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WHAT'S IN A GLAZE?

Introduction

Any piece of tableware, be it Wedgewood's best, Spode's finest, or just that cereal bowl obtained with a box-top and ten cents to cover postage, is essentially a baked clay body covered with a glaze. A glaze is a coating applied to a ceramic body. The coating becomes a glass on firing and provides an impervious covering as well as decoration for the product.

The development of fine china and glazes has tested the ingenuity of man throughout the ages, and the number of glaze formulas used since the beginning of ceramic history is infinite. There are several reasons for this: First, because of the wide variety of clays and ceramic body mixtures, it has been necessary in most cases to develop new glazes or alter known glazes to fit each new ceramic body; second, before the discovery in Europe of white-burning clays the desire to copy the white porcelain of the Chinese brought about the development of majolica, faience, and other ingenious imitations; third, for centuries, both glaze and body formulas were regarded as trade secrets, and each craftsman was forced to develop his own compositions; fourth, the artist has always been called upon to produce new and different effects in order to please the buying public; and finally, within the last century glazed ware has been used for wall tile, insulators, sanitary ware, chemical ware, etc., in which specific requirements such as hardness, resistance to moisture, frost, heat and resistance to chemical action had to be satisfied.

Exhaustive technical studies of the effects of various materials as well as methods of preparation, application, and firing on the properties of glazes have enabled workers to fit a glaze to a body more perfectly. Thus scientific rather than hit-and-miss methods are now used to make glazes which must meet specific requirements.

Glazes in general

Most glazes are prepared by mixing the constituents with water until the consistency of cream is reached. The glaze "slip", as the mix is called, is then applied to the body by spraying or dipping. The consistency of the slip is controlled by adjusting its specific gravity which should be about 1.75. Gelatin, dextrine, or gum tragacanth is often added to the glaze slip to improve the adherence as well as to add smoothness of flow. When the glaze is thoroughly dried, the ware is fired. An exception to these methods of application is the salt glaze, which is formed by vaporizing common salt in the kiln during the firing of the ware.

The composition of the fired glaze is different from the composition of the raw glaze. Likewise the composition of a glaze applied to a body and fired differs from the composition of the glaze when fired alone. The chemical changes which take place in the firing are not fully understood. Blakeley's work, "The Life History of a Glaze", describes the physical changes which occur during firing. In Blakeley's experiments, specimens to which a whiteware glaze had been applied were fired to various temperatures and quenched. Photomicrographs of cross-sections of these pieces showed the following results in the glaze:

750° C. Large holes or pores, undoubtedly the remains of space between particles in the raw glaze, were noted. Quartz and feldspar particles were readily determined. A definite boundary between glaze and body could be seen.

900° C. The pores had completely disappeared and the larger holes had formed bubbles. Feldspar grains were being dissolved by the glass which had been formed.

1025° C. Very little crystalline material was left.

1095° C. Most of the air bubbles had escaped.

1100° C. Quartz was completely dissolved.

1145° C. Erosion of the body by the glaze was definitely shown.

1150° C. All bubbles had escaped and a clear glass was observed.

The above investigation gives a general picture of the progressive changes which occur in a glaze during firing, but these changes do not take place in all glazes at the same temperature.

The ceramist refers to heat treatment in terms of cones, which are "pyramid shaped fusible bodies of progressive softening order, employed as a guide in determining the finishing point of a ceramic kiln."* The table below gives the cone temperatures referred to in this paper, converted to degrees Centrigrade and Fahrenheit.

Cone Temperature	Degrees C.	Degrees F.
010	890	1634
09	930	1706
08	945	1733
07	975	1787
06	1005	1841
05	1030	1886
04	1050	1922
03	1080	1976
02	1095	2003
01	1110	2030
1	1125	2057
2	1135	2075
3	1145	2093
4	1165	2129
5	1180	2156
6	1190	2174
7	1210	2210
8	1225	2237
9	1250	2282
10	1260	2300
11	1285	2345
12	1310	2390
13	1350	2462
14	1390	2534
15	1410	2570

* Lange, Handbook of Chemistry and Physics, 4th ed., 1941, p. 692.

