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Controlling Crystallization in the Cooling Glaze

As a glaze begins to cool, the bonding attraction of individual atoms and molecules eventually becomes more powerful than the disrupting action of atomic vibration (For an explanation of the importance of atomic vibration in ceramics, see the section on "Atomic Vibration and the Melting of Solids" in Chapter 1 of *Clay: A Studio Handbook*). Crystalline and non-crystalline connections begin to form in compatible compounds, just as ice crystals start to form as water cools to 32°F. As cooling continues, the most aggressively bonding crystalline and non-crystalline materials start to form bonds throughout the melt, quickly increasing viscosity. In a glaze, most bonds are non-crystalline glass, but much of the visual and actual textures in glazes is due to crystal growth within or upon the glaze. For every desirable crystalline effect there is a particular *zone of crystallization* in the cooling that is most favorable for the formation of that crystalline material. Above this zone, atomic vibration overpowers molecular bonds and crystals remelt as fast as they form. Below this zone, increasing viscosity prevents the continuing migration of crystal-forming materials in the melt, and therefore prevents further crystal growth. By regulating the cooling ramp, we can control crystal development.

The formation of desirable crystals within or on the surface of the glaze depends on three factors.

1. There must be an adequate supply of the necessary crystal forming materials in the glaze melt.
2. The temperature and viscosity must be such that crystal-forming material are kept available by migration and dispersion of materials throughout the melt.
3. This temperature must be maintained for an adequate amount of time through the appropriate zone of crystallization, low enough to allow the formation of crystals, and yet high enough to still allow dispersion of materials in the glaze melt.

Cristobalite is the only truly undesirable crystal, and it only forms above 2150°F. In bringing a midrange or highfire glaze-firing to maturity, we do want to fire slow enough to allow complete fusion and dispersion of the glaze, but once we have accomplished that, the firing can actually be cooled fairly quickly for the first few hundred degrees. That happens naturally as soon as you shut off the elements or fuel, so don't artificially accelerate cooling.

The most important zone of desirable crystal growth occurs around 1800°F. Much of the popularity of the book *Mastering Cone Six Glazes*, or MC6G, by John Hesselberth and Ron Roy rests on their explanation of these phenomena and instructions how to encourage beneficial crystal growth in order to achieve more-interesting glaze surfaces in electric kilns. This involves programming the cooling ramp on the electric kiln to turn the elements back on at 1900°F and hold the kiln through a slow descent over three or four hours to 1700°F, maximizing opportunities for desirable crystal growth.

Gas kilns generally have far more thermal mass, and thus this is not as much of an issue. To encourage crystal growth, at the conclusion of the firing, close the damper all the way for the first four to six hours of cooling. If you really want to maximize this possibility, monitor temperature with a pyrometer, and upon reaching 1900°F, reignite the burners and soak the kiln for three or four hours as the temperature slowly drops to 1700°F, and then turn the burners off and open the damper.

Minimizing Surface Crystallization - Some glazes and surface effects benefit from little or no visible crystals. If we want solid unmodulated color, or if we have complex slip or underglaze decoration covered with a transparent glaze, we might wish to minimize surface crystallization. In the handout on cone-10 glaze recipes, there is a nice honey-amber glaze called Honey Luster. When cooled slowly through the zone of crystallization, it becomes partially opacified with lovely manganese crystals. It's a beautiful glaze over slip decoration, but not if it forms a lot of crystals. When you wish to minimize crystallization, it is normal to cool quickly down to around 1500°F. Standard toploader electrics cool this fast by themselves and require special programming only when we wish to maximize crystal growth. On a fuel kiln, leaving the damper and burner or air ports open will usually cool the kiln fast enough to minimize crystallization.