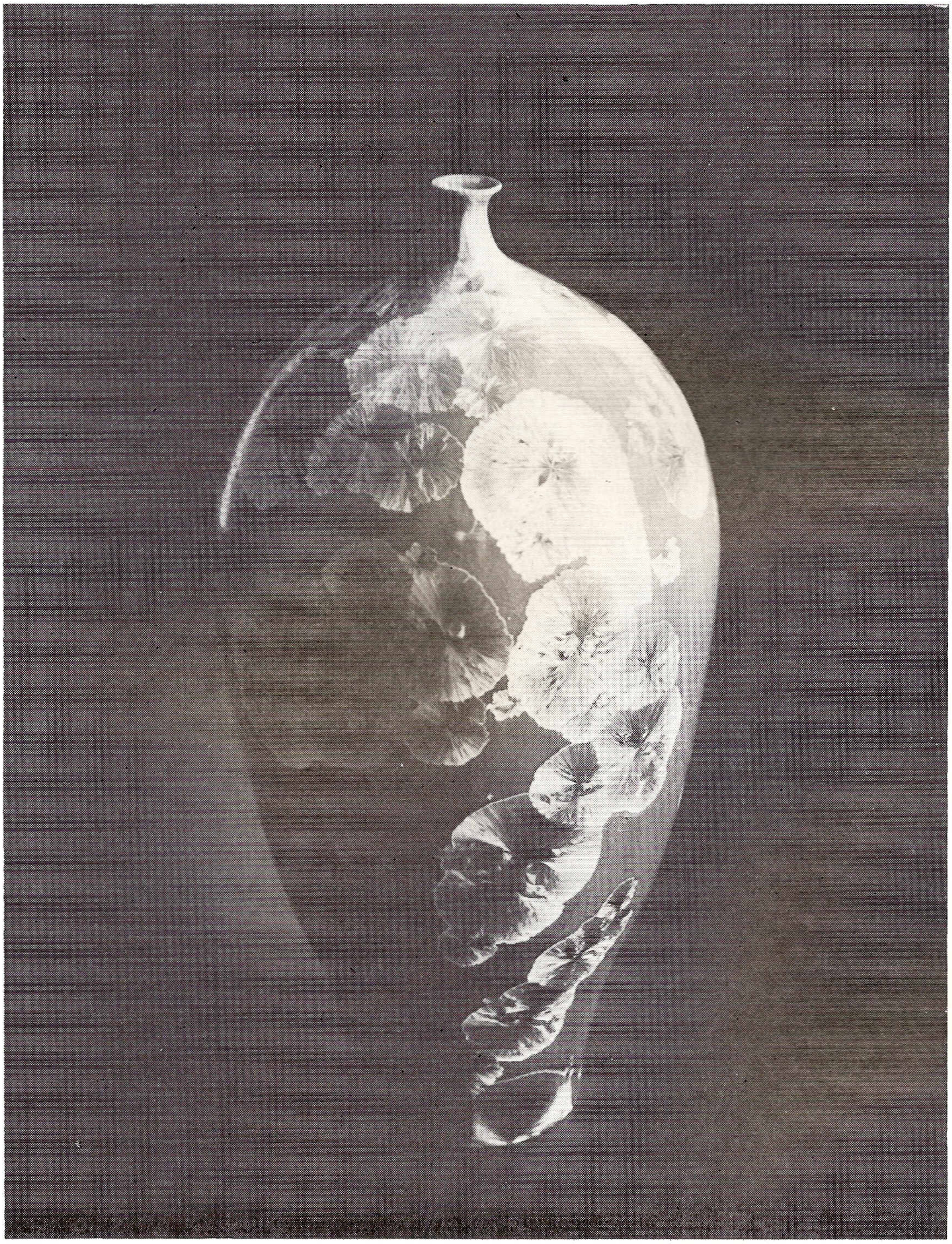
Making and Firing Crystalline Glazes

by David Snair

Photos: Roger Phillips

Although crystalline glazes enjoy a wide reputation, their compounding and preparation tend to be time consuming and complex, often placing them beyond the resources of the studio potter. Produced through specific glaze formulation and carefully controlled firing procedures, these glazes are similar to any others, except that during the cooling phase of the firing cycle, portions of the glaze separate from the batch in an orderly manner to form crystals. There is considerable information available in the technical literature, but much of it is incomplete and little of it is applicable to the studio situation



Porcelain form, 9¾ inches in height, by the author. Crystalline Glaze I with additions of 3.5% copper carbonate and 0.5% cobalt carbonate produced blue crystals on a sea green background.