Classification

Orton's classification of glazes is widely accepted and will be used in the following discussion. Any discussion of glazes should include a brief consideration of the bodies to which the glazes are applied. Glazes are classed either as hard or soft; and as a general rule, hard glazes are applied to hard-fired or high-temperature bodies, and soft glazes to soft-fired or low-temperature bodies.

Hard Glazes

Hard-fired wares include porcelain and stoneware. In appearance porcelain is light and graceful while stoneware is strong and forceful. Both types of ware are commonly once-fired. The body and glaze of both types mature within the same temperature range. For this reason the alumina-silica ratio of the body usually approaches the alumina-silica ratio of the glaze, and glaze defects may be more easily avoided. The art of making porcelain requires great skill, as the high temperature brings out flaws which may have developed in the forming process. Stoneware, however, is more easily made than porcelain because of its coarser texture and fired porosity, as compared to the vitreous nature of porcelain. This does not necessarily detract from the value of stoneware, for each type of ware has its own suitable forms and uses.

Porcelain glazes

Porcelain glazes consist of alkaline or alkaline-earth silicates free from reducible oxides. Lead or boron may not be present. Porcelain glazes have high viscosities, high fusion points, and high critical temperatures. The firing temperatures of porcelain glazes range from cone 8 to cone 15. A simple porcelain glaze is made by mixing the following:

Feldspar	167	parts
Whiting	60	"
Kaolin	26	"
Flint	84	"
Zinc oxide	8	"

Stoneware glazes

Stoneware glazes consist of alkali or alkaline-earth silicates, and are free from reducible oxides. Stoneware glazes often possess a matte rather than a glossy surface, and the firing range of these glazes lies between cone 8 and cone 15. The three main types of stoneware glazes are salt glazes, slip glazes or engobes, and Bristol glazes.

Salt glazes

Salt glazes are immediately recognized by their characteristic orange-skin texture as on glazed sewer pipe. Salt glazing is a simple process. When the temperature of the kiln is between cone 5 and 8, common salt is thrown into the flame and is immediately volatilized. The vapor is retained in the kiln by temporarily closing the stack dampers. The salt vapor reacts with the clay body to form a glaze. Not all clays will take a salt glaze, and this question may be determined only by experiment.

Engobes

Slip glazes or engobes are often natural clays. Engobes were originally white coatings applied to crude, dark-colored clays to produce a ware as nearly as possible like porcelain. Colored decoration in frequently added to the opaque engobe before firing. After the first firing the piece is covered with a clear glaze and refired. A typical engobe has the following composition:

Clay	50%
Feldspar	12%
Flint	38%
Whiting	2%
Sodium Carbonate	1%

Bristol glaze

The Bristol glaze is a compounded glaze that burns white or transparent. It is often artificially colored and is usually high in alumina and zinc oxide. The alumina to silica ratio is about 1:7. If the zinc oxide goes into solution, the glaze is transparent, but if the zinc oxide is in suspension the glaze is opaque. A typical stoneware Bristol glaze has the following composition:

Feldspar	185 parts
Kaolin	56 "
Flint	39 "
Whiting	33 "
Zinc oxide	27 "

Soft glazes

Soft glazes consist of raw lead glazes and whiteware glazes. The temperature range of the soft glazes lies between cone 010 and cone 7. The raw lead glazes are used mainly on yellow ware, roofing tile, terra cotta, decorative brick, and ornamental pottery. Whiteware glazes are used on the higher grades of ornamental pottery, white pottery, and glazed tiles; the whiteware glazes are too expensive to be used on cheaper ware.

