

TECHNOTES

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A TECHNICAL SUPPLEMENT

FROM BULLSEYE GLASS CO.

A misunderstanding that the compatibility or “fit” of two glasses is solely a function of the expansion properties of those glasses has led to an overemphasis on “expansion” and the numerical value of the COE (coefficient of expansion) of glass. Studio artists constantly ask for the COE of a glass—hoping to predict whether it will “fit” another glass such as other fusing glasses or their own furnace glass. Matching COEs is simply not an accurate measure of compatibility.

The viscosity characteristics of a glass are equally as important as its expansion characteristics. Together, these two properties determine whether one glass will fit another. But it will be useful to first discuss each individually as it pertains to this subject.

Expansion affects compatibility throughout the full temperature range (from the annealing point to room temperature). This is because by nature most materials—whether solid or liquid—expand upon heating and contract upon cooling. It is commonly assumed that if they expand and contract similarly they will “fit” or be compatible once fused together.

COMPATIBILITY OF GLASSES:

Expansion does NOT equal compatibility.

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MEASURED AND CALCULATED COES

The expansion of a glass may be determined by calculation or by measurement. The most common laboratory test (using a dilatometer) measures the actual expansion properties of a glass over the temperature range of 0 - 300°C. (A COE number must always be accompanied by the temperature range over which it was measured or it is meaningless.) Unfortunately the equally important range in this measurement—from 300°C to the annealing point—is ignored. It is a well known fact that the expansion properties of a glass change significantly through the transition range.¹ Therefore it is obvious that this measured COE number is not intended to describe the expansion characteristics of a glass for compatibility purposes. In actuality there is no one number that can describe the expansion properties of a glass through the full temperature range since it is not constant (linear).

To further confuse the issue many manufacturers publish a “calculated COE.” This so-called calculated COE is a meaningless number in comparing the COE of



different glasses in the context of studio usage. The calculated number² should only be used to compare projected relative changes in expansion of a given glass with changes in composition of the same glass or in comparing very similar glasses to each other—such as one soft soda lime glass to another soft soda lime glass. It should never be assumed to represent a real COE. It is a tool that a glass formulator can use to predict changes in expansion when making raw material changes such as substituting magnesium for calcium or sodium for potassium. But I would encourage glass and batch suppliers as well as educators not to publish this number (unless they provide considerable explanation as to its use) because it is very misleading to the user in the studio glass community, implying for his/her furnace melted glass a meaningful COE which it clearly is not.

WHY A MEASURED COE ALONE DOES NOT INSURE COMPATIBILITY

As mentioned above, the fitting of two different glasses is a function of both viscosity (resistance to flow) and expansion. Whereas expansion affects the compatibility predominantly in the lower temperature range—below the strain point, the viscosity properties affect compatibility predominantly in the middle temperature range—from the strain to the annealing point. Differences in viscosity between two glasses will cause compatibility problems. If one glass is stiffer than the other they will strain each other as they cool through the annealing range.

COMPATIBILITY VIA COMPENSATING ERROR

For glasses of different viscosities to be compatible (which is frequently the case) their expansions must be different. What happens in actuality is a process of

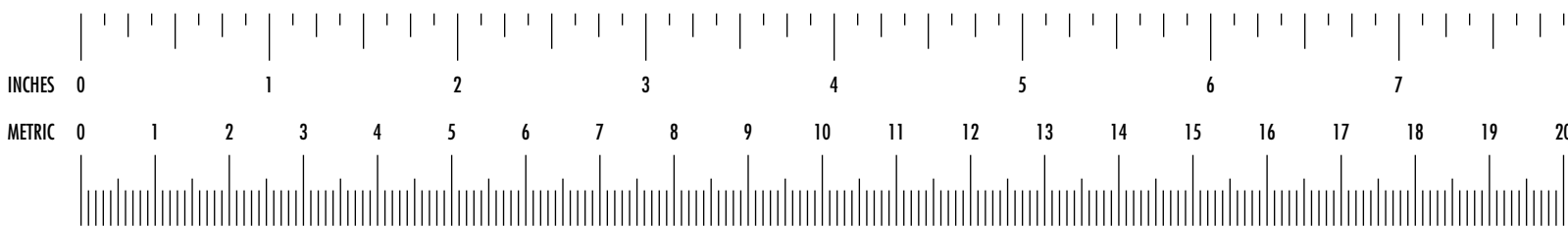
compensating errors. Two different glasses will be compatible if the strain set up by the mismatch in viscosity is cancelled out by the strain introduced by the mismatch in expansion (once cooled to room temperature and assuming, of course that proper annealing has occurred). For instance, if the viscosity differences result in tension between the two glasses and the expansion differences result in an equal amount of compression between the two glasses, the two stresses cancel each other out. This is the critical phenomenon that results in compatibility of two glasses with different expansion/viscosity properties. This explains why glasses of very different viscosity/expansion characteristics actually fit (such as a hard opal with a soft blowing crystal). If you were to have samples of these two types of glasses measured for expansion you would find that they could have COEs³ differing by as much as 5 or more points.

