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Alterations, Glaze Properties, Faults and Defects

Exceptional cooks alter recipes to suit their needs and taste. Exceptional ceramists do likewise, in the pursuit of a special, elusive quality. You may want to modify a glaze recipe to simplify the mixture, change the firing temperature, alter the fluxes, change the glaze surface quality, improve glaze fit, or to substitute materials when those suggested in a recipe are not available.

Glazes can be altered in a number of ways and for a variety of reasons. However, it should be remembered that when one alters a glaze, there is almost certainly going to be some change in the way that the glaze will respond to color development and in the way that it will flow on a vertical surface. Faults and defects may occur in the process of altering, requiring new solutions. There are many generalities in this chapter, because for each new

glaze alteration, there is inevitably a new set of questions. For each new question, there can be several answers. As you will have seen by now, there are no absolute solutions, and every alteration demands exploration.

GLAZE ALTERATIONS

Some of the most common and reliable methods for altering glazes are covered below.

SIMPLIFYING THE MIXTURE

When a glaze is developed through calculation methods, it will often have numbers following the decimal point, as in the following commonly

used High Alumina Matt glaze from *Clay and Glazes for the Potter*, by Daniel Rhodes.

Feldspar	48.9
China clay	25.1
Dolomite	22.4
Whiting	<u>3.5</u>
	99.9

This glaze can be easily simplified to either of the following, with little discernible difference in quality, but with much easier measuring.

Alteration 1		Alteration 2	
Feldspar	50	Feldspar	50
China clay	25	China clay	25
Dolomite	20	Dolomite	<u>25</u>
Whiting	<u>5</u>		100
	100		

Many ceramists around the world are using either of the above slight modifications of the original, and the principle used here works for all glazes which I have worked with. I have altered standard recipes in this way for many years and have had no problems in the process. I simply remove all decimal points and round off to the nearest whole number, or nearest multiple of five; for example, china clay went from 25.1 to 25, and dolomite from 22.4 to either 20 or 25, purely to aid in simple addition. The rationale behind these changes in the above glaze relate to the chemical constituents of whiting and dolomite. Both materials are calcium, although dolomite also contains approximately 50 percent magnesium. Making minor alterations in these two fluxes has little effect on the melt of the glaze. There might be a small effect on the color potential, particularly with cobalt, when the glaze is made up without whiting, but there is negligible effect on other qualities.

The concept of this form of glaze alteration is more important than the actual recipe given above, because many other fluxes could be interchanged with the dolomite and calcium, with obviously different results. It could be a very good exercise, rather like the section on flux variations in chapter 10, to maintain the feldspar at 50 percent, the kaolin at 25 percent, and make up the balance by the addition of any flux or combination of fluxes. Limitless variations are possible, and it all becomes part

of the creative play process of individual glaze development.

CHANGING THE FIRING TEMPERATURE

To raise the firing temperature, add refractory materials such as kaolin or ball clay. This can be easily done in percentage increments of 5, 10, 15 and so on until the glaze is altered enough to fire at the desired temperature. Alterations like this will undoubtedly affect the color potential of the glaze to some extent.

Lowering the firing range in glazes is generally done by removing some of the refractory materials, increasing silica or fluxes, or using more active fluxes which will fuse at a lower temperature. In some circumstances, it is possible to increase the volume of some of the fluxes. However, the erratic behavior of many fluxing agents causes a reversal in melting characteristics at a given point, after which any greater addition of the same flux will usually cause the glaze to fuse less. The reason lies with the development of eutectics within the glaze, and their seemingly illogical behavior (see chapter 7). These variations make the simplistic approach to glaze alteration unpredictable in these cases. One of the most useful active fluxes for this form of alteration, and one which works at almost any temperature, is colemanite, or its near cousin, gerstley borate. These materials have an extremely wide temperature range. For highfire glazes, the substitution of nepheline syenite for other forms of feldspathic material will generally lower the firing range by a cone or two. Midfire glazes can be lowered by substituting frits or colemanite for feldspathic materials.

ALTERING THE FLUXES

As demonstrated in chapter 10, altering the fluxes is one way of developing the color potential of a given glaze, and it is one where much research needs to be done. I have found that interchanging the color-affecting fluxes up to 20 percent can radically alter the color potential of the glaze, as well as its surface quality. Some of the more potent materials such as cryolite, fluorspar and lithium are

best used in only small amounts up to 5 percent, where they will have a profound effect.

