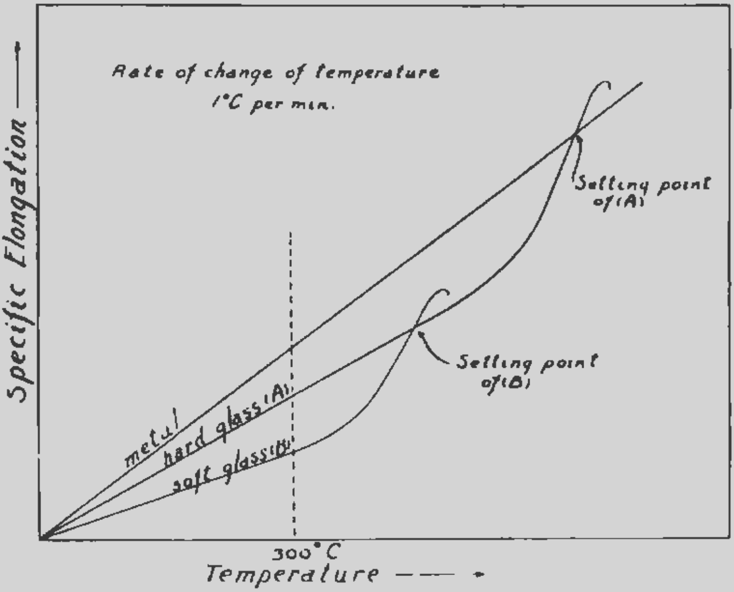


Figure 4 shows the elongation curves for a typical metal and glass. These are idealized cases which represent a perfect elongation match in which the curves intersect at the setting point so that δ is zero. The upper curve is typical of the pure metals which are usually nearly linear. The middle curve represents a hard glass (A) and the lowest curve represents a soft glass (B). These curves bring out one point which is nearly always true, that in sealing to a metal it is desirable to pick a glass of slightly lower "expansion". The reason for this is obvious from the relation of these curves. Extending the same line of reasoning further, in sealing a soft glass to a hard glass it is usually desirable to pick a soft glass with slightly lower "expansion". These curves bring out another interesting point that two materials which match the same material do not necessarily match each other.

Hard glass (A) would match either the metal or the soft glass (B) but the soft glass (B) would not match the metal.

FIGURE 4



Glass-Metal Combinations

Let us look now at some of the specific glasses and metals that are of practical interest for sealing. Figure 5 gives some typical metal elongation curves and shows the range of expansion encountered in the various metals that are normally considered for sealing. The lowest of these is tungsten with an "expansion" of 45 x $10^{-7}/°C$ and the highest is aluminum with an "expansion" of around 250. The highest expansion metal for which we have a matching glass, however, is iron.

You may wonder why Dumet, which is the most important sealing metal commercially, does not appear in the plot. This material is not homogeneous but consists of a nickel-iron core enclosed in a copper sheath. The expansion along the length of the wire is different from that along the diameter so it is impossible to represent its behavior in any simple way.

You may also be puzzled by the fact that Invar is not regarded as the lowest expansion sealing metal. You will note, however, that its curve turns up sharply around 250° to 300°C so that the elongation at the setting point of any of the ordinary glasses is quite high. It is, therefore, of no interest for sealing purposes.

FIGURE 5

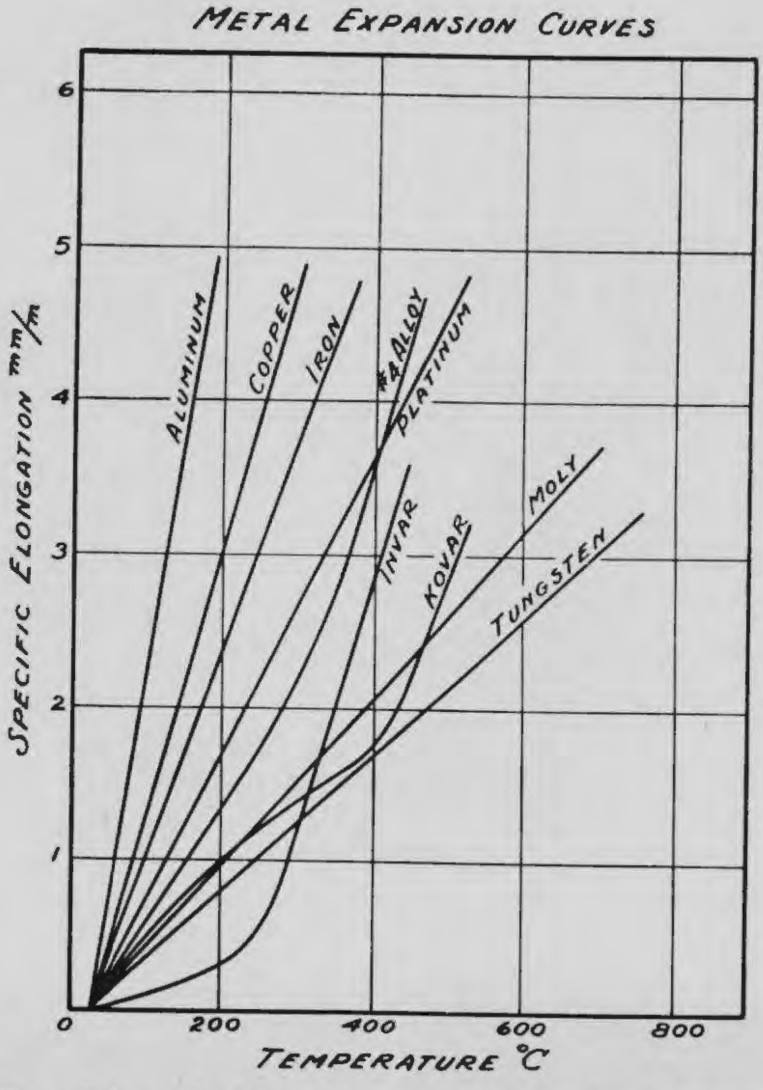


Figure 6 shows the elongation curves for a number of the glasses commonly used in sealing. The highest glass shown is Corning Brand No. 1990 which has an "expansion" of 127 x 10^{-7}/°C and is a good match to ordinary iron. The "expansions" range from there all the way down to 7.5 for the VYCOR Brand glasses like No. 7900. The curves all have the same general shape as the typical glass curve given earlier.

FIGURE 6

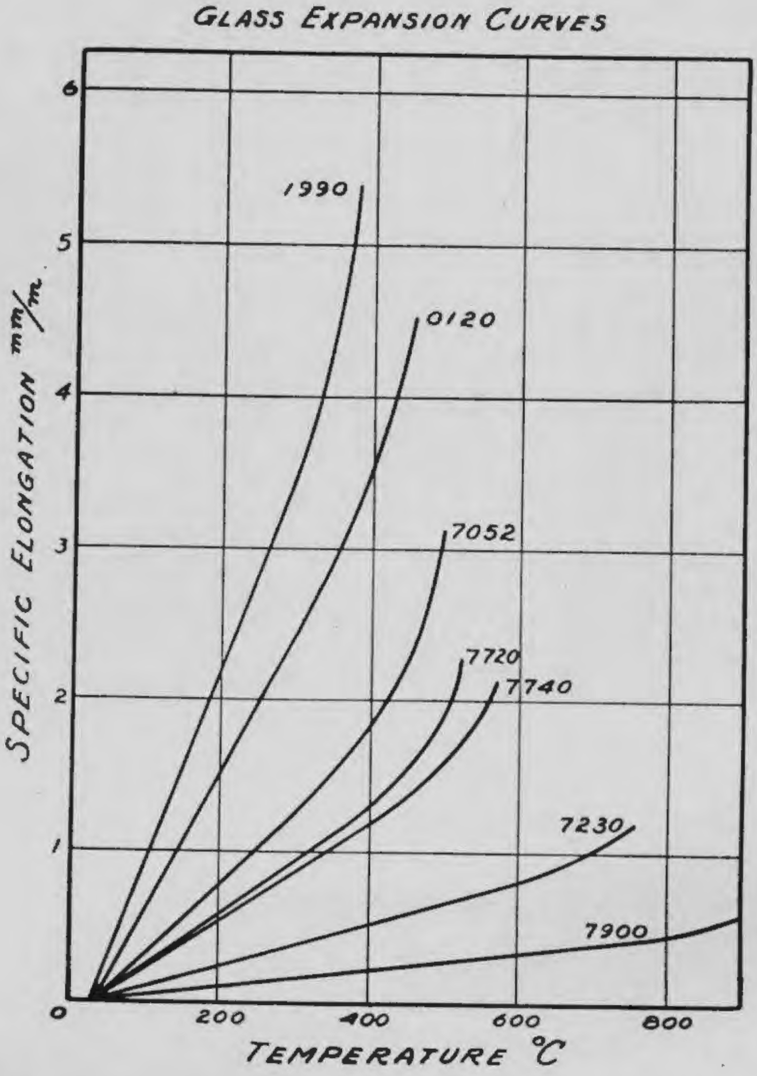


Table I lists the matching combinations of metal and glass that are of practical importance. In addition to the glasses which were shown in the previous curves a number of others are included. The combinations are listed in order of increasing expansion starting with the lowest at the top. Running through them in this order, PYREX Brand glass No. 7720 (Nonex) is the most commonly used tungsten seal glass but No. 3320 is a slightly better match and is used as a beading glass in some critical cases. Glass No. 7750 is softer than the other two tungsten sealing glasses and is used in some stems of large size where it is difficult to get good flow in the harder glasses. Going on to molybdenum, nearly all of the Kovar sealing glasses will also work well here since the setting point of these glasses lies close to the intersection of the Kovar and molybdenum curves. In addition, the combustion tube glass PYREX Brand No. 1720 may be sealed to molybdenum. Of the Kovar-sealing glasses the one which finds widest use for general purposes at present is No. 7052. No. 7055 is superior in some respects but has not found wide acceptance because it has a higher annealing point, and the working properties are not quite as good. No. 7040 is slightly superior to the others in dielectric properties but is poorer in chemical durability. No. 7056 is like No. 7055 but of optical quality.

TABLE 1

MATCHING GLASS METAL COMBINATIONS

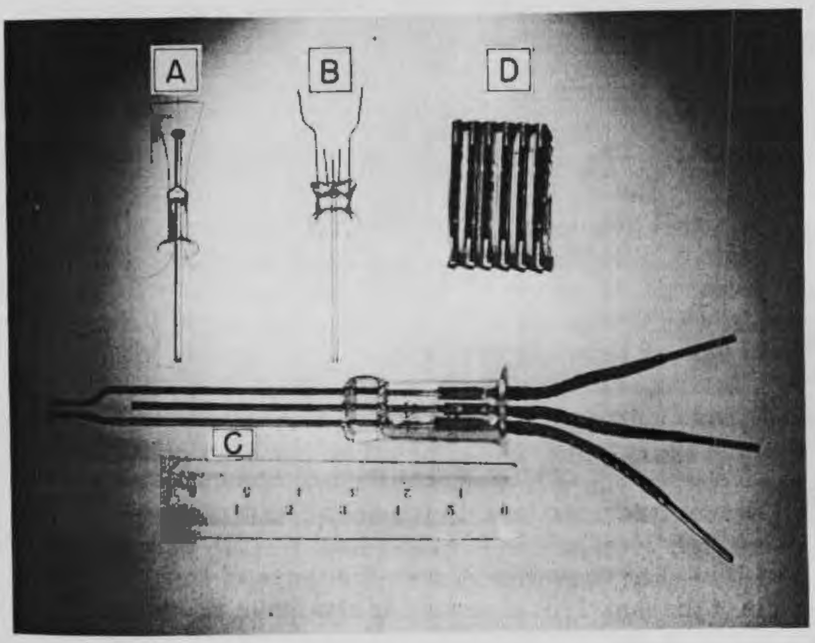
METAL	GLASS
TUNGSTEN	7720, 3320, 7750
MOLYBDENUM	7052, 7055, 7050, 7040, 1720
KOVAR	7052, 7055, 7050, 7040, 7056
SEALMET #4 DUMET, PT	0120, 0010, 0080, 9010, 7570
28% CR-FE	0240, 8871, 9015
17% CR-FE (TI)	8871, 9015
IRON	1990, 1991, 0110

We come next to the important group of high expansion glasses which seal to Dumet and to No. 4 alloy. Here the most important glass for sealing is undoubtedly Corning Brand No. 0120 which is used for the stems in nearly all small lamps and radio tubes. No. 0010 is the glass used in miniature bulbs and sign light tubing. No. 0080 is the common bulb glass for lamps and radio tubes and No. 9010 is the television tube glass. No. 7570 is a very soft, so-called "Solder Glass" which matches these high expansion metals.

Going above the ordinary high expansion range we come first to 28% chrome iron for which there are three glasses in approximately the right expansion range to make a good seal, Corning Brand Nos. 0240, 8871, and 9015. The 17% chrome iron, listed next, has about the same characteristics as the 28% chrome iron. It is used for the funnels in some television tubes. Finally we come to pure iron (ASE1010) which is the highest expansion metal for which we have matching glasses. Of the three glasses listed, Corning Brand No. 1990 is probably to be preferred. There is so little demand, however, for any of these iron matching glasses that they are seldom melted. The important sealing applications with iron are of a type where the metal and glass do not match, as considered later.

Figure 7 shows some typical examples of seals made with the matching combinations that have been discussed. (A) is a typical lamp stem, (B) a typical radio stem, (No. 0120 glass and Dumet), (C) a typical power tube stem (No. 7750 glass and tungsten). (D) is a section from a high voltage X-ray tube made by Machlett in which a long column of alternate rings of Kovar and No. 7052 glass

FIGURE 7



were sealed together. This was one of the most critical glass-metal seal match applications ever undertaken.

Non-Matching Seals

While in general a good glass-metal seal calls for a close expansion match of the type we have been discussing, there are some important special cases in which this factor can be largely ignored. Two schemes have been divised to accomplish this. They are illustrated diagramatically in Figure 8. One method consists in using a very thin metal so that it cannot exert a dangerous stress on the glass. This is the principle of the well known Housekeeper seal and is illustrated in two forms in (A) and (B). The second method consists of arranging the geometry of the seal in such a way that the stress in the glass is all compressive. Glass is extremely strong under compressive forces and a very high expansion difference is permissible where the glass is in pure compression. This case is illustrated in C).