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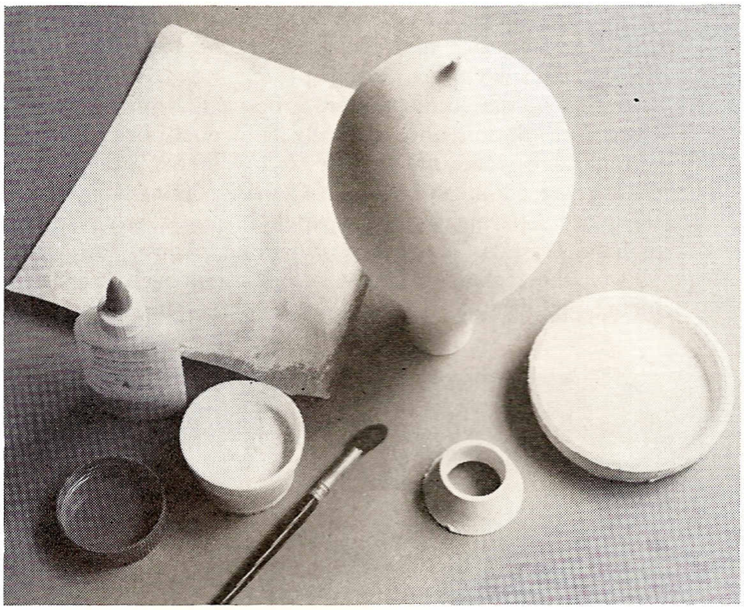
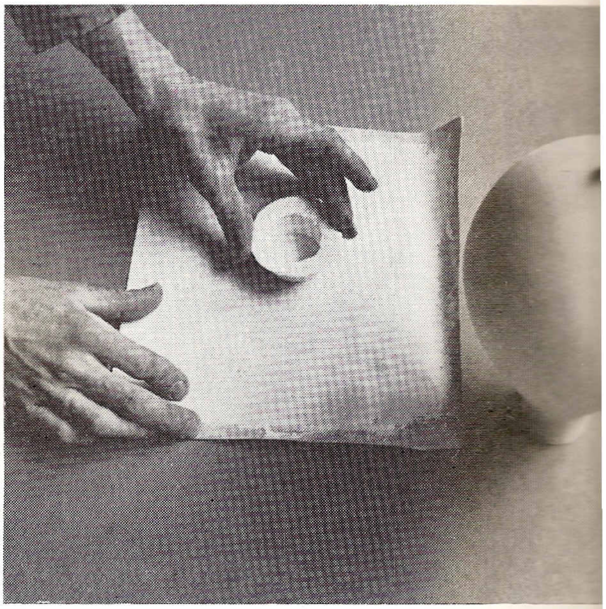


1. The form must be elevated above the glaze pool for successful separation of the foot after firing. The materials for this process include white glue, alumina hydrate, a thrown support ring, and emery cloth.



2. To form a tight seal, the ring and base of the pot are ground flat after bisque firing.

because of the need for facilities to produce suitable frits. Some time ago I participated in a workshop with Marc Hansen, the objective of which was the development of crystalline glaze formulas using commercially available frits. Since that time I have compounded several successful glazes from these frits and developed procedures for controlled firing.

Basic equipment for crystalline glaze preparation includes an electric kiln capable of Cone 9 operation; large kilns—either Kanthal element or Globar type—are most suitable. The kiln should be able to achieve Cone 9 in a 2-hour firing cycle (1½ hours in a test firing of the empty chamber). For regulating temperature accurately, infinite range controls are desirable; the kiln with only three settings—low, medium, and high—is somewhat difficult to manage, but may also be suitable. Several commercially available kilns meet these requirements if they are fired with only partial loads and an absence of kiln furniture.