CHANGING THE GLAZE SURFACE QUALITY

Making a glaze more matt requires the same procedures as increasing the firing temperature. By adding refractory materials, such as kaolin, the glaze is made temperature sensitive, as it is in effect being slightly underfired. It is probably better to use one of the fluxes which produce mattness in glazes. These are calcium, magnesium and barium. If the glaze contains calcium, increase the calcium to form a "lime matt." A "lime matt" is likely to develop in a high temperature glaze when the calcium content is over 20-25 percent, depending upon which other fluxes are in the glaze. Calcium can also be used in lowfire glazes as a matting agent, as it is refractory at low temperatures. Glazes which are matted by the use of magnesium may develop a smooth buttery surface, while glazes matted with barium will usually form frosty surfaces. If there is boron present in the glaze, barium may not work as a matting agent; a reaction can take place between the two that increases the gloss.

Making the glaze more shiny can be achieved in the same way as lowering the firing range. Decrease the refractory materials, calcium, magnesium and barium, and/or increase the other fluxes.

IMPROVING THE GLAZE FIT

To eliminate glaze problems such as crazing and shivering, see Faults and Defects in this chapter (page 100).

DESIRABLE PHYSICAL CHARACTERISTICS OF GLAZES

Regardless of the firing temperature, there are certain properties that should be considered at the time of glaze formulation, which relate to the working properties. A glaze that doesn't behave reasonably well before firing is likely to cause considerable annoyance. The desirable physical properties of a glaze include good suspension and adhesion, and low fragility. Occasionally, improvements in

one or more of these areas leads to the problem of glaze fermentation, discussed below. Note that as a general rule, very small additions of corrective materials (1 to 5 percent) are ample to make a profound difference to the pleasures of working with a delinquent glaze.

SUSPENSION

Does the glaze stay in a state of suspension while in use? Or does it continually settle to a rock hard mass at the bottom of the container, steadfastly refusing to budge? Settling often happens to a glaze with little clay because the heavy particles tend to sink. It can be improved by the addition of various materials called flocculants, such as epsom salts (magnesium sulphate), water softener (such as Calgon), carageenan (a form of seaweed), Sea Spen, Setit-A, bentonite, gum arabic, gum tragacanth, and cellulose gum (such as CMC).

Some flocculants will undoubtedly alter the fired glaze, often affecting the *color potential*. Adding clay to the glaze will definitely do this. A small amount of bentonite, however, is unlikely to change the surface, although it may affect the color. Bentonite should always be added to the dry materials before adding water, otherwise it will not mix properly. A gum solution can be made by adding gum tragacanth or cellulose gum to hot water; let this sit overnight to mix thoroughly before adding to the glaze. Gum arabic needs to be mixed with alcohol to go into a properly dispersed solution. There are various proprietary brands of suspender such as Setit-A, Sea Spen and CMC gum, which should be mixed according to manufacturers' directions.

ADHESION OR COAT

The thin film of raw glaze that covers the clay object needs to be sufficiently bonded to the surface to facilitate ease of handling. Glaze flaking is usually found when the glaze has either little or no clay in it, or conversely has an overload of clay. In the first instance, the glaze will be fragile, powdery and loose. In the second, it sometimes will have a network of fine cracks where the glaze has shrunk away on drying. Adding some clay, in the first case, or removing some, in the second, should im-

prove the situation. Using some part of the clay content in calcined form should also help. Some of the suggested additions for keeping a glaze in suspension will also help here, notably gums and Sea Spen seaweed suspender.

FRAGILITY

Glaze fragility is a concern when multiple layers of glaze are contemplated. If one intends to paint on top of the glaze, in the Majolica fashion, one needs a surface that allows the application of color without the worry of the wet brush removing the glaze at the same time as it adds the color. This can be achieved in various ways. First, the glaze needs to have at least 10 percent clay in it, so that it becomes less powdery. If this is likely to upset the desired quality of the glaze, it can instead be applied as usual, then sprayed with a thin coat of a solution of gum, honey, sugar, size or cornstarch mixed with water, before decorating. These materials may also be added directly to the glaze to form a hardening coat. This allows easier, more fluid movement of the brush, and doesn't grab and suck. Note, however, that the glaze may start to ferment with these organic materials, and a bacteriostat such as formalin will be needed.

FERMENTATION

Very occasionally, a glaze will start to ferment. As mentioned above, this may be due to some of the organic matter, such as gums, cellulose, carbonaceous matter, or wood ash, decomposing in the glaze. It is a fairly unusual occurrence, and may be remedied by drying out the glaze completely, then remixing with a small amount of formaldehyde, in the form of formalin solution added to the water. Without doing anything, the glaze will still work, but it will have a pungent aroma. This may be masked with a little oil of wintergreen, or oil of clove.