FIGURE 8

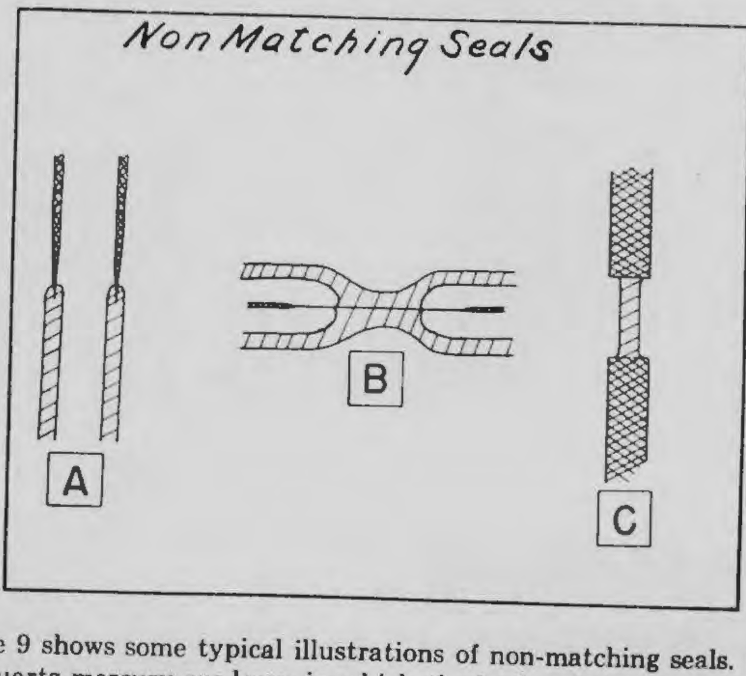
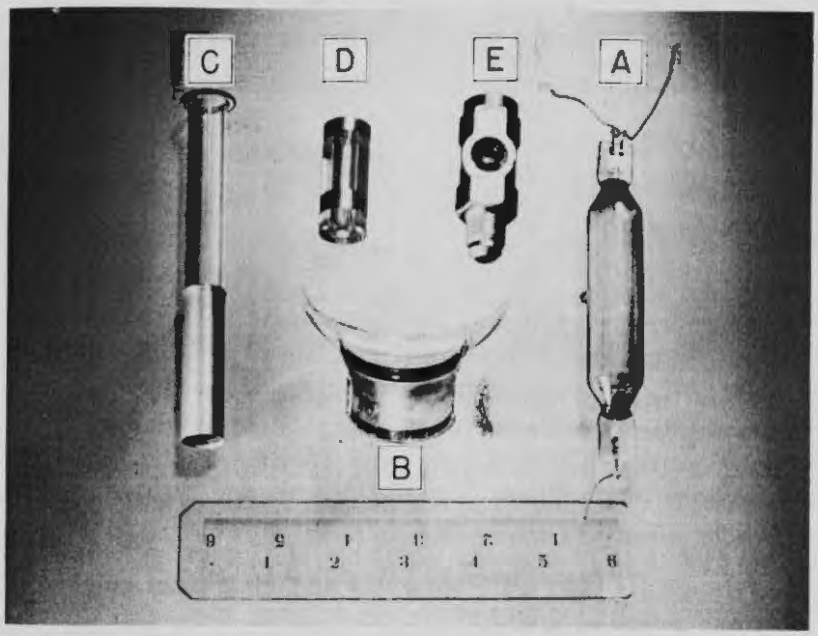


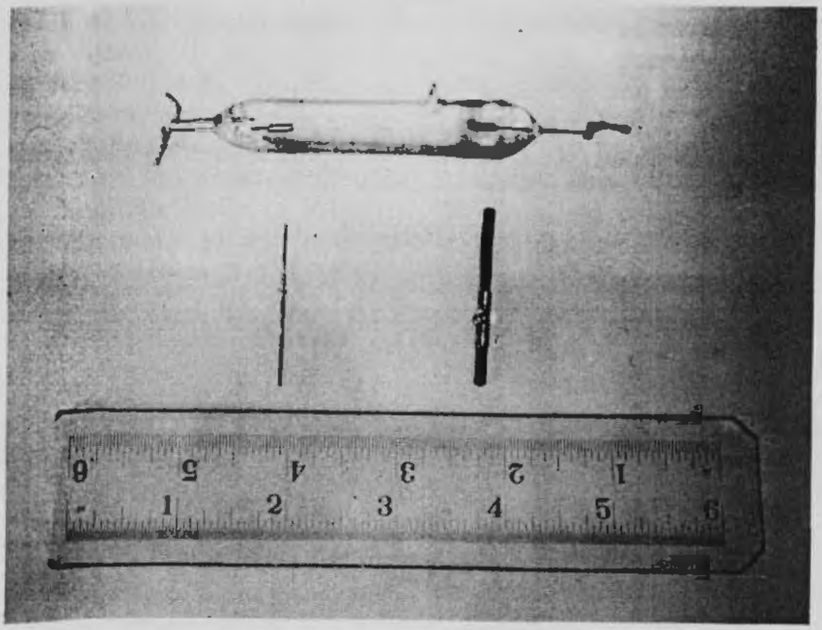
Figure 9 shows some typical illustrations of non-matching seals. (A) is a quartz mercury arc lamp in which the leads consist of very thin strips of molybdenum foil (0.0005″ thick). (B) is a section of a typical Housekeeper seal using a feather edge of copper. (C) is an example of the same type of seal using aluminum and tubing of Corning Brand glass No. 0080. To avoid melting the aluminum the join is made by means of the soft solder glass No. 7570. (D) is an example of a thin layer of silver fired on the glass surface. (E) is a brass bushing containing a glass window and represents an example of the second type of non matching seal in which the glass is under pure compression. Another example of this type is the disc of No. 0120 glass which is sealed into a ring of iron in the ordinary metal receiver tubes.

FIGURE 9



There is one more type of non matching seal that should be mentioned. Whether or not a seal fails will depend not only on the magnitude of the stress that develops but also on the strength of the glass, that is its ability to resist the stresses. Thus by careful firepolishing to minimize surface flaws and favorable shaping to avoid stress concentration it is sometimes possible to make successful seals even with a serious mismatch. A seal of this type which has actually been produced in considerable commercial quantity is the one involving the use of PYREX Brand glass No. 7230 for sealing tungsten leads into VYCOR Brand glasses and fused silica, as for example in the Sunlamp and other small mercury arcs. Figure 10 shows the arc tube of such a lamp and two tungsten leads that have been beaded with the No. 7230 glass.

FIGURE 10



For further information on this subject the Laboratory and Pharmaceutical Department of Corning Glass Works publishes a pamphlet entitled "Glass Blowing with PYREX Brand Glass." This contains some material on glass-metal seals and also a number of useful hints on glass working in general. It is available upon request without charge. There is also available at Corning a table of "δ" values covering almost all glass-metal and glass-glass combinations that are of practical interest.

Vycor Brand Glasses

M. E. Nordberg

Corning Glass Works

For decades glass technologists have been searching for glasses with higher resistance to heat shock and to deformation at high temperatures than is found in ordinary commercial glasses. Fused silica is an ideal glass in many ways, but it is difficult to produce in clear, bubble free form. In one method, pure Brazillian quartz is ground and melted in vacuum at very high temperatures and then subjected to pressure to collapse the remaining bubbles. Even at the high temperature the glass is viscous and release of bubbles is slow. Other methods also involve use of very high temperatures. After melting, one is still faced with difficulties in forming. These difficulties can be surmounted in tubing, sheet or certain bulb forms which can be made by drawing or blowing operations. Pressed ware, however, can be made only in crude forms since the temperature required for pressing is beyond the range of known materials for molds and plungers.

This discussion pertains to glasses with the desirable properties of fused silica which have been on the market for over 15 years under the trademark, VYCOR. Its aim is to describe these glasses and explain why glassblowers are, more and more, being asked to work with them.

Process of Manufacture

VYCOR Brand 96% silica glasses are prepared by a unique process which circumvents the need for extremely high temperatures in melting and forming. A relatively soft alkali-borosilicate glass is melted in conventional manner and is then pressed, drawn or blown into the desired, but oversize shape. The resultant article, sometimes after additional finishing operations, is subjected to a heat treatment above the annealing point but below that temperature which would produce deformation. During this heating, the glass separates into two continuous, closely intermingled, glassy phases. Opalescence results on prolonged heating. One phase is rich in alkali and boric oxide and is readily soluble in acids. The other is rich in silica and is insoluble.

After heat treatment, the article is immersed in a hot acid solution. The soluble phase is slowly dissolved, leaving behind a porous, high silica skeleton. So far, there has been no substantial dimensional change. A slight opalescence has developed. The leached article is washed and set aside to dry. The glass in the porous state is finding interesting applications as will be discussed later.

In the final step, the ware is slowly heated to above 1200°C whereby the porous structure is consolidated into a clear impervious glass. A shrinkage of 35% in volume or about 14% in linear dimensions occurs. This is illustrated in Figure 1 which shows a calcining dish of the original glass and a similar dish after leaching and firing.

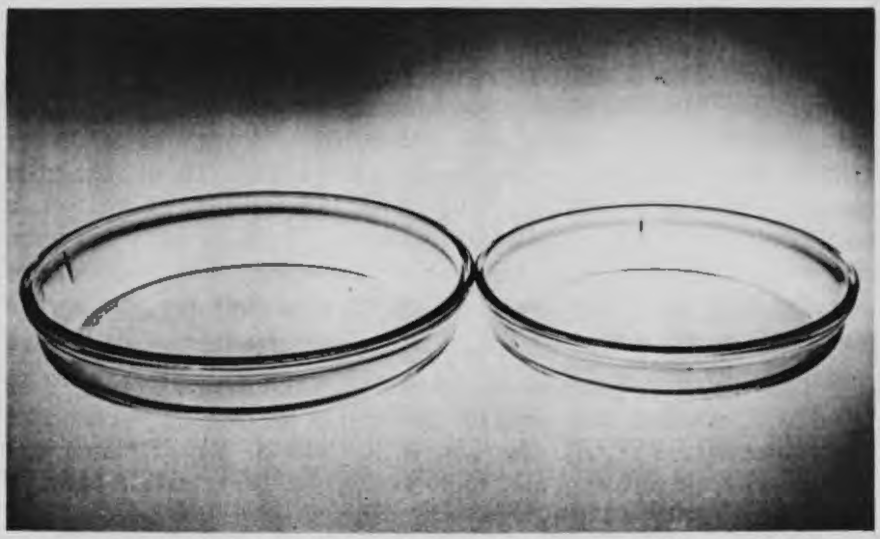


Figure 1 — Calcining tray before and after leaching and firing.

Diffusion of salts and acid through the porous glass determines the rate of leaching. For this reason, the rate decreases with increasing thickness. The process is therefore best adapted to relatively thin ware, a thickness of ⅜ inch being considered about the maximum for general purposes. However, plates nearly one inch thick have been prepared experimentally, showing that it is possible to make heavier ware for certain purposes where the cost of slow leaching can be tolerated. For massive ware or shapes that are not readily made by ordinary glass working techniques, the Multiform process can be used with VYCOR Brand 96% silica glass. In this process, the glass is pulverized, cast into shape by slip casting or dry pressing, and fired. The resultant product is translucent or opaque white, but similar in other properties to the clear glass from which it was made.

Properties of Porous Glass

Many laboratories have shown interest in the intermediate porous glass. It has been used experimentally as a membrane for the separation of gases and liquids, as a semipermeable membrane for osometers, an ultra filter, molecular sieve, adsorbent, catalyst support, and salt bridge in electrolytic cells. In addition, it has served in fundamental studies of gas and vapor adsorption, light scattering, infrared transmission of absorbed materials, flow of liquid helium at very low temperatures and other phenomena associated with porous materials.

Properties of porous glass are shown in Table I. Another way of indicating the large surface area around the pores is to say that a cubic inch of the glass has a surface area of 1½ acres. The pore diameter could be expressed as a sixth of one millionth of an inch. Water content of the glass will vary with the relative humidity of the ambient atmosphere and can reach a maximum of 25% of the weight of the glass after firing.

TABLE 1

Properties of Porous Glass (Code 7930)

Average Pore Diameter	Approximately 40 Angstrom units (a.u.)
Surface Area	Approximately 2 x 10^6 sq. cm/gm
Total Pore Volume	35%
Water absorption at saturation	25%

If the glass is rapidly heated, water is expelled violently and the glass shatters. It can, however, be heated slowly without breakage. Figure 2 shows the change in length of porous glass bars heated for extended times at 700°C, 800°C and 900°C. If porous glass is to be used at an elevated temperature, it is usually desirable to stabilize it by pretreating at a somewhat higher temperature.

Figure 3 shows the rate of flow of water and acetone through porous VYCOR Brand glass discs. The flow rate is extremely small. It decreases almost linearly with increasing thickness and is greater for acetone than water as a result of lower viscosity of the former. The flow of gases is considerably faster as shown in Table II. Flow rates may vary some from one lot of glass to another; values given are approximate. The differences between hydrogen and oxygen rates

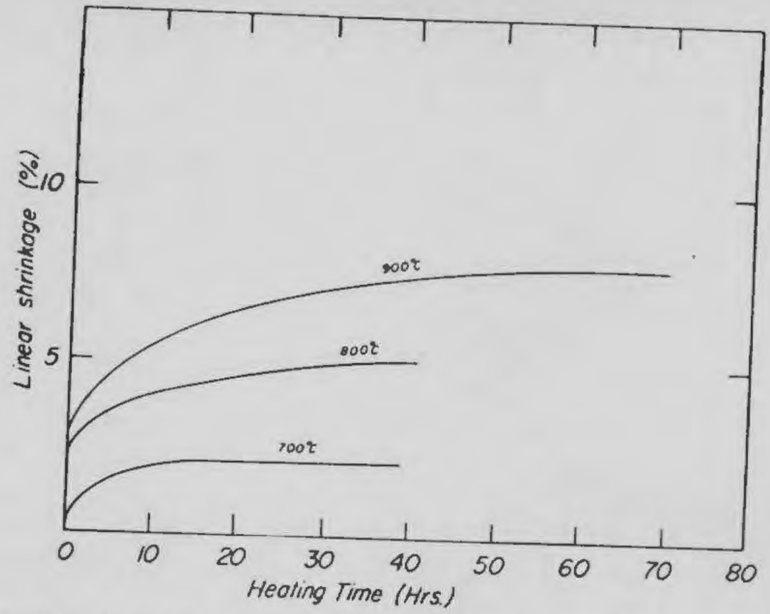


Figure 2 — Shrinkage of porous glass on heating. Maximum possible linear shrinkage 14%.