A pyrometer compatible with monitoring 2400°F temperature is also needed. If the thermocouple is a chromel/alumel type, which oxidizes rapidly at high temperature, the hot junction should be made of 10-gauge or larger wire. A platinum/platinum rhodium couple is a better choice, but it is extremely expensive. If possible, calibrate the pyrometer against one of known accuracy or, alternatively, standardize it against cones fired at a specific rate. It is not necessary to know the exact temperature, but rather to be able to reproduce kiln conditions for successive firings.

Ordinary ceramic chemicals are usually of sufficient purity for crystal work. It is important, however, that all chemicals be kept as clean as possible, because even trace amounts of contaminants can have drastic effects on the quality of the crystals produced. If working in a large studio group, it is desirable to have separate materials.

A porcelain or semiporcelain body is best for keepi the background glaze unspotted and for avoiding co tamination from impurities in the body. It may also b beneficial to use a body which is slightly immature a Cone 9 in order to keep the surface from being dissolve by the glaze, altering its composition. I have used tw bodies with slightly different results. The first is some what more mature and translucent; the second seems t favor the formation of a few large isolated crystals, bu has poor translucency.

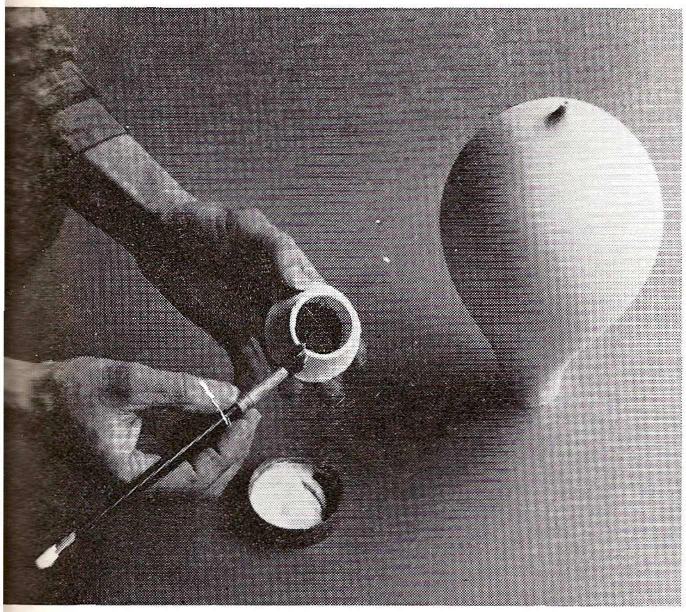
Porcelain Body I (Cone 9)

Edgar's Plastic Kaolin	40.0 part
Tennessee Ball Clay (O.M. #4)	8.9
Flint	17.7
Nepheline Syenite	31.6
Bentonite	2.2
	100.4 part

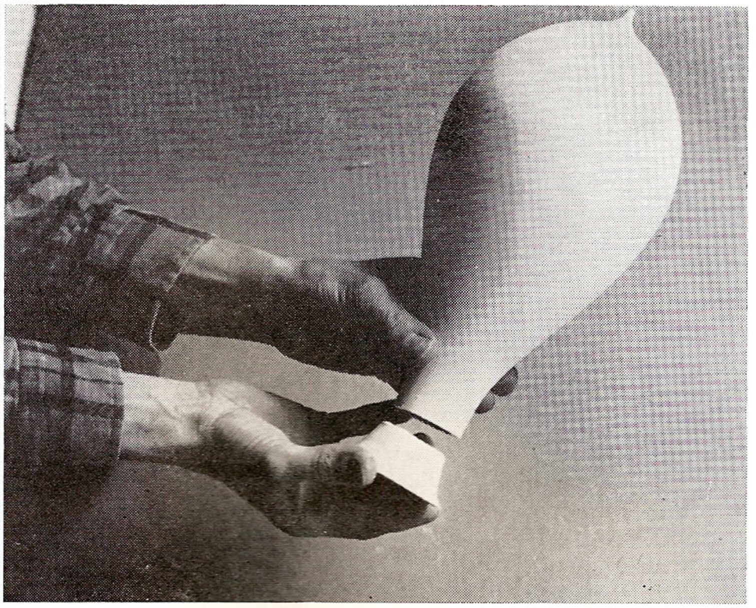
Porcelain Body II (Cone 9)