FAULTS AND DEFECTS

One person's fault is often another person's fancy! Except in those cases where a glaze needs to be faultless for some reason of hygiene, the in-

dustrial ideal of perfection has been a stultifying influence on the creative exploration of ceramic surfaces. A surface that might be considered defective on one object can be very exciting on another. It is for this reason that one should look very carefully at all aspects of glaze tests before discarding anything as worthless.

One only has to think of Chinese crackle glazes or the Shino and Nuka glazes of Japan, which show crazing, pinholing and crawling of glazes to wonderful aesthetic effect. Western civilization is unfortunately less in tune with the natural world and the serendipitous nature of the transformation process that occurs in a potter's kiln. We have not been ready to view these so-called glaze faults in such an open-minded way as the Oriental, and as a result, wares which have them usually end up without buyers. It is a sad reflection on the lack of sensitivity of the West that naturally occurring blemishes are looked on as suspect. Has one ever seen a perfect face, or perfect skin?

The ceramist generally recognizes some of the positive qualities of imperfection, but is more often than not harassed by the retailer of his work, as an intermediary with the public, into the belief that these occurrences are all defects. If the ceramist is producing functional ware in which glaze faults create any kind of health hazard, the retailer may be right. However, the same qualitative judgments on glaze surfaces are often used as criticism of surfaces which have no pretense of function. It is up to the ceramist to educate the buying public to the fact that glazes do not have to be slick, sanitary and soulless; they can and should have qualities which closely relate to the imperfections of people we love.

We generally talk about pots in anthropomorphic terms, with feet, bellies, waists, shoulders, necks and lips. If we move further along these lines, we can think of the glaze of a pot as its skin. If one then thinks of all the variety of skin textures which give individuality to the human race, one can easily see the analogy.

DETERMINING THE CAUSE

The best start in the process of detecting why a fault occurs is to break a piece of the work and

look at the cross section carefully. This can be done with a magnifying glass, under a microscope, or, for some faults, with the naked eye. A cross section can reveal problems quickly, and learning to read a shard is an important skill.

There are several reasons, all very logical, why a particular glaze fault may occur, but trying to deduce the cause of a fault from a single piece may prove quite difficult. When there are a number of pieces available, all of which have the same glaze and come from the same kiln load, or when there are several different glazes being used on a single clay body, the detective process becomes much easier. The following section outlines several factors which can cause faults or defects. Faults which appear to be glaze related may result not only from the composition of the glaze, but also from the improper selection and preparation of the clay body, from faulty kiln operation, or, as is often the case, from lack of skill and care in application.

GLAZE DEFECTS DUE TO THE BODY

1 A body that is too porous because of improper wedging, kneading, blunging, or pugging, may be the cause of small bubbles, beads, and pinholes forming in the glaze. As the body contracts, its gases need to escape; in some cases, they force themselves through the still porous body. I can't say that I have ever seen this, at least to be certain of the cause, but others have claimed its existence. It is said to be quite common in low temperature glazes. Firing the bisque to one or two cones above the lowfire glaze temperature should resolve it.

2 An excessive amount of manganese dioxide used as a colorant in a body or slip will cause bloating of the clay, and may also cause blistering of the glaze.

3 Soluble sulfates which are contained in some clays come to the surface in drying, forming a white scum. Pinholes and bubbles are created as these sulfates react with the glaze, forming gases. This condition may be corrected by the addition, to the body, of 1-2 percent of barium carbonate. A slight reduction fire at the point at which the glaze begins to melt will reduce the sulfates, and allow the gas to pass off before the glaze develops a glassy re-

taining film. The sintering or beginning point of the glaze melt depends upon the glaze being used. In low temperature glazes, it will be at about 800-850°C.; in mid-fire glazes, it will be at about 950-1000°C.; and in high temperature glazes, about 1050-1100°C.

4 If the body is underfired in the bisque, and therefore very porous, it may absorb an excessive amount of glaze. Soluble fluxes in the glaze, because of their relatively higher rates of thermal expansion/contraction, may cause the body to crack.

GLAZE DEFECTS CAUSED THROUGH APPLICATION

1 Blisters or pinholes may occur when coarse clay bodies have air trapped in the surface pores. This can be one of the major causes of white dots appearing on the colored areas of majolica. Slight moistening of the bisque-fired clay before glazing or firing the bisque higher help to eradicate this fault.