This, furthermore, is why the only practical test for compatibility is one that takes both phenomena into account—tests such as the chip test for fusing and the ring test for blowing. Looking at the COE alone is very misleading and cannot accurately predict compatibility.

CONTROLLING THE EXPANSION/VISCOSITY PROPERTIES DURING FURNACE MELTS

Accepting that expansion and viscosity both contribute to the compatibility of glasses, and given that one of those glasses may be your own furnace glass, how do you control its expansion/viscosity properties?

In insuring compatibility the melting cycle of a glass is as important as the composition. Melting the same composition glass using different melting cycles may





produce a glass of different expansion/viscosity properties, leading to compatibility problems that may not have occurred with glass from a prior melt. Several factors must be considered in a melt cycle:

1. size of the melt (e.g., 500 lbs of batch)
2. temperature to which the furnace is heated prior to first charge (e.g., 2500°F for 1 hour)
3. melting time and temperature (e.g., 12 hours at 2500°F)
4. charging rate (e.g., 3 charges of 100 lbs each at one hour intervals)
5. rate of temperature recovery after each charge (e.g., recovered to 2500°F after 45 minutes)

Based on the examples cited above we might establish a typical melt cycle as “500 lbs melted at 2500°F for 12 hours, charged in a furnace preheated to 2500°F in 3 equal charges spaced one hour apart.”

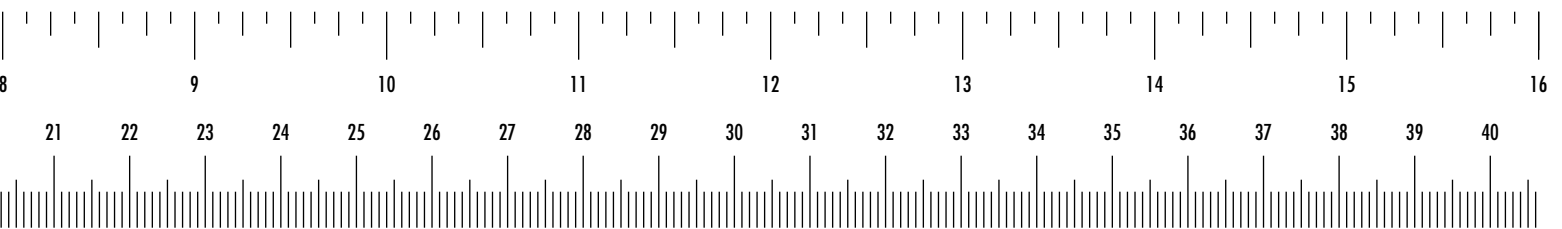
Since your goal is to produce glass with the same viscosity/expansion characteristics each time you melt, it is imperative—if you wish to avoid compatibility problems—that you follow the same cycle in order to insure the same results. (This is, of course, hoping that your supplier of color is doing the same.)

Changes to your cycle may alter the results and lead to problems of incompatibility. For instance, if your typical melting cycle is designed for a 500 lb melt but you melt only 300 lbs with the same cycle, that melt will very likely yield a lower expansion/higher viscosity glass. Consistency of procedure in melting your furnace glass is critical in maintaining compatibility with your color source (whether bar, frit or sheet). Once a melt schedule has been established as yielding acceptable results—do not vary it in subsequent melts.

It would be better if we in the glass community had never focused so much attention on the coefficient of expansion. We need to stop talking about it as if it defines compatibility. The only measure of compatibility is testing a sample appropriate for the type of forming—whether blowing, fusing, pâte de verre—and measuring the results. Unfortunately books and manufacturers and teachers continue to print this misguided concept and information. So—please—let’s quit talking about COE and talk about the real issue: all the factors that contribute to compatibility between glasses and how we can understand and control them.

NOTES

1. F.V. Tooley, The Handbook of Glass Manufacture, Vol 2, 1974, pp 906-907.
2. Of the many calculation methods (among them: English and Turner, Ol, Winkelman and Schott) all utilize an expansion factor for each raw material, assume an additive mathematical result, and do not take into account the melting cycle of the glass.
3. Assuming that all measured COE’s were measured from 0-300°C





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