Edgar's Plastic Kaolin	50%
Flint	25
Custer Feldspar	25
	100%
Add: Bentonite	2%

Crystalline glaze components should be especially accu-rately weighed; a triple beam balance is sufficiently precise if used carefully. Dry ingredients should be well mixed an passed through a 60- to 80-mesh screen at least once t break up any coarse particles and to thoroughly integrate all components. If colorants are added, it is advisable t screen the glaze a second time. These base glazes prepared with commercially available Ferro Frit 3110 produce a good variety of results, and experimental work should indicate which are most productive with available firing equipment:



3. A paste of white glue and alumina hydrate is brushed on the lip of the ring.



4. The ring is applied to the base of the form.

Crystalline Glaze I (Cone 9*)

Frit 3110 (Ferro)	48.40%
Calcined Zinc Oxide	24.35
Calcined Kaolin	1.52
Flint	17.95
Titanium Dioxide	7.78
	100.00%

Crystalline Glaze II (Cone 9*)

Frit 3110 (Ferro)	47.14%
Calcined Zinc Oxide	28.38
Calcined Kaolin	.60
Flint	18.02
Titanium Dioxide	5.86
	100.00%

Crystalline Glaze III (Cone 9*)

Frit 3110 (Ferro)	47.86%
Calcined Zinc Oxide	23.87
Calcined Kaolin	1.41
Flint	20.91
Titanium Dioxide	5.95
	100.00%

Crystalline Glaze IV (Cone 9*)

Frit 3110 (Ferro)	46.00%
Calcined Zinc Oxide	26.83
Calcined Kaolin	1.35
Flint	20.10
Titanium Dioxide	5.72
	100.00%

These recipes yield white crystals on a white background unless colorants are added. Because of the unusual composition of the glazes, color performance may vary greatly from the expected. Additions of five per cent or less of cobalt, manganese, or copper produce the best results and combinations are particularly interesting. Iron, nickel, and chrome are usable to a lesser extent.

Accurate firing is of as much importance as glaze compounding. The two are related to one another and in some ways a glaze may be adjusted to a firing cycle or a firing cycle adjusted to a glaze. Complete records of all firings and of all adjustments should be kept.

The glaze mixture contains particles from which crystals can grow, much in the manner a dust particle acts as a seed for a snowflake. A combination of high temperature and time is used to dissolve all but a few of the particles; then the temperature is dropped to a point more favorable for the zinc silicate to crystallize out of the molten glaze. Temperature is held in this range for several hours to allow the crystals to increase in size. In general, the longer the growth time, the larger the crystals. My firing cycle is:

Overnight	70-1500°F
1½-1¾ hours	1500-2360°F*
15 minutes OFF	2360-2000°F
2½-4 hours	2000-1850°F

Bottles or other convex forms are well suited to crystal work since they serve as ideal surfaces on which to display the crystals and also allow for glaze fluidity without pooling on the piece. The glazes must be extremely fluid to work properly, and some way of separating the piece from the glaze puddle at the base must be devised. Several methods are available, such as stilts, a soft cookie of clay which may be cut away with a diamond-wire saw, or, I prefer to use a carefully fitted clay ring, cemented to the base of ware and freed by gently tapping with a chisel after firing. For the fitted ring method, the piece is footed and a separate small cylinder or bowl is thrown to match

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**Firing cycle terminates with Cone 9 at the three o'clock position.*

the dimensions of the base. This cylinder should be formed from the same clay as the ware so that there is no shrinkage differential. After the ware and ring are bisque fired, their surfaces are ground flat with emery cloth to insure that there is no separation where glaze might leak through. The two pieces are joined with a paste of white glue and alumina hydrate. Enough glue is added to dry alumina hydrate to make a thick paste, then this mixture is thinned with a few drops of water added to about a tablespoon of the paste. It is important that the cement be applied liberally to the bisque surface and strongly squeezed from the seam to seal the area completely. A bowl made from groggy clay can be used to contain the glaze pool at the base of the ware. After firing, bowl and foot ring are separated from the ware by tapping with a sharp chisel just below the seam.

Glaze application is somewhat unusual in that about three times the normal amount of glaze is used to thoroughly cover surfaces. Crawling often occurs because of the high zinc content of the glazes, and contrary to typical glazing procedure, the generous application of glaze minimizes defects in crystalline glazes. I have obtained best results brushing on repeated layers of light-cream-consistency glaze, building up a 3/16-inch thick coating.