2 Dust or oil on the surface of the bisque may cause a resist effect and the glaze will not adhere. It can also cause pinholes or a scaly surface on the glaze.

3 If the glaze is applied too heavily, it may run, obscuring the decoration, and may stick the piece to the kiln shelf.

4 In addition to flowing excessively, thickly applied glazes will usually crack on drying. Often, when these glazes are fired, the cracks will not heal up, but will pull farther apart and bead up at the edges. If the drying contraction is great enough, the adhesion of the glaze to the body will be weak, possibly causing portions to flake off during the initial period of the firing.

5 Conversely, too thin an application of glaze will result in a thin, rough surface. This is especially true of matt glazes, which generally require a slightly thicker application than gloss glazes.

6 If a second glaze coating is applied over a completely dry first coat, blisters will probably form. The wetting of the lower glaze layer causes it to expand and pull away from the body. This can cause crawling to take place during the subsequent firing.

7 If the bisque ware is considerably colder than

the glaze at the time of application, bubbles and blisters may later develop.

GLAZE DEFECTS ORIGINATING IN FIRING

1 If freshly glazed ware is placed in a kiln and fired immediately, the resulting steam can loosen the glaze from the body, causing blisters and crawling.

2 Rapid firing can inhibit the normal gases from escaping. They can form tiny seeds or bubbles in the glaze. For some especially viscous glazes, a prolonged soaking period at top temperature for 30–60 minutes is necessary to remove these gas bubbles.

3 Excessive reduction can result in black or grey spots on the body and glaze, producing a dull surface.

4 Glazes containing lead should not be fired in reducing conditions, as the lead oxides will reduce to metallic lead. Also, the sulfur content of any combustion gases will dull the glaze surfaces, and possibly form blisters and wrinkles.

DEFECTS IN GLAZE COMPOSITION

1 Glazes which are not properly adjusted to the clay body are susceptible to stresses that may cause the glaze—and the body—to crack. If the glaze contracts at a slower rate than the body in cooling, it goes into a state of compression. This causes the glaze to buckle up and separate from the body, throwing off sharp and dangerous slivers of glass material. This defect is commonly known as *shivering*, although the problem is not very common in studio pottery glazes. It is most often encountered in glazes with a high lithium content.

2 Slightly similar to shivering, and also caused by unequal contraction rates in cooling, is *crazing* of the glaze. In this case, the glaze contracts at a greater rate than the body. This state of great tension causes numerous fine cracks to form. When done intentionally for decorative effect (or sometimes rationalized by potters after the fact), glazes with this condition are called *crackle* glazes.

3 An excessive amount of refractory colorant or opacifier, such as rutile, tin, nickel or chromium,

which are relatively insoluble in the glaze melt, can cause the glaze to become dull and rough.

4 A dull surface is likely to result if the balance between silica, clays and fluxes is incorrect for the desired temperature range of the glaze.

5 High zinc "Bristol" glazes and high colemanite glazes may tend to crawl or crack, particularly at high temperatures, when not fitted properly to the body. The fit can be improved by the addition of alumina or clay.

6 Glazes ground too finely, thus releasing soluble salts from the fluxes, feldspars, and so on, can develop pinholes and bubbles.

SOLVING MAJOR GLAZE DEFECTS

Crazing *Crazing* is the most common defect, and normally the easiest to correct. In both crazing and shivering the eradication of problems relies on matching the thermal expansion characteristics of both body and glaze. In practice, the most effective ways to correct crazing are:

- a increase the silica, in body or glaze
- b decrease the feldspar, in body or glaze
- c decrease any other material containing sodium or potassium
- d increase the boron
- e increase the alumina—i.e., the clay content
- f increase lead oxide.

Shivering *Shivering* is the reverse of crazing; therefore, the remedies are the opposite of crazing:

- a decrease the silica in either the body or the glaze
- b increase the feldspar, especially sodium feldspar or nepheline syenite, or other alkaline bearing materials.