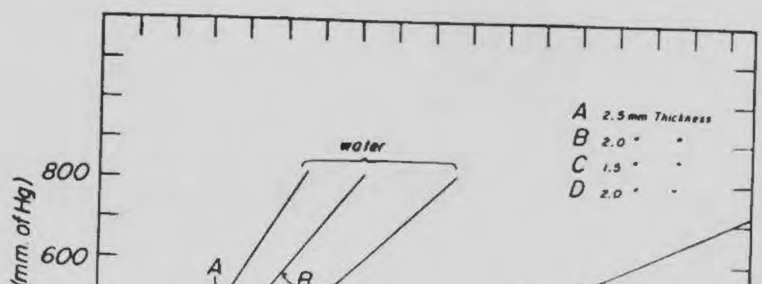


Figure 3 — Flow of acetone and water through porous glass.

indicate that mixtures of these gases can be separated by diffusion through porous glass. Thin walled porous glass tubes can be supplied with one or both ends fired to permit sealing directly to silica or VYCOR Brand glass systems or to other glass systems with intermediate graded seals.

TABLE II

Flow Rates through Porous Glass

Fluid	Flow Constant ml/sq cm/atmosphere of pressure/hr
Water	0.00065
Acetone	0.0018
Oxygen	4.0
Hydrogen	19.0

Properties of Final VYCOR Brand Glasses

Outstanding properties which set VYCOR Brand glasses apart from more conventional commercial glasses are as follows:

1. Heat shock resistance is extremely high. Ware can be repeatedly heated to redness and plunged into water without breakage.

2. Deforming or softening temperatures are high.

3. Light transmittance can be high from wavelengths below 2000 angstrom units in the ultraviolet to 3.5 microns in the infrared. Solarization or loss in transmission due to exposure to ultraviolet radiation is low. For this reason, the output of radiation from ultraviolet lamps with VYCOR Brand envelopes can remain high.

4. Electrical resistance is high and power loss is low.

5. Chemical durability is excellent in neutral and acid solutions and relatively high in alkaline solutions.

In Table III, physical properties of VYCOR Brand glass No. 7900 are compared to those of PYREX Brand glass No. 7740 and of fused silica. The average expansion coefficient of No. 7900 glass is about one fourth that of the heat resistant glass No. 7740 and but slightly higher than that of fused silica. Above 300°C and up to the annealing range the expansion coefficient of No. 7900 glass is still lower and about equal to that of fused silica. This is as shown in Figure 4. The softening temperature of VYCOR Brand No. 7900 is almost 700°C above that of PYREX Brand No. 7740 glass. Similarly, the annealing temperature is nearly 350°C higher.

TABLE III

Physical Properties

Glass	VYCOR Brand No. 7900	PYREX Brand No. 7740	Fused Silica
Coef. of Expansion (0—300°C)	$7.5x10^{-7}/°C$	$32.5x10^{-7}/°C$	$5.5x10^{-7}/°C$
Softening Temperature	1500°C	820°C	1650°C
Annealing Temperature	900°C	553°C	1150°C
Density	2.18 gm/cc	2.23 gm/cc	2.20 gm/cc

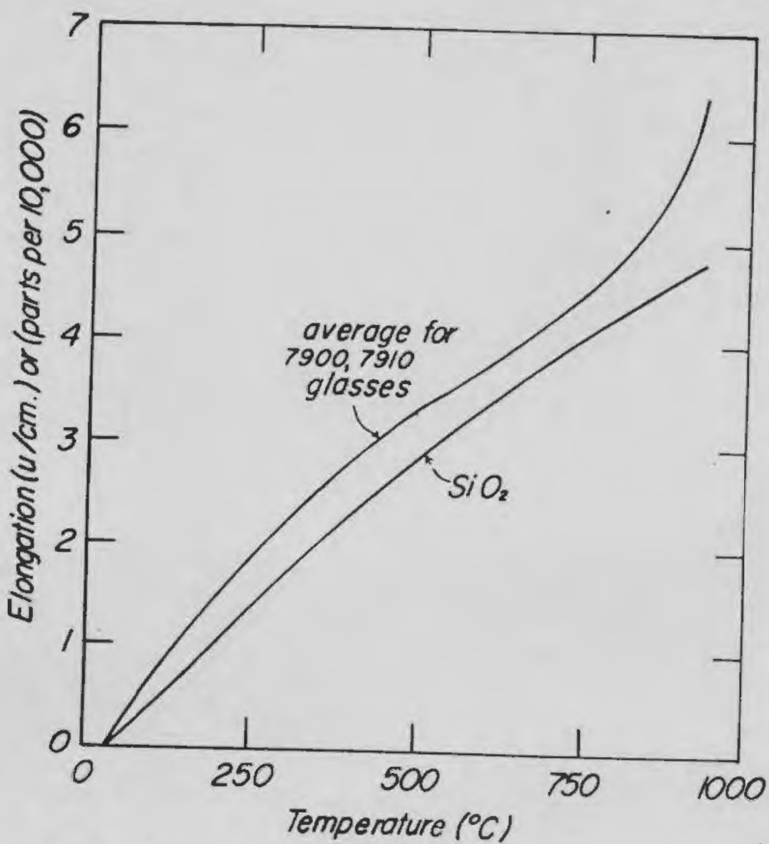


Figure 4 — Expansion Curves.

The high ultraviolet transmittance of glass No. 7910 is compared to that of conventionally melted glass in Figure 5. Since about 8% of the incident light is reflected from the surface, the maximum possible transmittance is 92%. Of special importance is the high transmittance at a wavelength of 2537 a.u. since this is the wavelength of the principal radiation from mercury vapor bactericidal and other low pressure lamps. VYCOR Brand No. 7912 glass will transmit still shorter wavelength radiation. Transmittance at the very short, ozone producing, mercury line of wavelength 1849 a.u. is at least 2% through one millimeter thickness of glass.

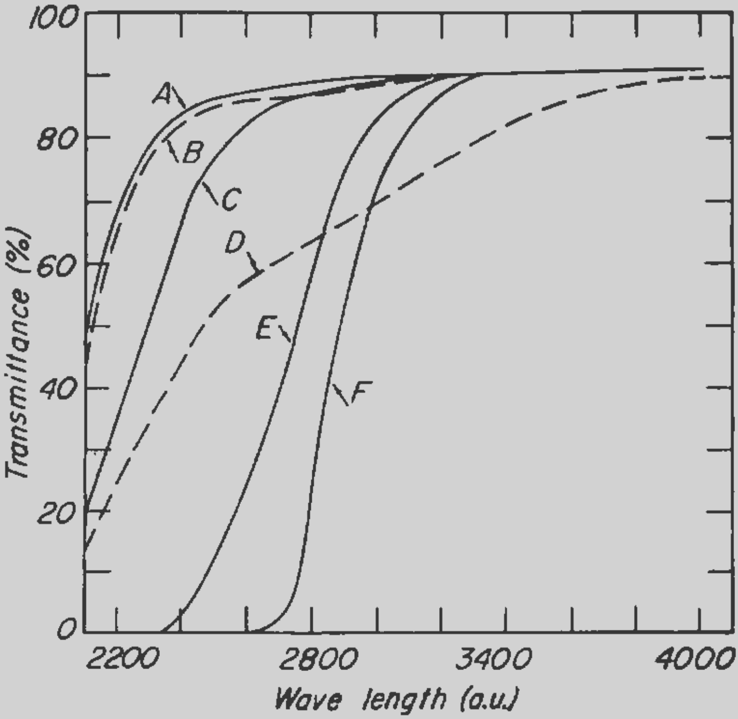


Figure 5 — Ultraviolet transmittance; curve (A) VYCOR Brand No. 7910; (B) No. 7910, solarized; (C) PYREX Brand No. 9741; (D) No. 9741, solarized; (E) PYREX Brand No. 9700; (F) PYREX Brand No. 7740.

It is difficult, if not impossible, to produce a satisfactory glass by conventional melting methods which has a high transmittance value at wavelengths as short as 2537 a.u. even after prolonged exposure to ultraviolet radiation. This can be accomplished in VYCOR

Brand glasses. Figures 5 and 6 show the small loss in transmittance of VYCOR Brand glass No. 7910 as compared to that of PYREX Brand glass No. 9741 commonly used for bactericidal lamps. The glasses were exposed on a rack six inches beneath the arc tube of a Hanovia 500S quartz burner. Its high sustained transmittance makes glass No. 7910 particularly useful for mercury vapor and similar lamps intended for maximum production of ultraviolet light.

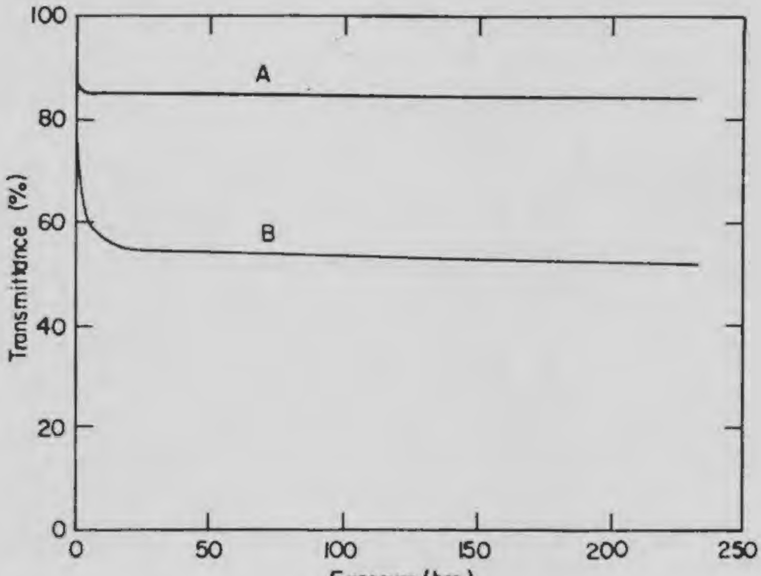


Figure 6 — Effect of exposure to U.V. on 2537 a.u. transmittance. Curve (A) VYCOR Brand No. 7910; (B) PYREX Brand No. 9741.

There is practically no absorption of visible light unless the glass is intentionally colored. Ordinarily, the infrared transmittance is above 85% through a two millimeter thickness for wavelengths shorter than 2.5 microns. An absorption band results from traces of water in regular No. 7900 glass and, peaking at 2.72 microns, lowers transmittance between 2.5 and 3.0 microns. However, a water-free glass, No. 7905, which shows practically no decrease in transmittance at wavelengths up to 3.3 microns can now be prepared.

Electrical properties of VYCOR Brand glass No. 7911 are compared to those of PYREX Brand glass No. 7740 and to fused silica in Table IV.

TABLE IV

Electrical Properties

Resistance	VYCOR Brand Glass No. 7911	PYREX Brand Glass No. 7740	Fused Silica
Log R (ohm-cm.) at 350°C	9.6	6.6	9.5
Log R (ohm-cm.) at 250°C	11.7	8.1	11.7
Power Factor (20°C) at 1 megacycle	0.02%	0.46	0.02%
Dielectric Constant	3.8	4.6	3.8
Loss Factor x 100	0.076	2.1	0.076

The high resistivity and low power and loss factors are of interest in certain electrical applications. It will be noted that electrical characteristics can be made fully equal, if not superior, to those of fused silica.

In Table V the chemical durability of VYCOR Brand glass No. 7900 is compared to that of PYREX Brand glass No. 7740. Losses in weight of small polished plates as the result of attack by an acid

TABLE V

Chemical Durability

	Loss in Weight (mg/sq. cm)	
Treatment	VYCOR Brand No. 7900	PYREX Brand No. 7740
5%HCl, (24 hours), 100°C	0.0005	0.0045
N/50 Na_2CO_3, 6 hours, 100°C	0.07	0.12
5% NaOH, 6 hours, 100°C	0.90	1.4

and two alkaline reagents are given. The VYCOR Brand glass is slightly more durable in the alkaline solutions and nearly ten times as durable in 5% hydrochloric acid as glass No. 7740 which itself has excellent acid resistance. Contamination of solutions by materials dissolved from the glass is usually of interest to the chemist. In this connection, it should be pointed out that since the VYCOR Brand glass contain only traces of elements other than silicon, boron and oxygen, contamination of solutions in contact with the glass by other elements, notably alkalies, will be extremely small. Attack by 60% hydrofluoric acid, although rapid compared to that of other acids, is about five times slower than for PYREX Brand No. 7740 glass and slower still with respect to lime glasses.

The high softening point of VYCOR Brand 96% silica glasses has extended their usefulness to higher temperatures than are possible with any other glass except fused silica. At these elevated temperatures the glass is relatively unaffected by acid and neutral salts and refractory oxides. Its rate of reaction with alkalies or alkaline salts is greater and depends on the temperature. It also reacts with electropositive metals in the molten state. It does not react with the ordinary gases including chlorine and hydrogen chloride, but it is relatively pervious to helium and hydrogen at elevated temperatures. This is a characteristic of high silica glasses.

As in the case of fused silica, devitrification takes place at high temperatures, with the formation of cristobalite. Cleanliness of the glass surface, where devitrification always starts, is an important factor in determining its rate. When a devitrified sample is cooled to below 300°C, an inversion of β cristobalite to the α form occurs, with an accompanying volume change which causes crazing or even breakage of the glass. In some applications, it is possible to prolong service life at higher temperatures by not allowing the glass to cool below 300°C.

The rate of devitrification is very low provided the glass is clean and the heating is done in air or other inert atmosphere. Up to 1200°C, the devitrification is faster than that of fused silica owing to its lower viscosity. Above 1200°C it is slower than that of fused silica and at no point does it reach the relatively rapid rate observed for the latter in the range 1300°C to 1500°C. Devitrification is accelerated by alkalies, alkaline earths and certain other metallic oxides or oxidizing metals.

In view of the variable rates of corrosion or devitrification which can be encountered in different applications, it is difficult to state a maximum operating temperature. For prolonged service in the absence of corroding or devitrifying agents, the glass temperature can be as high as 900°C. At this temperature deformation is slight. Temperatures can be above 1200°C in many short time applications. In fact, VYCOR Brand crucibles backed up with a crude refractory to prevent deformation are advantageously used for melting high purity glasses at temperatures up to 1500°C.

