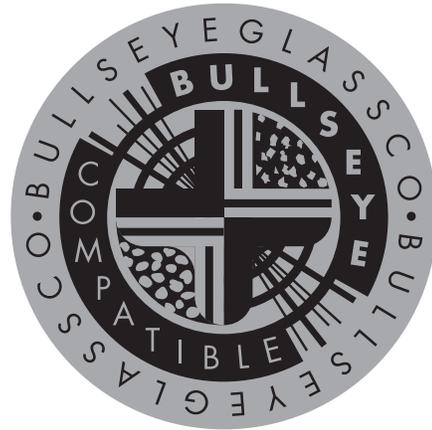


Compatibility of Glasses

TECHNOTES 3 | COE Does Not Equal Compatibility

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A misunderstanding that the compatibility or “fit” of two glasses is solely a function of their expansion properties has led to an overemphasis on “expansion” and the numerical value of the coefficient of expansion (COE) of glass. Studio artists continually ask us for the COE of a glass, hoping to predict whether it will “fit” other fusing glasses or their own furnace glass. We say the same thing each time: Matching COEs is simply not an accurate measure of compatibility.



The viscosity characteristics of a glass are equally 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. But this is not necessarily true. In fact we have tested some glasses with the same COE and found them to be incompatible.

Measured and Calculated COEs

The expansion of a glass may be determined by calculation or by measurement. A common laboratory test (using a dilatometer) measures the expansion properties of a glass over a given temperature range, for instance 20°–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). Furthermore, it is highly unlikely that an entire line of “compatible glasses” would all have the same COE.

To further confuse the issue, many manufacturers publish a so-called “calculated COE.” This calculated COE is a meaningless number when 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. However, we encourage glass and batch suppliers—and educators—not to publish this number. Unless they provide considerable explanation as to its use, it is very misleading to users in the studio glass community, implying a meaningful COE for furnace-melted glass, which it clearly is not.

1 F.V. Tooley, *The Handbook of Glass Manufacture*, Vol. 2, 1974, pp 906–907.

2 There are many methods for making this calculation, among them English and Turner, OI, Winkelman and Schott. They 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.

Why a Measured COE Alone Does Not Insure Compatibility

As stated 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 annealing range, from the annealing point to the strain 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 Differences

For glasses of different viscosities to be compatible (which is frequently the case) their expansions must be different. In actuality, what happens is a process of compensating differences. 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 stiff opalescent with a soft transparent. 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 five or more points.

This, furthermore, is why the only practical test for compatibility is one that takes both phenomena into account. One example is the chip test for fusing. Looking at the COE alone is very misleading and cannot accurately predict compatibility. The chip test can.

Bullseye developed the chip test in the late 1970s, based on the input of Robert Barber. It has been used since that time and is an industry standard for determining compatibility. Our records allow us to track the compatibility characteristics of every sheet of glass that we have made since that time.

The test is done by placing 12.5-mm-square chips atop a 63.5-mm-wide base sheet of a known clear test glass. The chips are positioned with at least 25 mm between each test chip and 25 mm between the chips and the edge of the base of clear test glass. (See Figure 1.)

The arrangement is then fired to 1500°F (816°C) and held at that temperature for 15 minutes before cooling

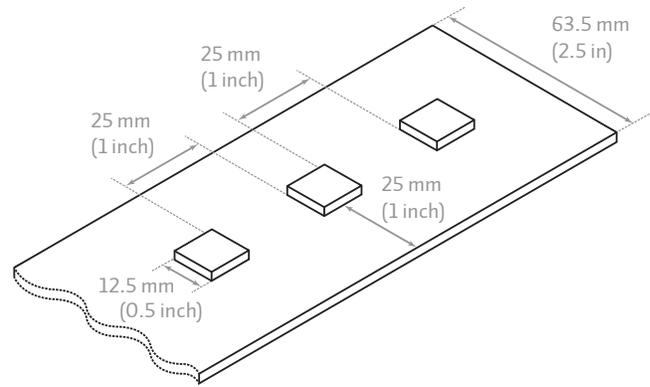


Figure 1: The chip test layout.

and annealing. Once cooled, the test is viewed for stress through cross-polarized light and graded accordingly using very strict criteria for acceptable strain. Glasses that are known to be fairly stable are tested in a single firing. Glasses known to be less stable are chip-tested in three consecutive firings to ensure good performance under typical fusing and slumping conditions (such as those used to make a simple plate).

This test works exceptionally well in predicting the compatibility of the glasses tested. Unlike calculated COEs or even measured COEs, the test takes into account both the expansion and viscosity characteristics of the glass. It also tests the glass in a manner in which it will actually be used, and results in meaningful data.

No test can take into account every process to which someone might subject a particular glass. If you intend to use a process that requires significantly more heatwork than described above, we recommend that you perform your own chip tests using the same cycles that you intend to use.

Some processes that may not immediately appear to exceed the parameters of the test for compatibility actually do. Firing some glasses very slowly or holding them for long times in the devitrification range starting at about 1375°F (746°C) can cause those glasses to change dramatically.

Conclusion

It would be better if we in the glass community had never focused so much attention on the coefficient of expansion. The only accurate measure of compatibility is testing a sample in a manner appropriate for the intended type of forming—whether fusing, kilncasting, blowing, or combining processes such as blowing and fusing—and viewing the results for strain. Unfortunately, there are those who continue to promote misguided and confusing concepts. In many cases, this can lead to failure for people using the material. Bullseye would rather have users feel confident about using the material and empowered to test their limits.

3 Assuming that all measured COEs were measured from 20°–300°C.