TECHNO FILE

flameware

by David Pier

It is possible to make pots that can go straight on the stove or over an open flame. The special types of ceramic used for these demanding applications are called flameware.

Defining the Terms

Flameware—Ceramic that can withstand direct and uneven contact with intense flames. Typically flamewares have COEs less than 2x10^{-6}/°C. Also called flameproof ware or fireproof ware.

Ovenware—As defined by ceramic scientist F. H. Norton, ovenware is in between the thermal shock tolerance of flameware and more common ceramic bodies. Ovenware must withstand quenching from 302°F (150°C) into cold water. It should have a smooth, hard, non-crazing surface, and it must have reasonable mechanical strength. Some regular porcelain bodies can qualify as ovenware. Typically ovenware has a COE of less than 3x10^{-6}/°C.

Thermal Expansion—The tendency of matter to reversibly change in volume in response to a change in temperature. The majority of materials increase in volume with increasing temperature, but a few notable materials actually contract over certain increasing temperature ranges.

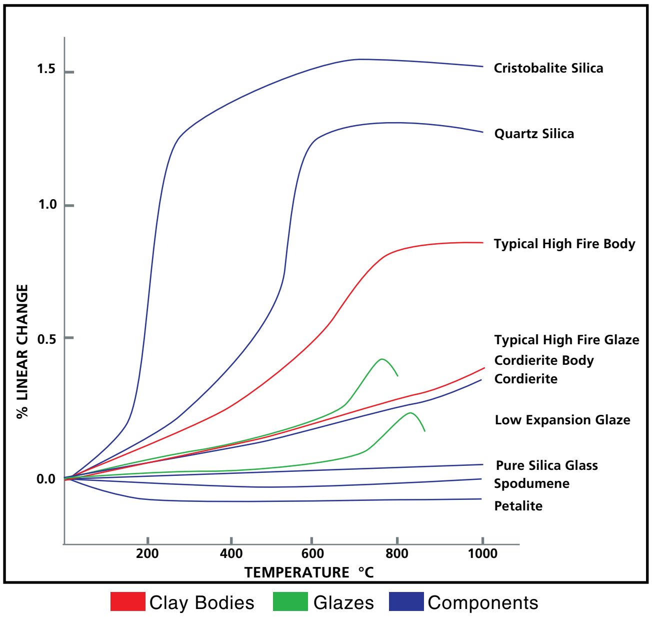
Coefficient of Thermal Expansion—Common ceramic COEs are for the linear expansion. Usually written as number/°C, where the number is the change in length for a given starting length for every change of one degree Celsius. A COE of 1.58x10^{-6}/°C means that every inch of the material will expand 1.58x10^{-6} inches with every rise of 1°C. Materials' COEs are different in different temperature ranges.

Inversion—The change from one crystalline polymorph form to another. Also known as transformation. Example: the inversion from alpha quartz to beta quartz over a short range around 1063°F (573°C). Often accompanied by a relatively large change in volume.

Lithium and Cordierite Bodies

Flameware bodies aren't necessarily any stronger than other bodies, but rather they have very low thermal expansion. The reason a normal ceramic pot cracks or shatters when exposed to intense heat is the stress caused by uneven expansion. The expansion is uneven because the temperature is typically more uneven the more quickly heat is applied. If you think of a pot as composed of many separate little parts, you can see that when some expand from heat, they no longer fit together with the other parts of the pot. If this mismatch exceeds the bond strength of the ceramic, then the ceramic will crack to relieve the stress. If you take away the expansion, you take away the stress and now you can heat as you please. A familiar example is Pyrex glass. Pyrex can take quick changes in temperature because of its low thermal expansion.

Expansion Rates for Typical Clay vs. Flameware

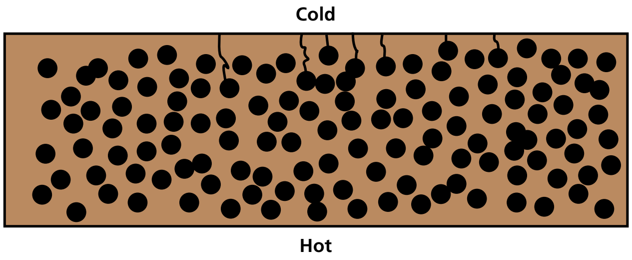


Not only do flameware bodies have overall low thermal expansion, but they have no crystalline silica. As you may recall from previous Techno File discussions of glaze fit, most bodies have a large amount of crystalline silica in them to intentionally increase their contraction during kiln cooling. Crystalline quartz and cristobalite silica not only have high thermal expansion, but they have inversions where they go through sudden large changes in size. This is necessary to get good glaze fit, but it reduces thermal shock tolerance. Flameware bodies have silica, but it is all melted, and silica glass has very low thermal expansion vs. the high thermal expansion of crystalline silica.