Lampworking techniques are similar to those used for fused silica. A much higher temperature is needed than for ordinary glasses but not as high as for fused silica. An oxy-gas flame is usually satisfactory, but some prefer oxyhydrogen, particularly with large items. Parts to be heated should be clean.

VYCOR Brand glasses do not flow as readily as ordinary commercial glasses. The high heat shock resistance makes it possible to heat the glass quickly or even to spot work relatively large pieces. Seals can be made by a method, simulating metal welding, in which a fillet of 96% silica glass is applied. A glass cane serves as the welding rod. The method is useful in making large seals, but in this case preheating of the ware or even occasional annealing may be necessary to prevent breakage. Large ware should be annealed by heating to about 950°C, holding at this temperature for a few minutes, and cooling.

The temperature required in lampworking is so high that silica volatilizes from the glass. The vapors condense to form a bloom on cooler areas adjacent to the heated portion. This effect can be minimized by preheating the glass beyond the area to be worked and by limiting final heating to as low a temperature and time as possible. If the bloom is not allowed to become too heavy, it can usually be dispelled by heating or at least partially removed by treatment with dilute hydrofluoric acid.

There is a tendency for bubbles to appear in No. 7900 glass on lampworking. This results from traces of water which are not driven off in the initial firing process but which are released at the much higher lampworking temperature. The bubbles usually do not impair the usefulness of the sealed article except in appearance. They, too, are minimized by working at as low a temperature and as quickly as possible. Glasses 7911 and 7913 are specially degassed in manufacture and do not show this tendency.

VYCOR Brand graded seals are available for joining 96% silica glasses or fused silica to PYREX Brand No. 7740 glass.

There is no metal alloy that matches the expansion characteristic of VYCOR Brand glasses up to the setting temperature. It is therefore necessary to use either intermediate glasses or graded seals to introduce metal electrodes or other parts into tubes or bulbs of VYCOR Brand glass or to use a very thin metal foil which will yield sufficiently to prevent breakage of the glass. For the latter, 0.005 inch thick molybdenum foil is commonly used.

Types of VYCOR Brand Glasses

Several types of VYCOR Brand glasses are sold under various code numbers. I have referred to some of these types in the foregoing discussion. The special features of these glasses are listed in Table VI.

TABLE VI

Types of VYCOR Brand Glasses

Code No.	Special Properties
7900	No restrictions on ultraviolet transmittance.
7905 (new)	Low gas content. Very high transmittance to infrared light at all wavelengths up to about 3.5 microns.
7910	High ultraviolet transmittance. At least 70% at 2537 a.u. for 2 millimeter thickness. High electrical resistivity and low power loss.
7911	Ultraviolet transmitting, low gas content. High electrical resistivity and low power loss.
7912	Similar to No. 7910 glass but more transparent to wavelengths below 2537 a.u. At least 2% transmittance of 1849 a.u. through one wall of thin walled (about one mm) tubing.
7913	Low gas content. No special restrictions on transmission.
7914	At least 20% transmittance at 2537 a.u. High resistivity and low power loss.
7930	Porous glass.
7931	Graded seal VYCOR Brand 96% silica glasses or fused silica to PYREX Brand No. 7740.

Excepting the last two, all glasses have high softening points and the same low expansion. The low gas content glasses, Nos. 7911 and 7913, are slightly harder than No. 7900 and can be used at higher temperatures without deformation. Glass No. 7911 was designed for medium pressure mercury vapor lamps.

The Annealing of Glass and The Measurement of Stress in Glass

BY S. D. BURDICK

Corning Glass Works

Glass when cooled after flame working, or after any other operation where it is worked at a high temperature, acquires strain. In some cases this strain may be quite low; in other cases it may be high enough to cause spontaneous breakage of the glass. This breakage may occur immediately after cooling, or it may be delayed for several weeks or even months, depending on the amount of strain and the damage to which the surface of the glass has been subjected in the meantime.

There are three factors which determine the amount of strain which glass acquires in cooling. These are: (a), the cooling rate; (b), the thickness; and (c) the thermal expansion of the glass. As the temperature of glass (and most other materials) is increased, the dimensions of the glass increase with, of course, a reverse change when cooling occurs. This thermal expansion is expressed as the fractional increase (or decrease) in length for a temperature change of one degree Centigrade. A piece one inch long of the borosilicate glass used in the manufacture of Pyrex brand ware will increase in length 0.0000033 inch for each Centigrade degree that its temperature is increased. It is customary to write this figure as 33×10^{-7}, which means that to obtain 0.0000033, the number 33 is divided by 10 seven times in succession. The thermal expansion of lime and lead glasses is approximately 90×10^{-7}, almost three time as much as borosilicate glass.

Purely as a change in size, this does not appear serious. Its importance to the glassblower lies in the fact that, during cooling, some parts of the glass cool faster than others, and set up or become hard sooner. Other parts, cooling slower and continuing to contract, set up later; and thus, a system of mutual forces, acting against each other, results in strain in the glass. This explains the statement made earlier that strain after cooling depends on the cooling rate and on the thickness. Both of these affect the temperature differences within the glass; and hence, the amount of strain left after cooling is completed. If glass could be cooled in such a way that all parts were at the same temperature at all times during cooling, it would be free from strain.

This condition is approached by cooling the glass slowly, so that the temperature differences are small. In general, by making this cooling rate slow enough, the amount of strain left in the glass can be made as low as desired. When preceded, if necessary, by a holding period to release strain already in the glass, this controlled cooling constitutes annealing.

Complete removal of strain in glass, besides being difficult or impossible, is in most cases unnecessary. In order for spontaneous breakage to occur from strain resulting from rapid cooling, the stress due to the internal forces within the glass must be at least 1,000 pounds per square inch. Commercial annealing is defined as 250 pounds per square inch, which gives a good margin of safety, and except for special cases, this amount of stress may safely be left in glass.

If the article being flame worked has fairly light walls, flame annealing may be sufficient. For heavier pieces, annealing in an oven or kiln may be necessary, and should start with a holding time at the annealing temperature of 15 minutes or more. Usually, the cooling rate of the oven will be slow enough so that no further attention will be required after the heating current is turned off; but, for very thick pieces, the cooling rate may have to be slowed up still more by manual control, or otherwise.

At the other extreme, of course, for articles with very light walls, no special annealing at all is required since, even when allowed to cool in the air, the final strain will not be great.

So far, we have been considering only those strains which occur in glass as a result of cooling after flame working, or from a temperature where the glass is soft. Strains due to other causes may occur in glass and may be of sufficient intensity to cause the glass to break.

The first of these, mechanical strain, results when an external load is applied to glass. A pebble picked up by the tire of a passing car and thrown against the windshield, or the steady pressure of a strong wind against a plate glass window, can cause breakage. Strains of this type disappear as soon as the force causing them is removed; and, unless breakage has occurred, the glass is unchanged.

A second type of strain occurs during heating or cooling glass if one part of the glass is at a different temperature from other parts. This type is similar to that occurring when glass is cooled after flame-working; but, unless the glass has been heated to the point where it is soft, there strains will disappear as soon as the glass comes to the same temperature throughout.

A third type of strain is set up when two pieces of glass of different expansions, or glass and metal of different expansions, are sealed together. When such a seal is cooled, the two components cool and contract at different rates, so that the longer part is stretching the shorter part and is itself being compressed by the shorter part. Such strains cannot be removed by annealing.

Commercial annealing has been defined as a stress of 250 pounds per square inch or less after annealing, and this limit applies in general to all glass articles. Exceptions may be made occasionally, as when, on account of expected service more severe than usual, a limit lower than this is established. There are other cases where the limit may safely be raised. If, for instance, a number of successive flame working operations are conducted on a piece of glass, stress after the final annealing should be within the commercial limit; but, after each of the individual working operations, annealing need not be as good. It is probably safe to leave 500 pounds per square inch in the glass, possibly more. The only requirement is that strain shall be low enough to prevent spontaneous breakage before the piece receives its final annealing.

We should now consider the ways by which the amount of stress in glass can be determined. For this purpose, the polariscope is most commonly used. Most polariscopes are arranged so that the field of observation is normally pink, and unstrained glass when viewed on a polariscope is also this color; but strained glass is either some shade of blue-green or of orange-yellow, depending on whether the glass is in tension or compression, and on its position on the polariscope.

With increasing strain, the observed color goes from pale blue through blue-green to intense green, or if the position on the polariscope is reversed, from orange through orange-yellow to bright yellow. These color changes are quite sensitive to strain, so that, with experience, the observer can estimate the amount of stress from the intensity of the color observed.

The limitation of the polariscope for determining stress lies in the fact that the effect, that is, the color, depends on the thickness of the glass as well as on the strain in the glass. Two pieces of glass may be strained to the same degree; but, if one is thicker than the other, it will show more color on the polariscope.

To a lesser degree, the color also depends on the composition of the glass. Two pieces of glass may be strained to the same degree, and may be the same thickness; but, if one is a borosilicate glass and the other is a lime glass, the borosilicate glass will show more color.

Standards for making comparisons of color are sometimes used with the polariscope. These show the maximum allowable color which a given piece should have when viewed on the polariscope. Such a standard may be a piece of ware similar to that being examined, which has been selected as having no more than the allowable strain, or it may be only a piece of flat glass which has the desired amount of color. In either case, the basis for the selection is the requirement that the standard, regardless of the actual strain, must show the proper degree of color.

Other instruments can be used for an actual measurement of stress. These instruments, called polarimeters, operate on the principle of compensation, by which an effect, which is opposite to that of the glass, is introduced. Imagine that a piece of glass in tension is placed on the polariscope and over it is placed a piece which is in compression. The two pieces would have opposite effects, and would tend to neutralize each other. At any point where the stresses were exactly equal and opposite, the combined effect would be zero, and the appearance on the polariscope would be the same as that of unstrained glass. Compensators are actually made of other materials which, however, have the same effect as strained glass.

Polariscopes and polarimeters get their names from the fact that they use polarized light. The effect of strained glass on polarized light is called retardation; and retardation is measured in millimicrons, the unit used to measure the wave length of light. When using a polarimeter, the compensator is adjusted until the effect of the glass is neutralized; and the retardation in millimicrons is obtained from the amount of such movement required.

Although the effect of strained glass on a polariscope or polarimeter depends on the degree to which the glass is strained, it also, as has been said, depends on the thickness of the glass and on the composition of the glass. When the proper allowance for these variables is made by substituting in a formula, a value of stress in the glass is obtained in either kilograms per square millimeter or in pounds per square inch, depending on the formula used.

A practical test of annealing may be made in another way. If dangerous stresses are present in a piece of glass, they may be discovered by scratching the suspected areas with carborundum. Excessive stresses will show up as checks in the scratches, or even by complete breakage of the piece, thus indicating the need for better annealing. By using a polariscope or polarimeter, stress in other similar pieces can be kept below the danger point.

For further study of the subjects covered in this paper, the following references may be consulted:

"Basic Principles of Glass Annealing" by H. R. Lillie. Glass Industry, July 1950.

"Analysis of Strains and Stress in Glass" by A. J. Monack and E. E. Beeton. Glass Industry, April, May, June and July, 1939.

On Polarized Light, consult any text book on Optics.

Glass Strength

E. B. Shand

Corning Glass Works

Glass strength is a subject of technical interest and practical importance. Its importance is constantly becoming greater because of the continued expansion of glass into structural applications. Corning alone makes many investigations and tests each year to increase the strength of its products, and thousands of tests in order to maintain technical control of this strength in manufacture.

Measured values of strength of glass cover a wide range, extending from a few thousand psi. in certain commercial products to several hundred thousand psi. in glass fibers, or a ratio of 100 to 1. Likewise the variation of strength found in a group of similar specimens is also much greater than is ordinarily the case in tests on metals.

In earlier days, such observations were baffling and confusing. However, the work of many investigators has shown that strength of glass as measured is not a basic property of the material but represents the condition of the surfaces subjected to stress. Glass with extremely smooth surfaces reaches the upper end of the strength range, while glass with severely abraded or roughened surfaces remains at the lower end.

These unusual characteristics are connected with the brittle nature of the material. A scratch or impact may, and usually does, produce a small check in the surface. Perhaps this will be a mil or so in depth but extremely narrow in width, often less than a wave length of light. Such checks produce high stress concentrations which may be of the order of 100 times the stress which would exist if the check were not there.

In a ductile material checks of this nature are uncommon and, furthermore, the localized stresses are relieved by the plastic yield of the material. Brittle bodies have no yield point so that when the local stresses reach some high value the checks begin to enlarge with a resultant weakening of the glass. At first the rate of this enlargement may be imperceptible, but as the depth of the fracture flaw increases the rate of propagation also increases until finally the fracture occurs with the characteristic abruptness of glass fractures. When this occurs the fracture speed may attain a value of 1 mile per second.

Usually there are many flaws or checks in a glass surface. One of these flaws which produces the highest concentrated stress will propagate and eventually develop into the final fracture. The size of this particular flaw and thus the measured strength of the glass is consequently a matter of probability.

The strength of any individual piece of glassware can be determined accurately only by actually measuring its breaking stress. If we consider 100 specimens of some article of glass, each individual piece will have a critical flaw or check differing in size and characteristics from the other pieces. If these 100 pieces are then loaded to failure, the breaking stresses may be found to range from 6000 to 12,000 psi. If we then take an additional piece from the same original lot, we can say that it will almost certainly break under some stress within the range just stated. From more careful examination of the data obtained on the 100 specimens broken, we may also be able to say that this single piece has an even chance of failing under a stress between 6700 and 8200 psi.

Experimental tests have shown that glass always breaks under tensile stress. This is true even when glass is subjected to compressive loading. In this case the fracture develops from some tensile component of stress, often highly localized. The slow growth of flaws or checks explains why the breaking stress is a function of the time duration of the load.

In the case of annealed glass, if the breaking stress under a load maintained for a period of only several seconds is 10,000 psi., it may be expected that the same piece might fracture under a stress of the order of 4500 psi. if the load is sustained for an indefinite period of time, say one or two weeks. Based on this same principle, a piece of glassware which sustains a single thermal shock successfully may fail if this same shock is repeated a number of times. Each successive shock enlarges the fracture flaw by a small amount until the thermal stress becomes large enough to produce failure.

The question is frequently raised as to what effect temperature has on the strength of glass. At temperatures below 0°C., strength tends to increase as the temperature is dropped. At —200°C. breaking stresses may be 50% or more greater than at 0°C. There is some evidence that glass is weakest from room temperature to 250°C. or

300°C. At temperatures beyond these values strength tends to increase with temperature until the strain point of the glass is approached.