Lead glazes

Raw lead glazes are composed of alkalies, alkaline earths, and heavy metal silicates. They are boron-free. Lead is the main fluxing constituent and is usually introduced as red lead to minimize danger of poisoning. Although toxic, white lead is sometimes used. The advantages of raw lead glazes are:

(1) The glazes have wide firing ranges.
(2) The lead silicates which are formed are fusible at low temperatures.
(3) Lead silicate is relatively insoluble.
(4) The glazes have a low surface tension and low viscosity which tend to produce a smooth glaze.
(5) Lead compounds have high fluxing power.

The disadvantages of raw lead glazes are:

(1) The glazes are soft.
(2) Lead compounds are toxic.
(3) The glazes have a tendency toward "crazing", which is the development of fine cracks.
(4) The physical properties of the glazes are easily affected by the gases in the kiln.

The most important forms of the raw lead glazes are:

(1) The Rockingham glaze which is a dark brown glaze obtained by additions of manganese dioxide and iron oxide;
(2) The jet glaze which is black and is used for jet pottery as well as for roofing tile;
(3) The majolica glaze which was one of the earliest imitations of Chinese porcelain (this glaze is now used as a decorative glaze for ornamental ware);
(4) The colorless raw lead glaze which serves as a base to which other colorants may be added.

A glossy transparent glaze has the following batch composition:

Red lead	160 parts
Whiting	20 "
Feldspar	56 "
Kaolin	26 "
Flint	40 "

A matte glaze which matures at cone 02 has the following batch composition:

White lead	129 parts
Whiting	30 "
Feldspar	111 "
Calcined kaolin	22 "
Kaolin	11 "

Whiteware glazes

Whiteware glazes consist of the alkalies, alkaline earths, and heavy metal borosilicates. Although lead is always present, it is not the principal flux ingredient. The whiteware glazes are always fritted, the purpose of which is to render insoluble the soluble ingredients of the glaze such as borax, boric acid, and soda ash. Fritting is accomplished by melting these soluble constituents with sufficient whiting, feldspar, and flint to form a glass. The molten glass is quenched in water, and the resulting product is called a frit. This product is ground and added to the remaining glaze ingredients. The glaze is then ready for application. The most important varieties of the whiteware glaze are:

(1) colored tile glazes;
(2) enamels or opaque glazes, which usually contain tin oxide or its equivalent;
(3) ordinary whiteware glazes, which are used in French frit porcelain, English bone china, American semi-porcelain, and American vitrified china.

A bright fritted glaze has the following batch composition:

Frit		Glaze	
Borax	114 parts	Frit	117 parts
Whiting	60 "	White lead	64 "
Soda ash	10 "	Zinc oxide	12 "
Feldspar	56 "	Feldspar	28 "
Flint	78 "	Kaolin	13 "
		Flint	60 "

Colored glazes

Colorless glazes would become monotonous. Color is introduced either into the base glaze or into the ceramic body itself. Five types of commercial ceramic coloring agents together with the temperature range over which they are used are:

(1) Vitreous enamel colors	1250-1550° F.
(2) Glaze stains	cone 010-cone 20
(3) Body stains	cone 9-cone 12
(4) Underglaze colors	cone 06-cone 4
(5) Overglaze colors	cone 014-cone 06

Vitreous enamel colors are used where the enamel or glaze is applied to metal.

Glaze stains can be used on nearly all ceramic ware. These stains are mixtures of raw and calcined material in which the color is developed before the stain is added to the glaze.

Body stains are very costly and their range is less extensive than that of the coloring oxides. The stains may be calcined mixtures or natural earths such as ocher and umber which are incorporated in the ceramic body itself.

Underglaze colors, or colors applied over the body before glazing, are used in hotel china. The underglaze color is developed at higher temperatures than the overglaze which serves to protect the underglaze. Underglaze colors are protected from chemical action and are permanent. The choice of colors is limited, and the coloring agents are difficult to use since they must be precalcined and have a high softening point.