Any serious work with crystals involves compounding and altering glazes to meet individual requirements. Presently, there are few commercially available frits which are suitable for this work. But, several thousand distinct glazes can be compounded by altering recipe proportions as well as adding other ingredients to the batch. The relative limits within which working zinc silicate crystalline glazes lie are approximately:

KNaO	0.300-0.600	Al_2O_3	0.000-0.120	SiO_2	1.200-1.900
CaO, MgO, BaO	0.000-0.150	B_2O_3	0.000-0.150	TiO_2	0.000-0.250
ZnO	0.400-0.700				

Calculations should be made to at least three decimal places.

My experiments indicate that the various oxides function in crystalline glazes as follows:

K_2O, Na_2O, Li_2O—These are the active fluxes which dissolve the other oxides and contribute fluidity to the glaze; they have a strong influence on colors. Na_2O and Li_2O seem to be the best bases. Tests indicate that K_2O base glazes produce smaller and poorer quality crystals or do not operate within the same limits as Na_2O and Li_2O.

CaO, BaO, MgO—The function of these fluxes is uncertain, but glazes compounded without them seem washed out and thin.

ZnO—Zinc and silica form the crystals; increasing the zinc content increases the size and number of crystals. Large quantities of zinc will tend to promote crawling. Calcined zinc oxide reduces this tendency toward glaze surface defects.

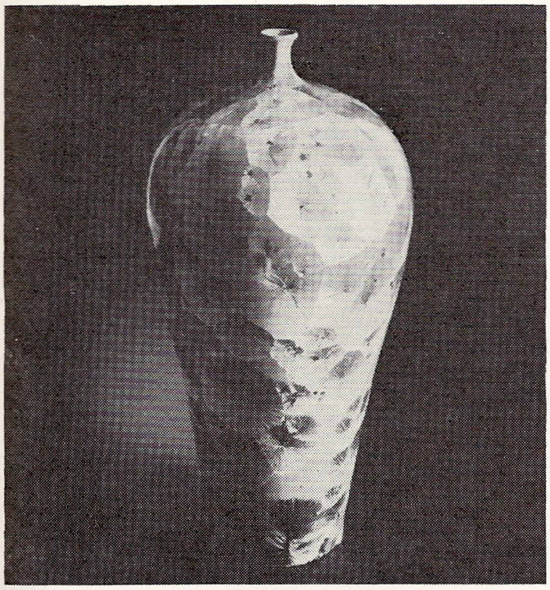
Al_2O_3—Alumina levels should be kept low since excessive amounts contribute to the formation of matt glazes composed of many tiny crystals, (and also to dark edging on crystals). About .05 Al_2O_3 is sufficient to maintain a reasonable glaze thickness on the finished piece. The fast rise to full temperature is to avoid alumina and silica pickup from the body.

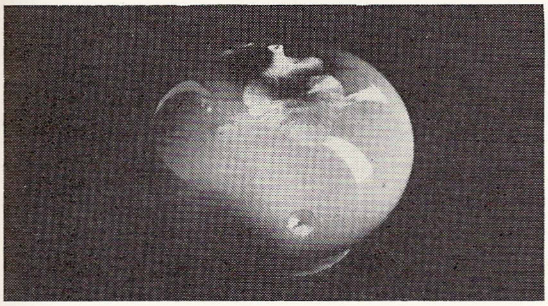
B_2O_3—Boron seems to function like alumina, possibly by increasing the solution of the body, resulting in excess SiO_2 and Al_2O_3 in the glaze. For this reason, many of the boron-based commercial frits are unsuitable for crystalline work.