Fatigue, or reduction of strength as a result of repeated load reversals, is a well-known characteristic of metals. If a load when applied several million times to a steel bar causes failure, the corresponding breaking stress may be only 50% of the ultimate strength of the same bar under a single load application. This reduction of strength, or fatigue, is associated with work-hardening of the steel.

The corresponding effect in glass is small and is ordinarily neglected. In its normal state glass or other brittle material may be considered to be completely work-hardened so that stress reversal cannot increase this condition perceptibly. However, the effect of long time loading already referred to must not be forgotten.

This effect is sometimes referred to as static fatigue. The decrease in strength of a glass article resulting from a stress of 10,000 psi. applied 1000 times for a period of 1 second is roughly equivalent to the same stress applied steadily for a period of 1000 seconds.

It is well known that the strength of glass can be increased very materially by tempering, a heat-treatment which produces residual compressive stresses at the surfaces of the glass. When an external load is applied to tempered glass, its tensile component at the surface must exceed residual compressive stress before a check can propagate.

In a general way the breaking stress of the glass is increased by the amount of this residual compressive stress. If the short time breaking stress of a piece of annealed glass is 10,000 psi., and the residual compressive stress after tempering is also 10,000 psi., the short time breaking stress of the tempered glass will be of the order of 20,000 psi. Also if the long time breaking stress of the same piece annealed is 4500 psi., the corresponding breaking stress of the tempered piece will be of the order of 14,500 psi. Thus the tempering process will have increased the short time strength by a factor of 2, and the long time strength by a factor of 3.2.

In conclusion it may be remarked that in recognizing the large part that the surface condition plays in the strength of glass, it follows that all reasonable care should be taken in the fabrication and handling of glassware to keep glass surfaces as free from additional scratches and impacts as possible in order to maintain a normal or representative values of strength. When serious scratches and impact marks are already present, strength can be restored by fire polishing the surface, by mechanical polishing and by acid polishing with a hydrofluoric acid solution. Special techniques are desirable in carrying out these operations in order to obtain the best results.

Photosensitive Glass

Dr. Donald Stookey

Corning Glass Works

We thought you might be interested in hearing a little bit about some strange effects that we can produce in special glasses that you don't ordinarily see in your operation. I would like to start by trying to indicate what the relationships are between these peculiar compositions and some of the ones with which you may be familiar. You normally use borosilicate or lime glass which do not have any secret materials in them; but sometimes you deal with colored glasses, red or blue or yellow tubing. You probably find effects on flame-working certain of these, especially the reds and the yellows, that show some peculiar chemistry is taking place. You may find that you're getting change in color or the glass turns opaque. Sometimes you may have worked with the so called opal glass (white opaque glasses). These glasses were transparent when they were in the melting unit but crystallized to a very few per cent of crystalline material, maybe sodium fluoride or calcium phosphate, as they were originally made. Sometimes you would find a change in their opacities when you flame-work them because more crystallization takes place.

There are other kinds of glass that would be a lot of fun for some of you glass blowers to play with. For example, I could show you at least a half dozen pieces of transparent glass, all of which look exactly the same, look like window glass for example, and every one of them would give you a startlingly different effect if you flame-work it. For example, I could have a piece of gold ruby glass or selenium ruby. The gold ruby, which you have seen in some cased glass ware, was probably originally colorless and then it was reworked in making the article to precipitate tiny crystals of gold; and the color might be blue or red or purple depending on the size of these gold particles in the glass. Another piece would be selenium ruby, which would be colorless to begin with, turn yellow on slight heat treatment and a brilliant red on further heat treatment. Another piece would turn white and opaque in the flame because it crystallizes sodium fluoride.

Following this path a little further, Dr. Dalton of our laboratory originally found that you can control these effects still further to produce a glass which would be clear and would stay clear while you flamework it or at least not change color too much. If you expose it to ultraviolet light before you flamework it or heat treat it, it would turn color a lot more. Now this has been the beginning of a continuous series of developments that seem more and more strange to us who are dealing with them and are starting to turn into very useful new forms of glass, and even changing glass to something entirely different—changing it to a rocklike material much harder and stronger than glass.

Starting with this discovery of Dr. Dalton's, we have developed a whole family of photosensitive glasses in which the glass is exposed to ultraviolet light through a photographic negative and a colored or opaque photograph developed by heat treatment. Some of these photosensitive glasses before exposure are so insensitive to heat treatment that they could be flameworked many times and still not change in color. There is one commercial product which is being made by this method. First, from an optical tank of photosensitive glass, a ½" cane is drawn. This cane is flameworked and repressed into jewelry items and still colorless at that stage. Then these artificial gems are put through a photographic process and are sold as cufflinks and lockets.

One of these photosensitive opal glasses precipitates lithium silicate crystals in a three dimensional photographic pattern and becomes more than a hundred thousand times more soluble in acid than the glass that has not been exposed to ultraviolet light. We expose this glass to ultraviolet light through a photographic negative or a stencil and then heat treat the glass at a temperature about 50° above the annealing temperature of glass and at that stage we have a white pattern penetrated throughout the glass. Then if we cool this down and put it in a bath of 10% hydrofluoric acid, which dissolves the white area and "chemically machines" the glass to intricate shapes. It is possible to etch as many as a quarter of a million holes in a square inch of the material and these would be about a thousanth of an inch in diameter. The electronic industry is very interested in this material. It permits things to be done that have never been possible before, such as new developments in memory tubes and complicated gadgets of this sort for which we furnish this insulating material in any structure they want. They fill the holes with phosphors or metal conductors, add wires and come up with fantastic electronic gadgets. Another example of one of the strange uses which you might not ordinarily thing of for glass is this; that we have found it possible by this etching process to make printing plates. We etch the pattern part way into the glass and this, when it is backed up so that it isn't bent, is a stouter printing plate material than engraved metal printing plates. It doesn't wear away and lasts longer than metal plates.

I mentioned that the glass can be even converted to something that isn't glass by these processes. We find that this same glass that I was just telling you about has still more remarkable properties. If I re-expose a plate of this glass to ultraviolet light and put it through a heat treatment, which gets progressively more severe, it would become stiffer as it crystallized so that I could heat it to a higher temperature without deforming it and if I take it up to about 1000°C. for awhile it is more crystalline than glass. This material after exposure and final heat treatment is converted to a material that looks like a rock-like, granite material, and it is much higher in melting temperature than the original glass. It is several times stronger and has entirely different electrical properties. We expect to find a wide new range of uses for this and the other strange new glasses that Corning is continually inventing.

Glass Technology

DR. C. A. BRADLEY, JR.

Corning Glass Works

I am a little embarrassed in some ways when I read on the program the title of this talk. It says: "Glass Technology with emphasis on imperfections in rod and tubing." That is just about like asking a person from California to talk about the foggy weather they have out there.

As customers, all of us, no doubt, complain at times about the quality of the glass we buy. I would like to have you know that we people who are in staff jobs responsible for glass quality are under very considerable pressure and criticism from the plant managers when the quality isn't what they think it should be. In other words, we are continuously trying to improve the glass quality.

However, I am inferring that the reason for getting me up here to talk was to tell you about some of the problems we have in making glass that keep it from being perfect. Now it is possible to melt essentially perfect glass but to do so would make it so expensive that no one could afford to buy it. So one has to tolerate a certain degree or amount of imperfection in everything we buy.

Now the use of the glass has a bearing on the amount and/or type, of imperfections which are tolerable. Specifications, in other words, differ widely. For example, in a piece of optical glass for a large camera lens one would require no defects which could be seen by the naked eye. Incidentally the face plates for television picture tubes are rapidly approaching this situation. You may not be aware of it, but the face plate for a 21" T V tube weighs about sixteen pounds. Any bubble or stone in the center 8¾" x 6½" rectangle that is larger than twenty thousandths diameter is cause for rejection of the whole sixteen pounds of glass. You will realize this is a pretty tight specification. On the other hand, specifications are much more liberal for ordinary containers.

You are all no doubt aware that the glass melting process consists in mixing together certain minerals and chemicals according to a formula, feeding this mixture into the back end of a furnace where the melting and refining of the glass takes place, and making the ware from the front end. One of the difficulties is that the container used to hold the molten glass is also made of oxides which are the same or similar to the oxides used in the glass batch. In other words, the container itself is slowly dissolving, and that has several affects on the quality of the glass coming from the furnace.

Now the types of glass faults which really concern us can be classified into about four different types: stones, bubbles (blisters and seeds), cords, and knots. I will discuss them in that order.

Stones generally come from four different sources. The first one is undissolved batch particles. The melting process is dependent on temperature and time. If you try to put too much glass through a tank in a given period of time (plant managers always want to have complete flexibility of production as business demands) all of the minerals won't be completely dissolved. They will appear in the ware as stones and if larger than the specifications allow, the ware will be rejected. Secondly, there are the stones from the refractories with which the tank was built. These refractories are generally composed of silica, almuina, and sometimes zirconia. These refractories are not completely homogeneous. Some small regions are more soluble than others, and types of crystals in them are more soluble than other types. As a result, the more soluble areas are dissolved away first, and may release a small lump of the more resistant material which may get all the way through the furnace before being completely dissolved. Then there is a third source of stones which is a result of chemical interaction between the glass and refractory. It is also dependent on the fact that a glass furnace does not run at a uniform temperature throughout; some parts are hotter than others. It is hottest in the center of the melting end where one is trying to complete the solution of the raw materials. Then as the glass moves toward the working positions it is gradually cooling off. As the glass dissolves the refractory, the composition of the glass up against the refractory (i.e., the interface) is changing. At certain places and under certain conditions this interfacial glass may be supersaturated with respect to certain components and these will crystallize. These crystals may be dislodged and appear in the ware. Finally (and this is particularly true for tubing) you may get to a certain place in the temperature-time cycle where the glass itself will devitrify or crystallize. You are all aware, I'm sure, that any glass, if held in a certain critical temperature range for a long enough time, will crystallize. And that we are able to make a satisfactory product only by getting it through this critical temperature range before it can crystallize. As I said before, this is particularly true of the tube making processes, and we are continually fighting this crystallization tendency. If conditions aren't exactly right, these crystals may pull loose and appear in the tubing. In many cases, these crystals are extremely small and very difficult to see. In fact, sometimes they can only be seen by looking lengthwise down a piece of rod or tubing. When this happens, we say the tubing is sandy. Of course, when the conditions are very bad, the sand is not hard to see.

There is also the problem of eliminating the undissolved gases which appear as bubbles. The larger ones are called blisters and the smaller ones seed. The latter we generally define as the residual bubbles left from converting the batch mixture into glass. That is these bubbles are due to air that is either absorbed on or trapped in the raw batch mixture. They also come from the decomposition of the sulphates, carbonates, etc., in the batch during the melting process. Since the presence of a few small bubbles in most glass ware is not detrimental to its use, a certain number of them are always present. It would be impossibly expensive to eliminate all of them. We keep track of them by making routinely what we call the seed count. That is, we regularly count the number of seed per cubic inch of glass. Specifications for various types of ware often include the allowable seed count.

Now bubbles which are somewhat bigger (usually 1/16" diameter and larger) are called blisters. They also may come from several sources. A few may actually be large seed which did not have a chance to be eliminated due to a high load on the furnace. Also reaction between the molten glass and the refractories will sometimes either release dissolved gas from the glass or chemically generate gas bubbles. If these reactions occur (as they sometimes do) close to the forming machine, the bubbles will appear as blisters in the ware. In addition, some blisters are formed mechanically. That is, air is trapped into bubbles by action of the feeder parts delivering glass to the forming machines. Stray or deliberately introduced electric currents in glass can produce blisters.

As you can see, there are many mechanisms by which blisters can be produced. The headaches develop in trying to determine which source is producing the blisters causing trouble. After all, bubbles from all of the sources look very much alike in a piece of glass.

There is also one other way for bubbles to be produced which is familiar to all lamp workers: it is very easy to form bubbles by improper reheating glass ware for working in a flame. You may not be aware of the fact that all glass contains a considerable amount of dissolved gases. In general, if you take one cubic inch of glass melted under usual production conditions and remelt it under vacuum, and then collect and measure the volume of the gas evolved, you will find that you have about one cubic inch of gas. This gas will be a mixture of water vapor, carbon dioxide, and other gaseous products from decomposition of the raw batch materials. It is very easy to reheat the glass in a flame, drive out these gases, and form bubbles. Some glasses are much more sensitive in this respect than others. However, it behooves one to take care in reheating all glasses.

The third big fault which bothers us is cord. In general a cord is a streak of glass of slightly different composition than the normal glass. Because its composition is different it has different physical properties; e.g. different softening point (viscosity-temperature relationship), different expansion coefficient, different density, different refractive index, etc. These differences of properties make it visible. Cords also have several sources. One source is incomplete homogenization of the rawbatch materials. This kind of cordiness is worse the faster the glass moves through the furnace. You see, the raw batch mix is not uniformly distributed in atomic dimensions; we are depending on the furnace to do that. Another is the solution of the tank refractories. The resulting interfacial glass is slowly carried away by the flow of the glass, and is not completely blended into the main body of the glass. This is continually occurring from the filling end to the working end of the tank. We are always looking for more resistant refractories, and actually great progress has been made on this problem in recent years. Very often these cords are not objectionable; they do not adversely affect the use of the glass ware and are so oriented that they are not easily seen.

A third source of cords is due to the volatilization of some of the glass constituents. This is particularly true of borosilicate glasses. Now in the 7740 Pyrex Brand Chemical Resistant Glass at the melting temperatures the sodium oxide and the boric oxide have appreciably higher vapor pressures than the silica. Consequently, relatively more of these are vaporized, and the surface glass composition is slightly changed. If this surface glass is not completely mixed into the main body of the glass, it will show up as cord.

The last fault I would like to mention is called a knot. This is like a sort of ball of cord. It is a small lump of different composition glass. It may be due to the same cause as the volatilization cords. It also may be the last stage of solution of one of the raw materials.

The forming processes often have a pronounced effect on the appearance of cords, blisters, and knots in the final glass ware. This is particularly true for rod and tubing. For example, cords are drawn out into fine streaks, blisters or seeds into fine tubes we call airlines or, if short, doghairs, and knots into rather chunky lumps with cord tails.

I hope the remarks I have made have told you something of interest about the problems we have in making glass. I can assure you that we are well aware that the glass is not perfect, but we are very actively working to make it better.

Lampworking

HERMAN SCHRICKEL, SR.

