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Techno File: Glaze Unity Formula

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Abstract
There are many approaches to modifying a glaze recipe, and different approaches can meet different needs. Some modifications change the colorant level while others change the colorant type altogether. Some may directly replace one material with another add a few weight unit more (or less) of one of the base ingredients in the recipe, or add an amount of an entirely new ingredient. These strategies we use to alter glazes tent to parallel how we cook and modify recipes in the kitchen, but adjustments to the base glaze using the kitchen method do not always give us the results we want. [*excerpt*]

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glaze unity formula

by Tina Gebhart

The proportion of silica to alumina in a glaze influences many things, from texture to crystallization to color to melt viscosity to opacity. A unity molecular formula testing grid can show us how shifts in our original glaze can improve or change these characteristics.

Defining the Terms

Unity Molecular Formula (UMF)—Also known as a Seger Formula. Glaze recipe format based on the number of molecules instead of on weights of raw materials, where the total molecules of flux in a glaze are calculated to total 1.0 (which means they are in unity). The formula shows the ratio between fluxes, but perhaps more importantly, it shows the ratio of combined fluxes to the silica and alumina.

Mole—The base unit of measure for the amount of a substance, either atoms (for elements) or molecules (for compounds).

Flux Unity—Unity Molecular Formula expressed as one mole of total flux in proportion to the silica and alumina. A UMF can be arranged to express non-flux components as the unified part in proportion to other parts, but flux unity is the standard format used in ceramics.

Flux System—The arrangement of fluxes in a UMF recipe, showing the internal ratio of fluxes in a given glaze; the common feature in all samples of a UMF grid as shown on the facing page.

Batch to Unity— Translation from a standard glaze recipe format (where the raw materials of the base glaze are written as weight percentages) to the UMF format.

Unity to Batch—Translation from a UMF recipe to a raw-materials-oriented, batching-friendly recipe.

Adjusting a Glaze Recipe

There are many approaches to modifying a glaze recipe, and different approaches can meet different needs. Some modifications change the colorant level while others change the colorant type altogether. Some may directly replace one material with another add a few weight units more (or less) of one of the base ingredients in the recipe, or add an amount of an entirely new ingredient. These strategies we use to alter glazes tend to parallel how we cook and modify recipes in the kitchen, but adjustments to the base glaze using the kitchen method do not always give us the results we want.

If we were using a baking recipe that called for a certain type of readymade baking mix and we added more of it because we wanted a thicker batter, and we had not changed anything else, we may end up with too much leavening (contained in the baking mix) in proportion to the two eggs we had already added. In our glazes, this becomes more complicated because a wide array of our raw materials are similar to baking mixes; they contain more than one glaze component. Many materials that do not say *carbonate*, *oxide*, or *sulfate* at the end of the name (for example) are complex materials similar to a commercial baking or cake mix. Imagine trying to make bread from a cake mix, a cookie mix, a pancake mix, and a biscuit mix. I, frankly, would not know where to start.

The difference is that, in ceramics, we have access to the exact ingredients in each of our raw material mineral mixes. This is the equivalent of knowing how much flour, leavening, salt, etc. is in all baking mixes. Once we know the components of the raw materials, and have these materials reorganized in terms of those components, we are looking at a more standardized, universal recipe.

This universal recipe form is called the *unity molecular formula*. The ingredients in our raw materials are regrouped so that we can see the accumulated amounts of silica (from our kaolin, feldspar, wollastonite, talc, frits, etc.), alumina (from our kaolin and feldspar), fluxes (from our feldspar, whiting, dolomite, talc, and many of the other white powders), and their proportions to each other.

AGATE V3 VARIATION

(cone 9–10 oxidation or reduction)

Dolomite	13.0%
Lithium Carbonate	4.0
Whiting	15.2
Custer Feldspar	20.2
Nepheline Syenite	10.3
EPK Kaolin	10.0
Silica	27.3
	100.0%
Add: Copper Carbonate	2.0%

UNITY MOLECULAR FORMULA

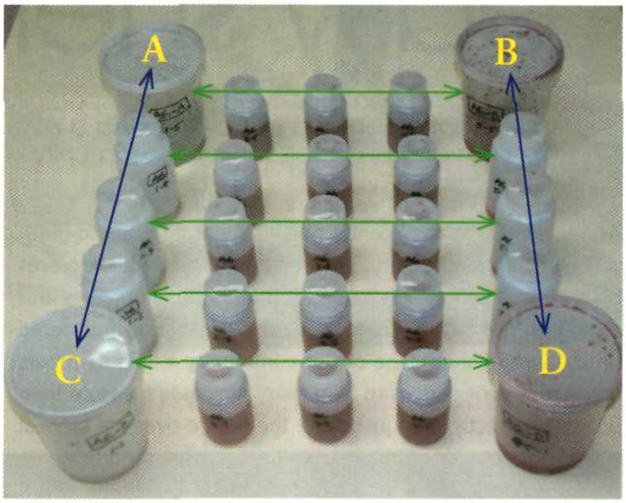
KNaO	0.13	1.00
Li_2O	0.13	
MgO	0.18	
CaO	0.56	
SiO_2		2.17
Al_2O_3		0.23

The unity (one) molecular (molecules) formula (recipe) looks at the *chemical* raw materials in the glaze rather than the *mineral* raw materials used to make that glaze. This version of the recipe reduces the fractions of these chemicals to show us a simple proportional relationship present in the glaze. By unifying the fluxes to equal one, and showing the relationship (ratio) of the silica and alumina to that single amount of flux, we can compare or manipulate glazes very directly. This allows us to make modifications that are quantitative, i.e. modifications that remove the ambiguity and guesswork.