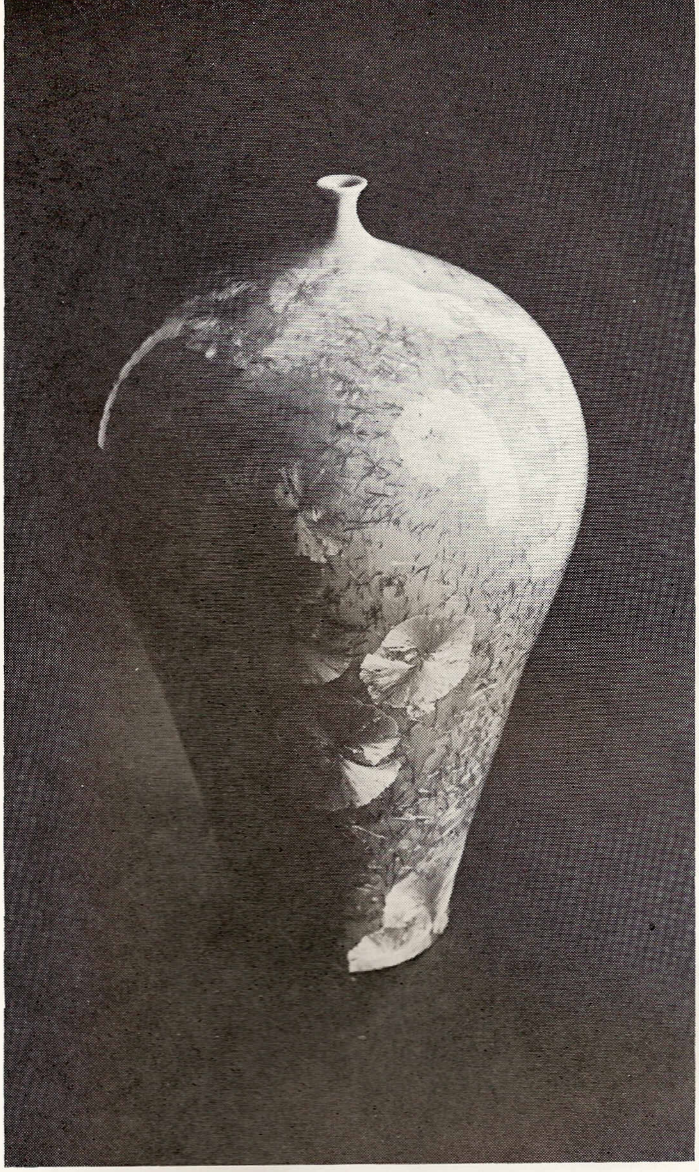
SiO_2—Silica acts as a glass former in the glaze and as a component of the crystals. Present in amounts above 1.90 it may cause the glaze to devitrify, developing a sandy surface.