Corning Glass Works

Corning, N. Y., July 20, 1956

Ordinarily it is not good to face backward, but on an occasion like this it is worthwhile to take a backward glance and see what has been accomplished. I intend to review, therefore, the history of scientific glass apparatus as it has occurred in this country.

Fifty years ago few shops in America were handling apparatus work. Their principal business was to repair imported ware, which was shipped in duty-free for educational institutions, then the biggest consumers.

These institutions trained generations to the idea that scientific ware could only be imported. There were few industrial research laboratories at that time and they shared the same outlook.

This made the United States so dependent on foreign producers that in 1907, for instance, when the American Thermos Bottle Co. installed a vacuum department, it used only German-made equipment.

In such a situation few Americans were willing to invest money in domestic production of scientific glass. The few apparatus shops in existence barely managed to stay in business.

This situation began to change in 1914 with the start of the first World War. Imports from Germany were cut off. Jena ware was hoarded and sold at black-market prices.

Japan was not yet ready to fill the gap thus created and England and France were poorly equipped. So American shops with primitive equipment tried to meet the demand.

The major glass-producing firms: Corning Glass Works, Durand (the present Kimble Glass Works), Demuth and others still lacked the know-how to produce scientific glassware.

However, Corning was already making thermometer tubing that could compete with Germany's products. This technology proved useful to this country and its allies during the war.

In 1915, Corning perfected Pyrex brand glass. Corning still lacked the facilities to produce laboratory ware in volume but a few Pyrex brand beakers, flasks and some tubing were made, and received with great enthusiasm.

Most manufacturers in this country were still using lime or flint glass at that time. The glass was of poor quality because of the use of ingredients such as potash.

Many ideas were tried in the effort to prevent weathering and devitrification. Most lampworkers kept a salt shaker on their work bench, others used diluted hydrofluoric acid.

When World War I ended most dealers and consumers and some leading educational institutions turned again to imports for their supply of apparatus products.

However, with active support from Corning Glass Works, movements to stiffen import and tariff laws were successful about 1925. Had it not been for the constant technological improvement made by Corning during the intervening period much of the progress and know-how gained during the war might have been lost.

In 1919, Corning Glass Works established a small lamp shop in New York City, and moved it to Corning in 1923. Since then progress has been marked by steady expansion in the blowing rooms, Apparatus Plant and finishing departments.

Today, we have a variety of glass formulas for apparatus work. I shall mention a few of them, and the techniques and equipment we have devised for working them efficiently.

Of our three most popular Pyrex glasses, 1720, 7280 and 7740, the first is most troublesome. Most glassblowers assert that 1720 glass devitrifies and is hard to work. Usually, the flaw arises from the fact that it has a higher softening point than 7740, so glassblowers use quantities of oxygen and the consequence is devitrification and surface boiling.

To avoid these difficulties, the worker must use less oxygen and give the glass a chance to heat throughout, using a soft flame instead of concentrated, intense fire.

Our alkali-resistant glass, 7280, is as workable as ordinary lime glass but slightly harder. To prevent fire checks adjacent to the working area, the glassblower must use oxygen with care.

Few glassblowers have complaints about 7740 glass. Difficulties seldom arise unless the glass has not been properly cleaned or annealed. And in some cases it is overheated, which causes a boiling surface glass.

Now, I would like to turn to equipment. Our silent burner has several advantages over its competitors. Without changing tips, it can cover an extremely wide working range; from a needle flame to a large, silent flame, providing there is sufficient gas and oxygen pressure.

Our high-frequency sealing equipment, developed by Dr. Edwin Guyer, has been a great asset in glass finishing. Without it, it would be impractical to produce many common items. Its greatest advantage lies in heating the glass on the inside as well as the surface.

The 60-cycle burner has the economic feature of heating faster without using expensive oscillators. However, more safety equipment is required.

These pieces of modern equipment graphically illustrate the progress made in scientific glassblowing during the first half of the century. I am certain that through cooperative effort we can make even greater advances in scientific apparatus manufacturing in the second half of the century.

Saturday Discussion Session

The review of the Saturday discussion session, which was taken from tape recordings of the meeting, has been re-arranged and edited so as to present a consecutive sequence of subject material. Repetition has been eliminated or compiled with previous material.

Every effort has been made to give the proper credit to the persons asking and answering the questions. In many cases however, names were not given or did not record satisfactorily. In many of these cases, either from the recorded voice or from memory, credit has been given to certain persons.

Whenever possible, the exact wording of the person speaking has been used. These include the indiscriminate use of the trade names of various articles and materials. So that proper credit may be given, these, together with definitions, are listed below.

PYREX — Pryex Brand Glass is a registered trade mark of the Corning Glass Works. Generally speaking, in this review "Pyrex" refers to Corning code number 7740 glass.

VYCOR — Vycor Brand Glass is a registered trade mark of the Corning Glass Works. As used in the text, this refers to Corning code number 7900 glass.

POROUS GLASS — This is the leached but unfired form of "Vycor Brand Glass" and is sometimes refered to as "thirsty glass." This glass is Corning code number 7930.

PHOTOSENSITIVE, PHOTOFORM, and PHOTOCERAM — These are light sensitive glasses that have been developed by the Corning Glass Works.

GLASCAST — Is a molding powder made from "Vycor Brand Glass" by the Corning Glass Works.

TEFLON — "Teflon" is the registered trade mark of the E. I. duPont Co. for their polytetraflourethelene.

Burners I

Question — Mr. Bacon

What torch should be used for working Vycor, and what gas pressures are used?

Answer — Mr. Schrickel

It all depends on what things you make as to what gauge pressure you would use. You may use low pressure on small things, high pressure on large things. It is impossible to say what pressure to use for any specific piece of appartus. It just will not work to set down any formula for any certain sizes. You use it as you need it. It all depends on what you are doing. There is no particular formula for this thing. We would like to have a torch that is resistant to Vycor but when you can melt iron or steel in Vycor, it becomes very difficult to build a burner that will resist that heat. You have an actual reflection which will ruin your burner. That is where our difficulty is. If we once get a material that is resistant to that reflection then we can solve the problem. We are looking for that.

Answer — Mr. Alexander

When we visited the Sylvania Electric Company in Bayside, New York, Mr. DeMaria showed us some very fine burners that they use for working Vycor and quartz. They have promised to let the society have the diagrams for these. When we were there we witnessed them working with three of these burners on a lathe. Each burner is about 1″ in diameter with a perforated head, and using these burners and oxygen and hydrogen, they were working 7″ or 8″ Pyrex tubing with ease.

Comment — Mr. Sampson

To work Vycor I use two cannon fires which I purchased from Eisler Corp. With these I have worked 1″ to 1¼″ very successfully by using a pair of them. These are set similar to crossfires. That is, they are set opposite each other although not directly at each other, but at a slight slope. I have an adjustment so that you can arrange the angle any way that you want, but I would say that with these I have worked Vycor with comparative ease.

Question — Mr. Wilt

What is happening to the quality of the original Corning burner? The original was one of the best and in fact is still one of the best torches ever put out, but recently we have been getting burners of the same design from other manufacturers and they are not as good as the original torch. Why is this?

Answer — Mr. Schrickel

We have had a good many complaints concerning this. The individual manufacturers have changed somewhat the construction of our burners due to recommendations from inside their company. We have examined some of these torches and have recommended that they be changed back to the original design. These companies are re-examining the problem and I think that as a result of this cooperation we will eventually come up with a better burner than any so far. But for use on Vycor and the other hard glasses we believe that the Corning torch is the most universal one on the market today. It is not too satisfactory for the soft glasses as it does not operate well with air.

Question — Mr. D. Whittemore

Is the Corning torch made under Corning patents?

Answer — Mr. Schrickel

No, the Corning burner is made under a General Electric patent but we have been licensed to manufacture and sell this burner. So many glass blowers wanted this burner that we have let out the manufacture of it. This burner has been modified from the original General Electric patents so as to make it much more universal and quieter than the original burner. We have also added the feature to it of making it so that it is not necessary to change the tips from a small flame to a large bushy flame. This was our addition to it. When we were making all of the burners, each one was tested individually before being sent out. It was also requested from each purchaser as to the pressure of gas and type of gas that they were using so that the burner could be adjusted properly before it was sent out. They were also put together very tight so that the glass blowers or people out in the field could not take them apart and ruin the orifices that have very close tolerances. You see, the inside must be tight or there would be danger of flashover with hydrogen or gas.

Comment — Mr. F. Whittemore

Periodically it is necessary for me to grind the seat for proper operation of the Corning burner. I have no difficulty in taking it apart and I grind it in with the finest emory available and it works very well. Since doing this, I have had no trouble with the torch back-firing across.

Question — Mr. Stein

What do you think of using acetylene for working Vycor?

Answer — Mr. Schrickel

We have tried acetylene and have found it gives no advantages of a greater heat. Although there is quite a bit of controversy on this, we don't care for using acetylene in our shop.

Solder Glasses II

Question — Mr. Baentsch

It is sometimes necessary to fuse or seal optical glass to chemical Pyrex. Is there any soldering glass or does Corning make such a soldering glass to seal optical glass to Pyrex glass?

Answer — Dr. Dalton

You cannot escape the regular seal requirements. The soldering glass must match the coefficient of expansion of the glass used. Optical glass, normally a very high expansion glass, is very difficult to seal to something like Pyrex 7740 glass. It would be necessary to have a graded seal to go through such a wide range of expansion. There is at present no satisfactory solder glass for Pyrex. We have solder glasses only for the high expansion range. I would suggest that you metalize the glasses and then metal solder them together.

Question — Mr. Cassidy

I am quite interested in these soldering glasses, Dr. Dalton. Do you have any literature on the availability of these things and if so in what form? I think it would be constructive to this group if people were more familiar with the application and the range of glasses that could be covered by the soldering glass, and the ranges expansionwise.

Answer — Dr. Dalton

We do not have much available in the way of literature. We do have a leaflet. Also reprints are available of a paper that I gave at Cincinnati last year on that subject. I will say a few words here as to where the thing stands as far as commercial use goes. We have a glass, 7570, which has been worked out to match the ordinary high expansion glasses. It will make seals in the range of 500 to 550°C. We have another glass that was really not primarily developed as a soldering glass but is quite suitable for the purpose. It is number 8363 and has an expansion of slightly over 100, so it is a little bit high for the ordinary high expansion range glasses, but it is still softer than 7570. Whereas the 7570 glass has a softening point of 440°C, the 8363 softening point is 377°C. You can make seals with it at around 425°C to 450°C. There is no problem in getting softer glasses. We have glasses with a softening point as low as 250°C. Of course, they are not of interest for most sealing purposes because the expansion is too high and also because a good many of those glasses have poor durability, and so they are not of very much interest in the apparatus industry. We do not, in general, have soldering glass for the low expansion range corresponding to Pyrex glass. The lowest one that we do have (Code No. 1826) is about expansion 49 and that is approaching the Kovar sealing range. It is not quite low enough to make a really good seal to Kovar. It should be lower than it is, but we do not know how to make it lower without making it harder. The softening point is 585°C., so you can see that it is not as soft as we would like to have it. It can, however, be used in solder type seals in the Kovar range with certain reservations.

Question — Mr. Cassidy

In what forms, other than powder, are these glasses available?

Answer — Dr. Dalton

They are available in bar and lump form and in general they are not available in any shapes such as cane or tubing. We did, at one time, make cane from 7570 glass but there has never been sufficient demand for shaped pieces to warrant setting up to do it.

Question — Mr. Cassidy

Have you tried this with a variety of metals?

Answer — Dr. Dalton

Yes, we have sealed them to a number of metals. One interesting factor is that 7570 glass can be used for making aluminum seals. By using that glass, you can seal to aluminum by using the Housekeeper technique. That is, the aluminum and glass do not match expansion-wise, so we must thin down the aluminum as we would thin down the copper when using the Housekeeper technique.

Vycor III

Question — Mr. Knisely

We have received requests for Vycor apparatus which necessitates larger tubing than is available through the catalogue. Can larger size Vycor be purchased, or would it be possible to buy the primary glass and fabricate the apparatus, then return it to Corning for leaching and baking? How can large Vycor be worked?

Answer — Dr. Nordberg

The welding technique is useful on the larger pieces. The welding rod is ordinary Vycor cane which is available. We have welded tubes 5″ or 6″ in diameter and also flat plates. In one instance two sections were welded together to make a 19″ plate, so the welding technique can be useful. The resultant seal is not particularly good looking, but it is very useful.

When you go to tubing larger in diameter than regularly available, blown cylinders are the answer. It is always more practical to make the tubing in the blown cylinder form rather than as tubing when only small quantities are required.

Working the original glass introduces many problems. In the first place the original glass is an unstable one. It is made that way purposely so we can leach it. If we proceed to make that glass, send it out to various customers, have it fabricated, heat treated in an unknown fashion, then sent back for baking, I don't think we would get anything out of it.

Question — From the floor

Is the fact that we cannot buy the primary Vycor glass a technical one or a business one for Corning?

Answer — Dr. Nordberg

It is a technical problem. As I have said, this glass is a very unstable glass. We keep it in special dry rooms until we are ready to fabricate it. We do this to avoid weathering which give us a frost that destroys surface finish. Now some of these difficulties could possibly be overcome but there would be more problems introduced in so doing. The second factor is that in order to fabricate the ware, one must keep under control all the variables involved, which means the glass quality, the glass composition, and the processing conditions. Processing control starts as soon as the glass is made. We have to watch annealing treatments because they may contribute to part of the heat treatment that we have to add in measured quantities to this glass in processing. I think the process is difficult enough as it is and if we could not keep it under careful control, things would get pretty tangled.

Answer — Mr. Schrickel

Perhaps I can enlighten you a little more on the difficulty that you can get into in the working of the primary glass. No matter how careful you are there will always be difficulty. Now you can imagine what it would mean if you were fabricating an expensive article and then sent it here to have it processed. The argument would be, if it did not turn out right, you have ruined it for me. For instance, here in Corning there was a lot of harm done in one plant that could not be overcome in another. On one lot we lost over 90% just simply to a very careless manner in the way the work was performed. So we changed the method and said no you do it under this condition and we have overcome a lot of it. Now you can imagine what difficulty you will get into and it would be the same if you would set up a method of leaching and heating and firing and so on. The expense involved would be almost prohibitive. In my opinion I wouldn't advise it because it is a very involved process.

Question — Mr. Campbell

Does the shrinking process continue on Vycor after it has been heated past its firing point?