You can certainly learn to make these calculations by hand, but there are several software programs that can do the recipe translations for you. I use HyperGlaze as well as a programmed Excel spreadsheet. There are other commercial programs available, such as Insight, GlazeMaster, Matrix2000, GlazeChem, and even a free version online at www.glazecalc.com.

Creating a Unity Molecular Formula Testing Grid

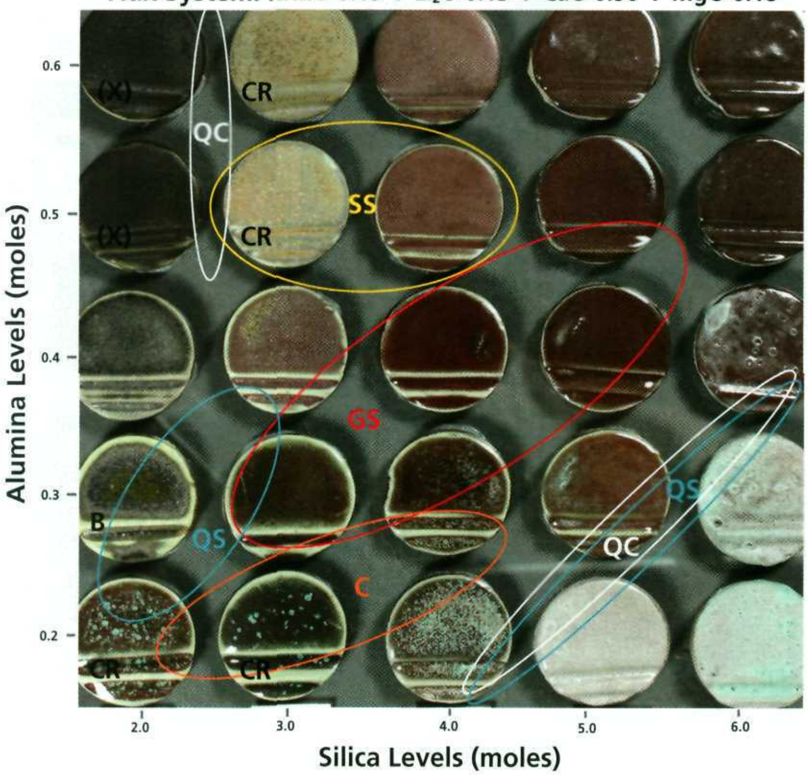
- Select a glaze recipe to investigate.
- Determine the UMF (with flux unity) of that glaze with the batch-to-unity feature of your software.
- Using the flux system identified there as a constant, and using the unity-to-batch feature of your software, determine four corner recipes. Point A: low silica (2.0), high alumina (0.6). Point B: high silica (6.0), high alumina (0.6). Point C: low silica (2.0), low alumina (0.2). Point D: high silica (6.0), low alumina (0.2). These levels could be expanded to a wider range, but it can become difficult to combine materials to meet those extremes.
- Batch each of these corner recipes as 500g batches in quart containers, making them exactly the same volume in each container. Label each container carefully as you batch.
- Volume blend A with C and B with D to create the side column samples (as volume percents 75:25, 50:50, 25:75 in smaller containers). Note that this does not produce fully even or accurate increments for the UMF grid, due to the volume blending, but this approach is wildly faster than batching each individual sample.
- Volume blend each side sample with its corresponding opposite side to make the horizontal samples (as volume percents 75:25, 50:50, 25:75 in even smaller containers).
- Apply each glaze sample to a well-coded test tile.
- Fire and arrange the grid of glazes, the expanded family of your original glaze.
- Notice glazes near the UMF of your original glaze (the original glaze is near the lower left of the grid below, with levels of 2.17 silica and 0.23 alumina) and note which may look similar but with one changed characteristic. Which samples are crazed? Where does this glaze family change from gloss to satin? From satin to matte? Has one solved a problem for you? Are there substantial color or surface shifts throughout the grid? Which are interesting? Which are undesirable to you?
- Note also where two adjacent samples are extremely different from each other. These may be areas to investigate further (such as a line blend of 1–3 samples in between those two) to discover what surprise glaze might be hiding in between them. These areas also may be ones to avoid if what you want is a very consistent, exacting sameness in your glaze results; these may be the ones that could be somewhat variable depending on mixing/stirring times and glaze settling rates.



Batch corners first (500g each), then volume blend side columns (200ml each), then volume blend center rows (80ml each).

Agate V3 Variation

Flux System: KNaO 0.13 : Li_2O 0.13 : CaO 0.56 : MgO 0.18



UMF Diagram Coding

QC: Quickly changing color response; area between good for further testing; what color will be between black and beige? Between dark rose and very light green? Potential high-variability.

SS: Good satin surfaces; appear smooth and consistent in this small region.

GS: Good gloss surfaces; ranging from full gloss to semi-gloss in this fairly large region; good potential for consistency in this area.

C: Visible crystals formed; varied frequencies and sizes; good area to explore for additional crystallizing results.

QS: Quickly changing surfaces (gloss to matte); potential high-variability.

B: Blister-puckering in crevices; test toward neighboring samples to remedy.

CR: Crazed sample; can move recipe toward neighboring samples to remedy.

(X): Possibly crazed sample; surface and color interfering with assessment.

This grid method is related to both the Stull Grid (R. T. Stull, *Transactions of The American Ceramic Society, XIV, 1912)*, the Currie Grid (Ian Currie, *Revealing Glazes*, 2000), and grid work done with Bill Carty et al, at the former Whitewares Research Center.