Overglaze colors consist of pre-burned glazes which are finely ground and applied to ware already glazed.

The ordinary base glaze is often artificially colored with ceramic oxides. Colors obtainable with the more common oxides under oxidizing conditions are:

Cobalt oxide	Light blue to dark blue
Copper oxide	Light green to dark green
Iron oxide	Yellow to chestnut brown
Manganese dioxide	Light purple to deep brown
Chromium oxide	Medium green to dark green
Uranium oxide	Light yellow to strong yellow
Nickel oxide	Soft brown to medium brown
Titanium oxide	Straw color

Intensity of coloring can be determined only by experiment.

Conclusion

Application of glazes to ceramic ware in the Pacific Northwest has been confined to the production of some stoneware and pottery. In addition, work with glazes has been done in a number of art studios and college laboratories. The ability to develop new glazes and to adapt nearby available raw materials as ingredients in ceramic ware is of the utmost importance. There is much to be discovered, and the use of new raw materials in ceramics opens a new field which should be thoroughly explored.

Esther W. Miller

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IN APPRECIATION

Don't you recall when ..... at least once or twice in your lifetime ..... not one but two or more events causing deep emotion have occurred within the space of a few days? The week past has been that kind of period for me.

It happens that I was born, during the 90's, in Emporia, Kansas, a town made famous by a country editor, William Allen White, and infamous by vaudevillian association with Oshkosh, Kalamazoo and other points on Main Street, mentioned with the intention of conveying the antithesis of cosmopolitanism.

There is a legend in our family which runs to the effect that at the age of two years and some months, I took off on what probably was the first exploration trip of my career. It ended, so the yarn goes, in the backyard enclosure of the W. A. White residence, with me on quite friendly terms with the White's negro maid. The mystery seems to have been how I covered the considerable number of blocks from our cottage to the White home - whether under my own doubtful power, by thumbing a ride, or otherwise. Whenever I've heard the story it, quite plainly, was told not to suggest that any importance attached to my being found on the premises of a celebrated family. Rather it was told, always by my mother, to illustrate her contention that I possessed a constant and congenital desire to be somewhere else, and that I started early in life to demonstrate the characteristic. Judging by the number of places in which I've lived, I've been demonstrating it ever since.

About that time, say 1900, William Allen White was not a celebrity in Emporia, but he was considered one of the solid citizens in that part of Kansas. As a youngster, I went to grade and high schools in the next county-seat town south of Emporia, but I doubt if a week passed when Dad didn't refer in some complimentary manner to William Allen White - his searching analyses, his humaneness, or his interesting political observations. On certain occasions when I was a youngster I recall Dad's taking me with him to Emporia on some school business, and stopping to chat with White at the Emporia Gazette office. I remember the man as a shortish, roly-poly fellow with kindly mien and the brightest eyes, sitting at a much cluttered desk in a badly cluttered office.

William Allen White's WHAT'S THE MATTER WITH KANSAS? placed him foremost in the minds of Kansans as a keen, accurate, fearless, and very humane citizen and editor. His WHEN A MAN'S A MAN heightened his standing not only at home but wherever books are read.

When one lives closely within the influence of an important person, one is apt to gauge that person's stature without proper perspective - like guessing the height of a church from its front step. Through the years we who lived under William Allen White's local influence appreciated and revered him, but perhaps we were too close to see his full stature. In later years from across the country he shone with greater brilliance when compared with others of his calling.

I'm proud to confess to my addiction, as a youngster in school and as an adolescent, to hero worship of the person and life of William Allen White. And now, as I read of his passing a week ago, I am deeply aware of a loss that seems more personal, because of memories as a child and later, than I have any real right to claim.

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And then yesterday's headlines.....Ray Clapper!