Answer — Dr. Nordberg

No, the shrinkage is completed in firing.

Question — Mr. Campbell

Then why does Vycor tend to shrink away when you are attempting to seal it in the flame? The seals won't flow together like quartz. Even though you don't have the velocity of the flame to push it back it still won't flow.

Answer — Dr. Nordberg

I am not sure of the answer to that. You may have gotten hold of an incompletely fired piece. Vycor and quartz should be quite similar in working. Perhaps you have some high gas content Vycor. In that case, you may get bubbles that will upset the flow characteristics and give a spongy effect.

Answer — Mr. Schrickel

We have not noticed any of this difficulty. In some cases we cannot deny that quartz is preferred to work on, particularly if you have been used to working with quartz. Once you have a light spot you can very seldom fill it up. Unless you push it and fill in glass and then you have to work adjacent to it in order to keep the glass there. These are typical in quartz as well as in Vycor. The technique is demonstrated very easily in welding. If you put the flame directly on to where you want to weld, you never get past there. You always want to put it behind so you can push the glass with the force and velocity of the burner. That is the thing that you can sometimes misconstrue and the glass sometimes blows apart. Try that and see if it doesn't work better. Put your torch back of it and try to push the glass on to the light spot. However, if it is too light you will never get it there. It will blow a hole before you can get the glass into it.

Answer — Mr. Alexander

In working Vycor we sometimes forget that we are not working with Pyrex and we do not heat sufficiently far back. I find that you get much better seals if you heat quite a considerable surface on each side of the seal. Heat 3" or 4" back and get this up to temperature. We haven't had too much trouble with Vycor seals using hydrogen and oxygen.

Question — From the floor

Do you use high frequency current for sealing and working Vycor?

Answer — Dr. Nordberg

No, the electrical characteristics are such that electrical sealing is not feasable. The resistance is too high and the power loss is too low.

Question — Mr. Weir

What is the minimum size Vycor that has to be annealed? What is the annealing temperature? Does it have to be annealed?

Answer — Dr. Nordberg

The annealing temperature is 900°C. I would heat the article to 950°C and then cool it. The minimum size that should be annealed is difficult to state. It depends on what the shape is and what the finished piece has to stand. You can make relatively large pieces and still get by with flame annealing. I don't think that you will run into much trouble if you watch out for intense spot stresses on tubing up to 2" in diameter. Wash out the stresses a little in the process of lamp working and you can get by without oven annealing, although oven annealing is preferred.

Answer — Mr. Kelm

When using the welding rod technique it becomes important that the strong spot stresses that are introduced in this type of working be eliminated. It certainly should at least be given a good working over in the flame after welding.

Question — Mr. Dusek

Is there any way to thermal shock Vycor in order to break it?

Answer — Dr. Nordberg

No, in general it is not possible to break Vycor by thermal shock. Sometimes it is possible to break large Vycor pieces by plunging them into water.

Question — From the floor

Are quartz and Vycor stopcocks available?

Answer — Mr. Schrickel

Vycor stopcocks can be made special but are not available as a standard item.

Comment — Mr. Stein

If you don't mind being a ceramist for a while I would suggest that you try Corning's glasscast. We think it would be worthwhile to investigate this as we have successfully molded and fused 2" conical flanges.

Glass Coatings IV

Question — Mr. Barr

Can E-C coated tube be obtained with inside coating? This should be about 70 MM inside diameter and have a linear resistance from end to end.

Answer — Mr. Jolley

Inside E-C coatings are possible, however there are limitations on size.

Question — Mr. Barr

Is this coating resistant to mercury?

Answer — Dr. Dalton

Yes, it is resistant to mercury.

Question — Mr. Pool

We are interested in having an E-C coated glass which will transmit 75% of the light in the blue spectrum. Is such glass possible to get?

Answer — Dr. Dalton

We, of course, make E-C coated tubing. You state that you need a high light transmission, however. The transmission will depend on the resistance and in general, the lower the resistance, the lower the transmission. Therefore, if you want all complete transmission, you will have to take a high resistance. These would not be the standard heater panel but would have to be a special E-C coating.

Question — Mr. Pool

How do we order these panels and also where do we order Photoform glass?

Answer — Mr. Jolley

Order should be placed with PLANT EQUIPMENT FOR E-C GLASS and NEW PRODUCT SALES FOR THE PHOTOSENSITIVE GLASSES.

Question — Mr. Guzik

Can Pyrex tubing 3 to 20 MM be coated with a tungstic oxide coating .001 to .003″ thick and then bent without this coating deteriorating?

Answer — Dr. Glaser

It is very difficult to make a permanent coating of tungstic oxide or tungstic acid because the mobility of the tungsten is very low and the temperature requirements are very high. It might be possible to fuse it to one of the softer glasses, perferably soda lime. If you could alloy one of the wetting metals such as platinum or nickel with the tungsten and fuse it into the glass, it could then possibly be bent or reformed without ruining the surface, but it would have to be tried.

Question — From the floor

I would like to know what sort of coating you would put on a piece of plate glass to splash an arc? This is used to prevent the film from burning as it passes by the arc in a movie projector.

Answer — Dr. Glaser

There is a coating produced by the General Electric Company. This is a polyethelene material which is fired on, and when a hot spark hits it, is carbonized and prevents it from sticking. Normal arc coating or even arc welding and metal coating has a tendency or affinity to stick to glass and burn in. By having this gaseous coating you actually form a vapor coating between the hot spark and the glass which will prevent it from adhering to it.

Question — From the floor

Does it actually splash the arc?

Answer — Dr. Glaser

Yes, when it hits it actually vaporizes a minute amount and so prevents the spark from burning up. General Electric has a patent and the license for this. Most of the welders cover glass produced today have this coating. If you want to make an inexpensive coating yourself, take a 50% sodium silicate solution. Coat the glass over and dry it on and it will be quite excellent.

Porous Glass V

Question — Mr. Buchler

I have recently tried to make some apparatus with porous glass for use on electrodialysis and electrodesalting. Upon trying to seal on a piece of Vycor the porous glass broke into a million pieces. How can this glass be worked to avoid this type of breakage? This is about 18 MM tubing.

Answer — Dr. Nordberg

This glass has to be heated *very* slowly! It is recommended that this glass be heated in a furnace although it can be heated in the flame. To heat it in the flame is tricky. You have to approach the flame very slowly otherwise the glass will crack. It may blow up like popcorn. You will do better if you preheat the whole glass to 500°C. For your electrodialysis, this preheating will probably not destroy the glass properties. It will reduce the surface area but for the electrodialysis the larger pores are the ones that control the flow of material through the membrane, and these should not be substantially affected. The tube should be put in a cold furnace and gradually brought up to temperature. You must remember that the porous glass will hold over 25% of water by weight. Even though it is dried over phosphoric or sulphuric acid, it will retain from 2 to 5% of water in its structure. This residual water requires higher temperatures for removal, and is sufficient to shatter the glass if heated rapidly.

Question — Mr. Martinez

I have not had any particular difficulty in sealing porous glass to Vycor. However, after a period of time it breaks of its own accord at the seal. Is there any way that this glass can be annealed to prevent this breakage?

Answer — Dr. Norberg

When you start talking about the porous glass, you must consider different effects than are present with ordinary glass. Porous glass expands when it takes on moisture, and if you dip a relatively large piece of it into water it may break from too sudden expansion. Silica jel shatters under these same conditions. Thus the breakage that you have encountered may have been from causes other than normal strain.

Question — Mr. Martinez

If I put it under a polariscope I can still see strain, no matter how much I try to anneal it.

Answer — Dr. Nordberg

Yes, you will get a strain pattern. In addition to the effect of mechanical stress, there is birefringence due to the structure of the porous glass. Pores do not extend straight through the glass, but they have a preferred direction which is not completely at random. If you have a porous structure with the pores oriented a little bit more in one direction than the other, you may have birefringence which is independent of mechanical stress on the system. As a result of this, it is sometimes hard to judge the stress in porous glass by what you see in a polariscope.

Question — Mr. Alexander

Will Corning furnish this glass in tubes, the end of which has already been shrunk down in preparation for fusing to Vycor?

Answer — Mr. Jolley

Yes, we have done this and it is now available on a special order basis only through the Special Apparatus Section, Laboratory and Pharmacuetical Sales.

Answer — Dr. Nordberg

We would hesitate in going to large sizes in this kind of glass because of the breakage problems encountered when it takes up water or is dried too rapidly. We would rather stay, for experimental purposes at least, with thin wall tubing of relatively small diameters. The maximum sizes that we would recommend would be 25 or 30 MM thin wall tubing. Tubing up to these sizes are available with a test tube closure on one end, the other end having been treated for fusing to Vycor.

Glass to Metal Seals VI

Question — Mr. Baentsch

Sometimes it is necessary to fuse platinum through or to Pyrex glass. What kind of wire can we use to make this contact?

Answer — Dr. Dalton

The simplest thing to do would be to seal a tungsten wire through the glass, then a nickel bead is put on the tungsten and the platinum is welded to the nickel.

Comment — Mr. Ball

I would like to give my idea on a new type of tungsten sealing.

If you take the blue glass which is very close to Pyrex in expansion, bead this to the tungsten and seal the blue glass to the Pyrex it will give you a very good vacuum seal.

Question — Mr. Cardial

I have been working on an apparatus where two ¼" x 3/16" tungsten rods must be sealed in glass with a 20 mil space between. Then some of the glass is cut away so that acid can be introduced and remove the molybdenum spacer. My problem is that I cannot get a good oxide bond between the glass and the tungsten. I am wondering if the blue glass mentioned by Mr. Ball would work for this?

Answer — Mr. Ball

I haven't done any work on this size of tungsten with blue glass. The maximum size that I have sealed is about 1/16".

Answer — Dr. Dalton

Ordinarily, we would say that for large diameter tungsten you should use 7750 glass. We have made glass to tungsten seals that are nearly ¼" in diameter which have very good color and very good bonding. For your use there is one thing that worries me about this. This glass is not very acid resistant. You may have some trouble along this line.

Question — Cardial

What effect will the weak acid solution have on the glass's strength?

Answer — Dr. Dalton

In general, the attack on the surface of the glass will lead to a weakening of the surface. That is not true if you cut away the surface completely as with Hydrofluoric acid. Hydrofluoric acid can considerably improve the strength of used glass because it will tend to eat away the old surface and you will obtain a good virgin surface underneath it.

Acids, in general, attack the glass differentially. That is, they do not attack the silica but do remove the other materials. This usually leads to a weakening of the glass.

Question — Mr. Cardial

Would you suggest using HCL to remove molybdenum and then put HF in it to counteract any action that it may have on the glass?

Answer — Dr. Dalton

It would have to be done in the right way or it might make matters worse. It might be possible to use a combination of acids. To get this strengthening effect you have to use quite strong hydrofluoric acid and sometimes it is mixed with concentrated sulphuric acid. In fact, it is desirable to work with almost nonaqueous conditions. How far you can dilute this and get a positive beneficial effect I am not able to say.

Answer — Dr. Nordberg

Unless breakage occurs in the actual cleaning process I would treat first with hydrochloric acid and then follow with the hydrofluoric acid treatment to renew the surface of the glass.

Question — Mr. Killich

Is there any extensive work being done on the sealing of platinum to glass for high and low temperature work and for vacuum techniques? This should be a glass with higher temperature requirements than soft glass.

Answer — Dr. Dalton

This possibly can be done with a very thin platinum through Pyrex 7740 glass as a Housekeeper type seal. Another method would be to use a graded seal which brings you up to the expansion of the soft glass. The size of the seal also has some bearing on the possibilities.

Answer — Mr. Alexander

There is a paper by someone from General Electric for making platinum through Pyrex seals. This states that you take a very thin tube of platinum and seal it through the Pyrex. Actual cracks develop around the edges of this glass but the center remains clear. This is good for high vacuum, these seals having gone to 10^{-7} and being used at liquid nitrogen temperatures.

Question — From the floor

What type of glass is recommended for rhenium seals?

Answer — Dr. Dalton

We have not done any work on glasses to use with rhenium seals as they have not been commercially important.

Answer — Dr. Glaser

Rhenium has an expansion coefficient of 92×10^{-7} which is close to platinum. It is one of the platinum family and therefore it should seal to one of the soft glasses such as lime or lead glass.

Question — Mr. Kessler

I would like to know which glass you would recommend for Kovar seals; 7050 or 7052?

Answer — Dr. Dalton

We would recommend in general 7052 glass. It is a little bit better in expansion match than 7050. It is a more durable glass, more available and is made in larger quantities. It also has better electrical characteristics. However, it is possible to make the seals with the 7050 glass.

Question — From the floor

What glass is used for making Tantalum seals?

Answer — Dr. Dalton

We have a glass which is approximately the right expansion for Tantalum. Although we have not done a great deal of work with Tantalum, we have worked out the expansion relationships. I believe the glass is 7520.

Question — Mr. Lipson

Did Dr. Dalton say that there is a glass for Tantalum?

Answer — Dr. Dalton

Yes, it is 7520. We haven't had a great deal of experience with it but it is a fairly good match. As it is one of the glasses that is used in the sealing series from soft glass to hard glass, the availability is somewhat limited. It is usually available only in ½" OD by 12" long tubing. Tantalum seals can be made in the same way as an ordinary tungsten to glass seal. The geometry would not be important as it is a reasonably good expansion match.

Question — From the floor

Is the greenish color of the Sylvania No. 4 alloy oxide a necessary requisite of a vacuum seal? In other words, if the seal does not have a green color, does that mean that it is a poor vacuum seal?

Answer — Dr. Dalton

A green color is desirable, but it is not essential. You can make perfectly good seals without the green color. In general, the chromium oxide has a better adhesion and a stronger oxide layer than the other oxides of that alloy.

Question — From the floor

If you bend a wire that is coated with glass and the glass breaks clear from the wire is this an indication that the oxide bond was not good enough?

Answer — Dr. Dalton

That is right. That indicates that the oxide conditions are not good. The best type of seal will give a break in which little particles of the glass adhere to the wire. If it breaks clean between the oxide layer and the metal it usually indicates that there is either weak oxide or too much oxide.

Miscellaneous VII

Question — Mr. Beer

What causes 1,000 ML erlenmeyer flasks to break when placed upon a hot plate when boiling perchloric acid in them? When placing the glass on the hot plate and heating it up, it cracks around the bottom. Examination of new flasks through a polariscope shows a color which seems to indicate strain. Upon placing the glass in an annealing furnace over night at 1072°F., the color is gone and the residual strain seems to have been removed and the breakage described has been reduced. Is it possible that this residual strain is causing the breaking of the glass ware?