Crawling *Crawling* is caused by a high index of surface tension in the melting glaze. It is triggered by adhesion problems, often caused by bad application. It occurs where a glaze is excessively powdery, and does not fully adhere to the surface of the clay. This can be alleviated by the addition of a small amount of gum to the glaze batch. *Crawling* is more common in matt glazes than in fluid

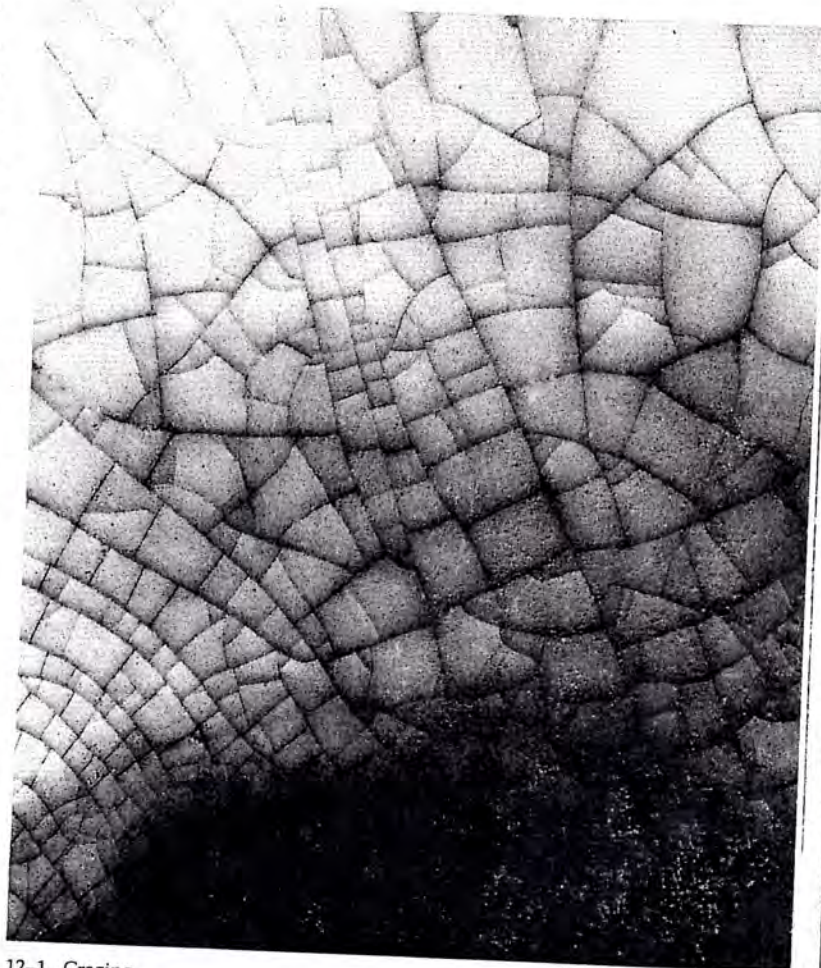
ones; sometimes the problems of crawling can be adjusted by the addition of a small amount of extra flux. Crawling can also occur when one glaze is applied over another, particularly if the first is allowed to dry out completely before the second application. Some fluxes, particularly zinc and magnesium, are likely to cause crawling when used in excess. Calcining part of the zinc can help this problem.

Pitting and Pinholing These are the most annoying and difficult glaze flaws to cure. They can be caused by a badly controlled firing cycle, the glaze composition, or can originate with the body, particularly highly grogged clay bodies. The following remedies should be tried to cure pinholing or pitting:

- a lengthen the firing cycle
- b apply the glaze less thickly
- c add more flux to the glaze to make it more fluid
- d decrease the content of zinc or rutile in the glaze
- e where zinc is used, try calcining half of the zinc content
- f increase the maturing temperature of the glaze
- g hold the kiln at the glaze maturing temperature for a soaking period of up to four hours
- h cool the kiln slowly.

Blisters Blisters and blebs are usually the result of either excessively thick application of glaze, or incomplete clay preparation, wedging, blunging, etc. Sometimes, however, these faults can be due to overfiring, or to the use of soluble fluxes in the glazes. The following fluxes might cause this problem: borax, boric acid, potassium carbonate, magnesium sulfate, and sodium carbonate. If these materials are present in a problem glaze, it would be well to replace them with other fluxing agents, or fritted materials.

Devitrification Devitrification is the process whereby some glazes change from an amorphous clear solution, at the point of maturity, to a crys-



12-1. Crazing.

talline glaze, during the cooling. It is fairly common in high temperature glazes that are high in silica, clay, lime and barium; microcrystalline frosty or buttery matt surfaces develop in these glazes. Devitrification is the basis of crystalline and aventurine glazes (see chapter 13), and thus in many glazes is desirable, rather than a fault. If devitrification is occurring where it is not wanted, it is usually necessary to speed up the cooling cycle to eliminate it. If this is not possible, the crystal-forming materials—calcium, magnesium, zinc, barium, manganese, titanium and iron—will have to be partially or wholly replaced by other oxides.