5. A thick layer of wet crystalline glaze is applied to the form.

6. After firing, glaze has pooled in the bowl below the base of the ware.



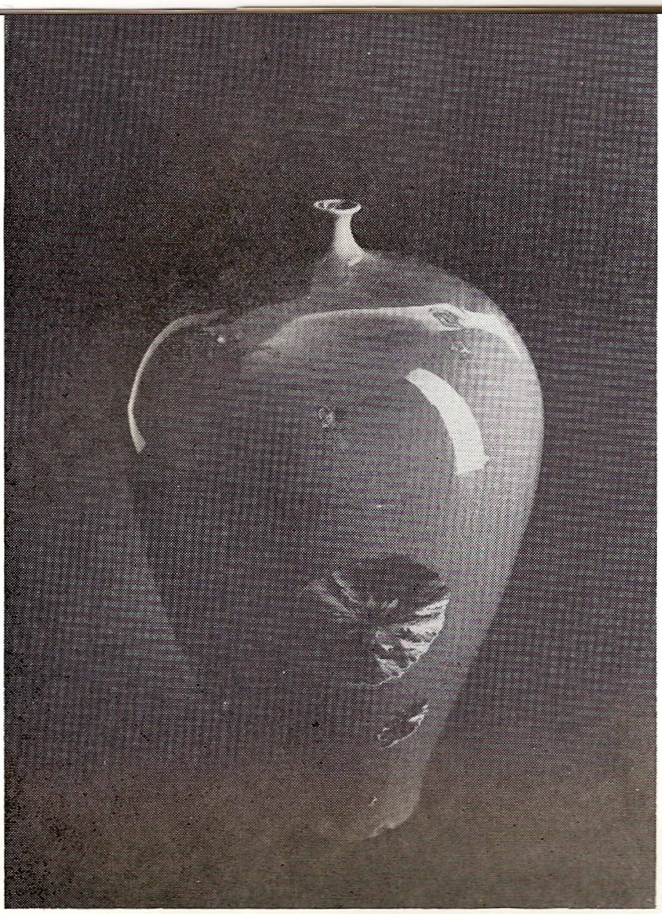




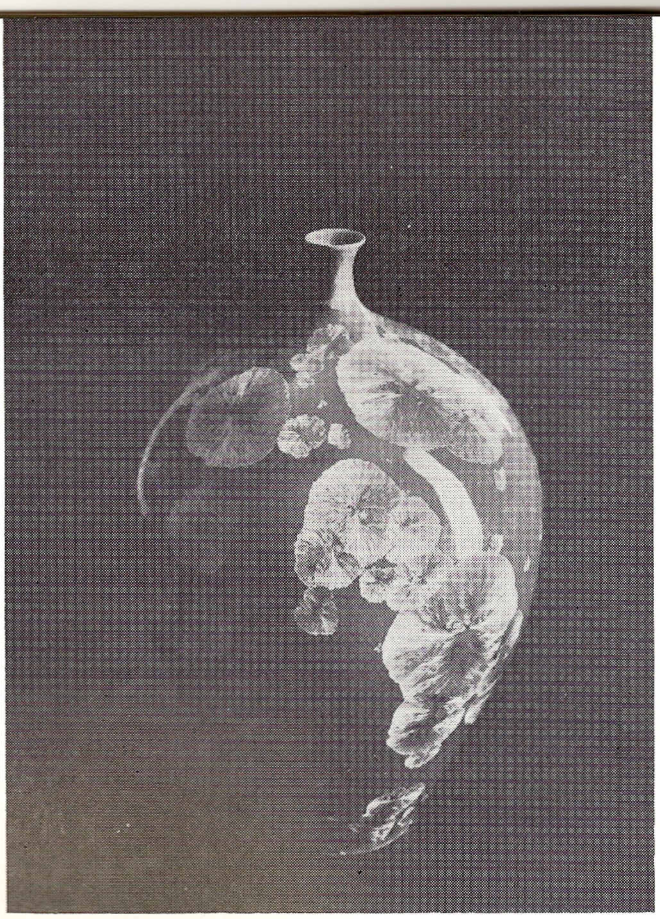
Above and right *A variety of crystalline effects may be produced with colorant additions to Crystalline Glaze I.*

7. By gently tapping with a sharp chisel, the glaze is cleanly fractured at the base to separate the fired form.

8. The completed form may be smoothed further at the foot with emery paper.



Porcelain form with steel gray crystals on an orange background, 7¾ inches in height. The effect was produced with Crystalline Glaze I and additions of 3% manganese dioxide and 0.5% cobalt carbonate.



Porcelain form with copper green crystals on a sea green background, 7½ inches in height. The effect was produced with Crystalline Glaze I and additions of 3.5% copper carbonate and 0.3% cobalt carbonate.

TiO_2—Titanium is a color modifier and seems to enhance the richness and silkiness of the crystals. Although crystals may be grown without it, they are smaller and washed out in appearance. Excessive amounts act somewhat like alumina.

Compounding a glaze which produces crystals is the first step; then the glaze, the firing, or both must usually be adjusted to achieve good results. Most of my adjustments are with the glaze rather than the firing. Especially in the growing range of the crystals, the glaze composition and the holding temperature are strongly related. Increasing the size of the crystals may be accomplished by raising the holding temperature 10-20°F, or by maintaining the same holding temperature and slightly increasing the zinc oxide or silica content of the glaze. Raising the zinc oxide while lowering the silica, or vice versa, may change the color response of a glaze considerably, although crystal size remains the same. Increasing the titanium content increases the size of crystals. After about 0.130, titanium serves primarily as a color modifier and agent for visually enriching the crystals; beyond about 0.250, it causes background darkening and dark edging on crystals, similar to the effects of excessive alumina.

The number and form of crystals produced are largely dependent on temperature. Glazes which work well and produce few crystals at Cone 9 peak temperature are often completely covered with crystals if fired to Cone 6 peak temperature. Increasing the holding temperature favors growth in one dimension; lowering it tends to produce crystals more circular in form. Temperature differences of 5°F or less can be significant, and measurements, records, and equipment should be accurate enough to meet this specification, particularly when developing new glazes.

Crystalline glazes provide fertile ground for the potter wishing to involve himself with the more challenging aspects of glaze formulation. With experimentation, it is possible to develop a wide range of interesting and personal glazes, using commercially available materials.

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