Answer — Mr. Burdick

Usually when we get a break such as you have described, we would say first that the glass had been heated previously and so introduced the strain, but as you say, the glass has been taken out of stock and has not been previously used. Therefore, we must assume that something in the use of the flask introduced the strain. Now if there were a high temperature reaction going on in the flask, then that would introduce such strain. It is, of course, possible that some of our ware gets out without being completely annealed. Why don't you send some of these flasks back to Corning for inspection. I would suggest that you contact your area representative on this.

Answer — Dr. Nordberg

I don't think that it is a matter of the chemical reaction going on. There is the possibility that the high temperatures involved with the use of perchloric acid could contribute to heat shock and resultant breakage. However, if you can see strain in the flasks as received, we must assume that they were not fully annealed.

Answer — Dr. Dalton

If they can see strain in the glass as received, quite possibly the annealing was not adequate. On the other hand, if the hot plate is a very high wattage one, it is likely that strain is introduced through that medium. It is suggested that perhaps a wire grid on the surface of the plate would reduce this breakage greatly.

Answer — Mr. Alexander

I would suggest that an asbestos pad or one of the wire screens with the asbestos imbedded in it be used to absorb the thermal shock. I agree that you should send samples back to Corning for inspection.

Question — Mr. Beer

We are trying to find a good way to break heavy wall ampules containing phosphoric acid or potassium without introducing any water into the system. Usually we put on a deep scratch and break them open by hand, but there is some positive pressure inside. What we use is ½ inch OD heavy wall Pyrex tubing.

Answer — Mr. Jolley

Usually with wall of that size it is not necessary to add water, only scratch, and it will break itself when a hot rod is applied.

Answer — Mr. Alexander

My suggestion is to use a cotton swab wet with water but not so wet that it would introduce any water into the system. Then scratch, and the hot rod and the wet swab should crack the glass.

Question — Mr. Ball

What is the best way to handle a Carius tube after it is sealed off? I am familiar with two methods. One is to stick the end of the tube in the flame and blow the end out. The second is to have a constricted section and knock it off.

Answer — Mr. Jolley

You must be very careful because the pressure inside is unknown and when you scratch it the whole thing may blow up. I would suggest that the tube be placed in a metal shield, then burn a hole in the end of the tube to relieve the pressure. Then you can take it out, crack it in two, and do with it what you want. No one knows how much pressure you may develop in this reaction.

Answer — Mr. Weir

Rest them in the Carius furnace with the long constricted end out. Use a file to knock the long ends off. I have never had one blow while doing this. They have blown in the furnace but not after they have cooled.

Question — Mr. Meyers

Is there any type of drill for drilling a series of holes less than one MM through a standard wall tubing?

Answer — Mr. Buchler

You can use a diamond drill.

Answer — Mr. Alexander

It may be possible to make the holes by using the sand blasting technique.

Answer — Dr. Glaser

Sand blasting will give a tapered hole. If it is necessary to have a parallel hole the best method would probably be the ultrasonic method. A standard size diamond core drill would probably be the easiest from a practical point of view. It should be one with internal cooling which on the thinner glasses will give a cleaner hole. The three corner file method is only good if you can drill from both sides. They will tend to break through if all the drilling is done from one side.

Question — Mr. Meyers

Is it necessary to anneal the glass after drilling each hole, as the glass seems to break after drilling several holes?

Answer — Dr. Glaser

I would suggest that the tube be filled with wax. Drill your holes and then remove the wax. The general rule of the thumb is that the distance between the holes should never be smaller than the diameter of the hole, otherwise you lose strength and the glass cracks and propigates around.

Answer — From the floor

I would suggest that the gentleman might get sintered glass, make a mold, and mold his object and fire it with the holes in.

Answer — From the floor

If the wall thickness isn't too great, you can punch holes in it with a hot tungsten wire. We have made as many as 10,000 holes in a two inch tube and we never have to bother to anneal it while working progressively down the tube.

Answer — Mr. Searle

By using a phonograph needle you can punch holes in glass. However, these give a tapered hole. After finishing punching, you grind off the inside

Answer — Mr. Ball

We had a problem similar to that. We had to have a series of very small holes in a cylinder. We finally gave up on glass and used Teflon. By punching holes with a needle, we found we had very good diffusion and the holes can be any distance apart.

Answer — Mr. F. Whittemore

There is an old technique that is used on soft glass and I used it some time ago to make spargers which are a series of small holes in the glass. You take a wire of copper or platinum, make a spider from it, set the spider on the end of the tube like a cartwheel without any rim on it with the spokes protruding past the edges of the glass. Heat and butt seal another piece of glass to it. You have to do this very carefully so that you do not melt the wires. After sealing, the wire is dissolved out with acid. I believe that there is a paper printed on this by someone from the Bureau of Standards. With this technique it is possible to obtain very, very fine holes.

Comment — From the floor

I move that we do not use three corner files for marking glass. Generally speaking they are unsatisfactory for the use to which people put them.

Answer — Mr. Graves

In reference to the three corner files, I have found that if you just take the three cornered files and grind the corners off you form a serrated edge which is very sharp and does a better job.

Answer — Mr. Alexander

We no longer use three corner files. Instead we use a piece of Carboloy. This is 3″ long and about 1/16″ thick and ¾″ wide. We have a small holder which is a piece of ⅜″ brass rod that has been milled out for the Carboloy to fit. The Carboloy is soldered in and a handle attached. If any of you gentlemen would like a drawing of this knife I would be very glad if you would write to me at the Atlantic Refining Company. The number of the Carboloy that we use is 883.

Answer — Mr. Walton

I have made a 4 sided Carboloy knife by fitting it to a handle and grinding down with a fine diamond wheel. The original Carboloy as it comes is not suitable for cutting. It must be ground to get a good edge. If you grind the Carboloy on the bias you will put a very fine serrated edge on it. This makes a very fine mark and the glass breaks much more easily than when using cutters that are not properly ground. When regrinding a new edge it is only necessary to take off a very small amount to renew it.

Question — Rev. Hilsdorph

Is there any way of simply cutting off a very thin quartz tube without a glass saw?

Answer — Mr. Alexander

You can mark it all around and break it by snapping it.

Answer — Mr. Schrickel

It all depends on what size you are referring to. Up to 1″ quartz can be marked and broken the same as any other tubing but if it goes beyond that the best method is to use a carborundum saw.

Answer — Mr. Schaefer

One method that can be used to cut quartz is to mask it and sand blast through it. A sand blaster can be made of glass, and carborundum powder can be used for the blasting.

Answer — Mr. Kelm

Another way that this could be done is to wax the tube, scribe it, and etch it out with H. F. acid.

Answer — Mr. Walther

It is possible to cut quartz tubing by placing it in a lathe, and looping a wire over the glass. Then by turning the lathe and adding an abrasive to the wire, it will wear through the tubing.

Question — Mr. Knisely

It is possible for Corning to furnish standard wall Pyrex tubing larger than 4″ in diameter? There have often been requests for apparatus made from larger size tubing and we have not been able to purchase this tubing although we have been referred to other suppliers.

Answer — Mr. Kelm

Heavy wall tubing is available up to 7″ in diameter. However, standard wall tubing brings in many problems of manufacture. It is hard to pull larger tubing without cracking it. Light wall large diameter tubing is available as light wall blown cylinders. 24″ to 36″ long. This is listed in the cylinder list which is available from your area representative. The large diameter tubing is tied in with the pipe line of glasses and it is just impossible to afford the runs that would be necessary for a special draw of large size thin wall tubing. It becomes practically impossible to hold it round and it crushes on the machine. It involves many problems in manufacture.

Question — Mr. Miller

What is the reason for diameter differences in standard taper stoppers compared to standard taper joints? For example, the number 19 stopper is not interchangeable with the 19/38 standard taper joint.

Answer — Mr. Jolley

Ground joints and stoppers are made to specifications as set up by the Bureau of Standards years ago. There is a difference between stopper sizes and ground joints, and the 19 stopper and the 19/38 joints are not interchangeable. The Bureau is now re-standardizing. We will not, we cannot, after all the equipment is out in the field, start re-standardizing to make all of them ground joint lengths and diameters. There will be a change in the 29 bottle stoppers so they will be interchangeable with 29/42 ground joints. It was just one of those things that came about. Why they did it originally, I don't know, but it is here and we are stuck with it. We are making changes where we can.

Question — Mr. Ball

I would like to ask someone at Corning if number three and four stopcock plugs are interchangeable?

Answer — Mr. Schrickel

They are made from standards and they are made on the same mold so therefore, they should be interchangeable.

Question — Mr. Walther

Has anything been done on making Pyrex ball joints hollow rather than having a solid heavy glass through the ball?

Answer — Mr. Jolley

We have made a survey on that and the consensus of opinion was that most people prefer the straight flow through on the ball joints. We can't make it solid on our Vycor joints because we can't process it. That is also the reason for the hollow joints on the large size 7740 joints. We ran a survey on the road and all the Corning representatives contacted their principal customers. Their opinion was that the straight through solid ball joints were preferred.

Question — Mr. Weir

Why doesn't Corning make a 250 ML round bottom flask? The situation now is that when we need a 250 ML flask we must buy a distillation flask and remove work that Corning has done on it in order to seal a joint to it. It would be much more economical if we could buy a common vial neck flask for this purpose.

Question — From the floor

I would like to know why Corning does not make a 4 liter round bottom boiling flask?

Answer — Mr. Jolley

I don't believe that there has been sufficient demand for these sizes of flasks. If there were sufficient demand, I am sure that Corning would make them.

Question — From the floor

What large sizes of boron free glass tubing are available?

Answer — Mr. Jolley

The largest size that is available in the catalogue is 13 mm. If larger sizes are needed, they should be ordered and will be drawn at the next melt. It is hand drawn tubing and is only melted once or twice a year. Therefore, it would not be necessary to order large quantities.

Question — Mr. Weir

Does Corning make a glass that will withstand strong alkali solutions?

Answer — Dr. Nordberg

Glass 7280 has a much higher alkali resistance than that of an ordinary glass. Under some conditions this resistance may be over 25 fold greater. The durability is relatively less at high alkali concentrations and high temperatures, but remains something like six fold greater, on the basis of loss in weight, than that of code 7740 glass under these drastic conditions. It is rather difficult to find a silicate material that will resist the action of alkalies at the high temperatures encountered in boiling concentrated caustic solutions.

Answer — Dr. Glaser

There is the possibility that if you metalize your glass internally and fire it in, you could build up a much higher resistance to alkali. If you take a solution of any of the noble metals, coat the glass internally and fire it, your resistance might go up to 20 times the normal.

Question — Mr. Griffith

Can vacuum tight electrical leads be put through multiform and can high temperature seals be made from multiform to multiform without distortion of the glass?

Answer — Dr. Dalton

In general the multiform glasses behave the same as any other glass. Electrical leads can be and are sealed in a great many cases. In fact, this is one of the major uses of the multiform glasses. When used in the strictest sense of the term, multiform cannot be sealed without distortion. When sealing together without using any other material you must have some distortion the same as any other glass. The amount of distortion depends on what conditions you use to carry out this sealing. The best way to minimize or eliminate this distortion on the softer multiform glasses is to use a soldering glass for sealing the two parts together. In this way virtually no distortion would occur.

Question — Mr. Killich

What is the melting point of 707 glass? There is no softening point on the list and I would like to have this information.

Answer — Dr. Dalton

That is not listed because in the range of temperatures where the softening point would occur the glass is undergoing a change, so it is not possible to make a softening point measurement in the way that we normally do. It would be possible to give you an approximation of the softening point.

Question — Mr. Killich

Will the softening point always range in the same degree?

Answer — Dr. Dalton

This will depend on the rate at which you are heating it.

Question — Mr. Killich

Why does it seal so nicely to Pyrex without breaking?

Answer — Dr. Dalton

When you have to go to the temperatures that are needed to fuse the glass, you completely wipe out all the effects of previous heat treatments, and so it behaves in the normal way. The expansion of this glass is reasonably close to 7740 so it should make quite a good seal.

Question — Mr. Killich

Is Pyrex the only glass that it will seal to?

Answer — Dr. Dalton

It will seal to a number of other glasses in this expansion range.

Question — Mr. Bradway

Has any work been done at Corning on the changes of the physical properties of glass between the temperature of liquid air and liquid helium?

Answer — Dr. Dalton

Some work has been done with porous glass on the superfluidity of helium and we have also done some work on the diffusion of helium through glass when using the glass as a container for liquid helium, but in that temperature range we have not done much work on the changes in the physical properties of glasses.

Question — From the floor

Has Corning been doing any work on the effects of radiation on Pyrex? We have found that it becomes a little more brittle after it has been subjected to radiation and wondered if it related to strain and, if so, could it be relieved by an annealing process?

Answer — Dr. Dalton

High energy radiation does have an effect on the structure of glass. Darkening and compacting of the surface layers may occur with neutron irradiation and in x-ray tubes. The compaction may introduce stresses in the glass surface. X-ray tubes have disintegrated as a result of changes in the glass structure. Colorless high expansion glasses have been stabalized against darkening when irradiated. Both discoloration and stresses resulting from irradiation disappear on annealing.

Question — Mr. Walton

Is it possible for the research glass blower to put a surface treatment on the glass which will increase its strength?

Answer — Dr. Dalton

It is possible to put a surface chill on glass if it is done in just the right way. This will give surface compression and so add to the strength and the shock resistance, but it requires a very careful set up and very careful control. If you try to do it and you do not have that very careful control, you may be much worse off then if you had not chilled it at all.

Question — Mr. Altier

Is the portable battery powered polariscope that Mr. Burdick has shown commercially available?

Answer — Mr. Alexander

Mr. DeMaria of Sylvania has developed a similar device. This is commercially available from the Bethlehem Apparatus Company and Tubelite Engineering Company.

Answer — Mr. Looms

Mr. Burdick manufactures and sells polariscopes similar to the one that he has shown you here.

Answer — Mr. Weir

There is an article in the Review of Scientific Instruments, October 1955, by Randolph Searle. There is no patent and it is for anyone's use.

Persons Attending

The following are on record as having attended the First Symposium on the Art of Glassblowing held at Corning, New York; Friday and Saturday, June 8th and 9th, 1956. The address immediately following the name is the mailing address as listed on the Society files.

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