Let's go back thirty years. Have any occasions or situations in your life burned their trace any deeper into your memory than those of the first day or the first weeks of your entrance into college? Perhaps I was the more deeply impressed because I came from a country town, had never been anywhere, and therefore was frightened nearly to death at every aspect of getting started in this school of several thousand students all of whom seemed better equipped than I. Enrolling was a nightmare so agonizing that the details are somewhat confused. But my very first class at 8:00 a.m. and in freshman English was something never to be forgotten. I milled around the fatal door with other frightened sheep, then slithered in after the gong rang and sat on the edge of a chair where I could be the first one out if the going got too tough. The teacher, Miss Sarah Laird, calmed our fears slightly by giving a casual outline of the course, then suggested that if we had pencils and paper she would give us some rules to observe in writing our weekly English themes. She called off several rules pertaining to paper margins, punctuation, length of themes, and selection of topics, and then ended with the rule, "And never use a preposition to end a sentence with."

I fairly exploded - a regular Moon Mullins guffaw but with Li'l Abner Yokum innocence, in a room of perfect strangers. Both teacher and class were so taken aback with my outburst that they were struck dumb for a second. Then, to my amazement - and salvation - Miss Laird threw her head back and laughed out loud unrestrainedly like the thoroughbred she was. By that time, of course, I had realized the enormity of my crime and was trying to select a convenient crack in the floor through which to sink. The class had begun to snigger, but it was plain that they were laughing <u>at</u> me whereas Miss Laird had been laughing <u>with</u> me.

Within two weeks Miss Laird was reading my themes as exhibits, and letting me arbitrate discussions on grammatical points, and it was "Mr. Nixon" this and "Mr. Nixon" that. Then, after some of the misfits had been weeded out or had gone back to their homes, our English section was combined with another of Miss Laird's to form a single class of some twenty-five. And then it came to be "Mr. Nixon" this and "Mr. Clapper" that. I had a rival, a nemesis. My star stopped shining so brightly; in fact, it seemed to me that it dimmed somewhat by comparison. Clapper's themes were read as often as mine, sometimes more often. Our progress began taking on slightly different patterns. In matters of grammar we were equal. Either of us settled arguments for the class, and we rarely argued between ourselves. We'd both evidently had the same excellent training in grammar. (Lord, how I miss it now!) But in rhetoric Clapper distinctly had the edge on me. And his themes had a consistent high quality, excellent mechanical construction, smooth flow of words, and orthodox style. At times I'd turn out a job that was an inspiration, and Miss Laird would go to town praising it; at times my stuff was terribly mediocre. Never did I attain the consistency Clapper did.

I came to know Ray Clapper well and to admire him greatly. Then, in 1913, he was of slimmish build but wiry, and he walked with a very slight stoop. I recall distinctly his longish neck and prominent Adam's apple but his voice I remember best. It then was hoarse and crackly. Often we sat outside that first-built wing of the "Ad" building at the University of Kansas, and gabbled about some point of English or rhetoric. He, a few years older than I, had stayed out after finishing high school and had worked in a newspaper office. That accounted for his excellence in writing.

For twenty years now, from various parts of this country or from one or two other countries, I've read his column when I could get it, and I never ceased to admire his plain common sense, his directness, his honesty. I didn't always agree with him - although mainly, I did. But I doubt if any columnist ever attained Clapper's consistency as a reporter. That's something he brought from Kansas. Now, I'm going to miss him - awfully, as I'm going to miss that other great Kansan.

In telling reminiscences - those intimate "I remember when" stories - the teller is likely to spill over slightly and unconsciously overtell his own part in the play. Guess that's just because we're human. So, if I've let my hair down a bit too much, or have brought out of the past an anecdote or two of the kind one would ordinarily forever keep locked in his book of memories, it is because when I, like some other humans, experience a sorrow, that feeling translates itself into a certain mellowness. And that mellowness in turn finds expression in my desire to write down - for someone else to share - the basis of my sorrow. In a way that may be a bit unfair, although I have no apology. Anyway that's how it happened.

E.K.N.

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