Flashing Flashing is the name given to the habit of some materials to be volatile in the kiln.

This fuming causes interesting—or annoying—effects in the color and surface of glazes. It is noticed in various ways. Volatile materials such as sodium, lead and boric acid, and to a lesser extent, barium, zinc and potassium, produce shiny glazed areas, occurring like a haze in unglazed areas of the ceramic object. The hazy surface is often an attractive toasty color on stoneware, and a pinkish blush on porcelain, and can be used for special decorative effect.

Some colorants—chromium, copper, and to a lesser extent, manganese and cobalt—are also volatile, and can distribute themselves onto other glazed pieces in the same kiln. In the case of chromium, even the kiln walls can be impregnated: The oxide can volatilize out in another firing, turning tin opacified glazes pink. These serendipitous occurrences can be encouraged, as they have been for hundreds of years. The Chinese potters of the Sung dynasty often painted the inside of saggers with copper to volatilize onto the pots, giving pink, red and blue flashing to the glazes known as Chun.

Flashing is also the name given to the surface effects of wood firing. Flames lick at the clay, creating exciting and varied surface effects. Small ash deposits graphically illustrate the movement of the fire through the kiln by the color and surface alterations which take place.

Underfiring *Underfiring* occurs when the kiln has not achieved a high enough temperature to mature the glazes properly. Underfired glazes will generally be opaque, dry surfaced, and usually quite a different color from the properly fired glaze. They will often be crawled or bubbled, in a state of arrested development. When refired to the correct maturing temperature, they should behave normally, although colors may change slightly in the process.

Overfiring *Overfiring* is usually the result of not watching the kiln closely as it approaches top temperature. Its symptoms are very glassy, sometimes blistered glazes, and often bloated clays. The solution to this is to take more care in firing. If the kiln temperature is being gauged by the usual use of three cones, the guard cone should be taken as a warning; it is wise to slow the firing at this point

to allow proper maturation to take place, without worry of overfiring. A kitchen timer can also be a useful aid.

Spluttering *Spluttering, or Spit-out*, is a defect in which small pieces of the glaze fall off the ware during firing, and are found firmly attached to the kiln shelf after firing. The glaze layer sometimes heals over, and sometimes crawls. The cause is generally from a loose glaze layer that fails to adhere during fusion. Firing ware which is still wet from the glazing process will frequently cause spluttering. It also occurs with glazes containing colemanite, which releases its chemically bonded water at around 800°C. There are two other times when this anomaly may occur. One is when the bisque fire has been very low, and has not completely burned off any carbonaceous matter in the body. Subsequently, the glaze spits off small parts as a result of gases being released. The other is when reduction may be started too early in the firing, again causing gases to spit out.

Dunting *Dunting* is a fault of irregular cracking, more related to clay than glaze, and usually caused by uneven cooling, or by cold drafts getting in the kiln. This cracking can occur from passing through the point of quartz inversion too quickly, or from compression-shattering.

Glaze dunting is most likely to occur when a piece is heavily glazed on one side only with a glaze that has high surface tension. This would typically be a high expansion glaze, possibly containing a large amount of nepheline syenite. For example, a pot made of a well vitrified stoneware clay, covered either inside or outside (but not both) with a saturated iron or temmoku glaze would be a prime candidate for dunting. With this combination, one can often find the piece splitting in half during or after cooling. The solution is to take the glaze over to the other side of the piece to relieve the tension, or to change the glaze.

If dunting does occur, it is helpful to scrutinize the piece for evidence of when the cracking occurred. If the crack formed in the heating cycle, its edges will be softened and rounded; if in the cooling cycle, the crack will leave sharp edges.

Some dunting can also occur in conjunction with black coring, particularly if the wall thickness is uneven. In this case the dunting and black core will occur in the thicker section. The crack should be examined to see if the core of the clay is black or dark grey.

Black Coring A *black core* occurs when the carbon in the body is not successfully burnt out in the bisque firing. All clays contain some carbona-

ceous matter, which must be completely eliminated before the completion of the bisque firing. In the process of burning out, local reduction takes place, turning the iron oxide black, possibly with some carbon. Black coring can be attributed to a lack of sufficient oxygen between 750 and 900°C., through either an unclean atmosphere or through too rapid a firing cycle. The remedy for the problem is to make certain that the atmosphere is oxidizing, and to slow the firing slightly.