There are two common types of flameware bodies, cordierite bodies and lithium bodies. Cordierite ($2MgO{\cdot}2Al_2O_3{\cdot}5SiO_2$) results from bodies composed of magnesium minerals such as talc along with clay. Besides low expansion, cordierite is a very tough material and less brittle than most ceramics.

Lithium bodies are composed of clay along with the minerals spodumene ($Li_2O{\cdot}Al_2O_3{\cdot}4SiO_2$) or petalite ($Li_2O{\cdot}Al_2O_3{\cdot}8SiO_2$). They generally do not require firing ranges as exact as cordierite bodies, but it is difficult to make a non-porous body when fired below cone 11.

Many earthenware bodies can appear to be flameware, but each exposure to direct flame causes new tiny cracks. The porosity of the earthenware stops these cracks from spreading all the way through the pot, but eventually the entire pot becomes very weak and fails. Many civilizations have used earthenware cooking pots, with the expectation that they would be replaced regularly. These pots usually had even thickness and curved or globular forms, both of which help reduce thermal stress.



Cracks spreading in a porous body and the interruption of a crack by a pore. Further spreading is to be expected in the next heating and cooling cycle.

Weighing the Risks

If there is a clay that allows us to make pots to withstand this kind of thermal punishment, why do we ever use anything else on the stove top? There are plenty of reasons.

The biggest problem is that flameware can be dangerous. If a pot full of boiling liquid suddenly splits in half, that hot liquid can spray everywhere.

There are two main reasons flameware can fail, and they are not at all uncommon. The first is that flameware bodies are difficult to fire correctly, and if they aren't fired right they won't have the expected thermal shock tolerance. The second common reason for catastrophic failure is steam pressure. If your technique isn't perfect and the finished pot has any pores, these can fill with water. When the pot is suddenly heated, if the path for the steam is constricted, the pressure will cause the pot to blow apart. Besides the danger from the hot contents of the pot, flying hot shards present their own obvious danger.

Robbie Lobell's ovenware set with casserole/covered pot, made with Flameware Clay Body, glazed with recipes listed below. Lobell's article and recipes on flameware originally appeared in CM, December 2008.

The very specific compositions required for flameware can be less than ideal in terms of body color and workability. The kind of small adjustments, ones that would be trivial in other bodies, that you might want to make to change some aspect of workability, such as changing the amount or size of grog, can cause the body to no longer qualify as flameware.

It is very difficult to make a glaze that fits, and if your glaze doesn't fit, then the pots can be weaker as well as more difficult to clean. The narrow range of glaze compositions that will fit flameware bodies severely limit the available colors and textures.

So, in the end, most people chose (because of potential legal liabilities) to leave the stove top to the metal and Pyrex pots. If you do make flameware pots, you must do all the necessary testing and take all possible safety precautions with the assumption that the pot could fail at any moment.

SIMPLE CORDIERITE FLAMEWARE BODY

Cone 11

Pioneer Texas Gray Talc	33.33	%
Coarse Fireclay Grog	33.33	
OM4 Ball Clay	32.33	
Bentonite	1.01	
	100.00	%

LOW EXPANSION GLAZE FOR FLAMEWARE BODIES

Cone 10–11

White Talc	14.2	%
Whiting	3.4	
Spodumene	47.0	
Kaolin	5.5	
Silica (200 mesh)	28.9	
Bentonite	1.0	
	100.0	%

FLAMEWARE CLAY BODY (FROM ROBBIE LOBELL)

Cone 10

G-200 Feldspar	10	%
Spodumene	30	
Pyrax (HS)	10	
Fire Clay (Hawthorne)	25	
OM4 Ball Clay	25	
	100	%
Add: Red Iron Oxide	1.75–2	%
Grog (48 mesh)	5	%

INTERIOR GLAZE ANN'S KAKI (ANN STANNARD)

Cone 10

Bone Ash	9.2	%
Talc	5.6	
Whiting	6.6	
Custer Feldspar	43.9	
Red Iron Oxide	9.7	
EPK Kaolin	5.6	
Silica	19.4	
	100.0	%
Bentonite	2.0	%

EXTERIOR GLAZE—ROBBIE'S Y GLAZE

Cone 10

Whiting	28.00	%
Custer Feldspar	48.37	
EPK Kaolin	10.74	
Silica	12.89	
	100.00	%
Add: Titanium Dioxide	8.60	%
Bentonite	2.15	%

This has been altered from Karen's Y Glaze, which uses G-200 feldspar instead of Custer feldspar and rutile instead of titanium dioxide. All percentage weight amounts are the same.

Gold: Titanium Dioxide	5–8	%

Note: No guarantee is made by the author or *Ceramics Monthly* regarding these recipes. All individuals must test materials and maintain quality control to ensure proper performance of any clay body—particularly flameware. To test if you actually have flameware after you fire it, don full protective clothing including a mask with a face shield and apply a propane torch flame directly to one spot on a test piece. Once it gets red hot, pick it up with tongs and drop it in a metal bucket of water. If it can take that, then it is flameware. You still need to be careful because you can never be sure there aren't any pores that may create steam pressure in the future.

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