

# LA MERIDIANA

INTERNATIONAL SCHOOL OF CERAMIC ART IN TUSCANY



## Notes on glazes

These notes on glazes represent a summary of some topics treated over the years at La Meridiana. They are incomplete, but constitute a sufficient base for all those who wish to start preparing their own glazes, starting from raw materials.

### THE CHEMICAL NATURE OF GLAZES AND THE USE OF SYMBOLS

**Glazes** (and clays) are made up of **oxides**. Oxides are combinations of pure materials, **elements**, with the element oxygen. Oxygen combines with other elements not in a casual way, but in a precise ratio that depends on the context.

Ceramic literature follows the practice of scientific literature and it uses the chemical symbols of the elements, for example **K** for potassium; **Pb** for lead; **O** for oxygen.

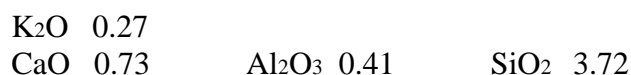
The atom is the smallest particle of an element; the **molecule** is the smallest particle of a compound. One molecule of  $K_2O$ , potassium oxide, contains 2 atoms of K, potassium, combined with 1 atom of O, oxygen.

### SEGER AND THE MOLECULAR APPROACH TO THE GLAZES (facultative reading)

A German scientist and ceramic chemist, Herman Seger, was a pioneer in the scientific study of glazes. He was the first to introduce the idea of using the **ideal formula** in the materials for glazes in order to be able to represent and compare **molecular formulae** of different glazes.

The reason the ideal formula was introduced is that many materials that we find in nature have a relative constant composition, and that once determined the presence of the major components, the minor impurities (even though always present) can be ignored. Therefore the ideal formula of potash feldspar is  $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ . This shows that the ratio of the major oxides in this feldspar is 1 : 1 : 6.

Seger's idea was to express glazes as a way of comparison; therefore a particular glaze for high temperature can be expressed like this:



and such expression is known as **Molecular Unity**.

The important aspect is that the sum of the fluxes ( $K_2O$ ,  $CaO$  or other in the first column) have to total ONE. The quantity of the other glaze components (the stabilizer  $Al_2O_3$  and the glass former  $SiO_2$ ) are instead always related to this ONE. This allows for a precise comparison with other glazes and is the reason of the name "unity"

Seeger method has withstood the test of time. At first sight, it can be seen highly precise and complex, while in reality, it is based on a procedure that ignores the “minor impurities”. Specialized industrial sectors that require sophisticated elaborations still use the same method, with more complex forms, based on a more complete analysis that would also include impurities.

## THE PARTS OF A GLAZE

Glazes are formed by three parts that represent three main requirements. The first and the most obvious is the necessity of a **glass former**. Silica,  $\text{SiO}_2$ , is a glass former. Very cheap and abundant in nature, silica is the oxide most commonly used. But its melting point is higher than that of the clays. This immediately poses a second need, which is that of an oxide that lowers its melting point. There are many of these oxides and they are known as **fluxes**. Combinations of silica and fluxes normally pass from the state of non-fusion to the state of high fluidity in a very small range of temperature and this calls for the need of a third oxide, the **stabilizer**.

Alumina oxide,  $\text{Al}_2\text{O}_3$ , added to silica and the fluxes on the right proportion, has the effect of stabilizing fluidity in such a way that the combination is vitreous but not excessively fluid with a wide range of maturing temperatures.

**All normal glazes, made with a few or many materials, will contain the oxides in a precise proportions for these three specific functions.**

FLUXES (basic)		STABILISERS (amphoteric)		GLASS FORMERS (acid)	
Lead	PbO	Alumina	$\text{Al}_2\text{O}_3$	Silica	$\text{SiO}_2$
Sodium	$\text{Na}_2\text{O}_3$	Boron	$\text{B}_2\text{O}_3$	Boron	$\text{B}_2\text{O}_3$
Potassium	$\text{K}_2\text{O}$				
Calcium	<u>CaO</u>				
Magnesium	<u>MgO</u>				
Barium	<u>BaO</u>				
Lithium	$\text{Li}_2\text{O}$				
Zinc	<u>ZnO</u>				
Boron	$\text{B}_2\text{O}_3$				

The underlined oxides are generally used for high temperatures.

Boron oxide, in the relation to the context, can behave as a flux, stabilizer and glass former.

The main oxides to be used are therefore around twelve divided into three different groups.

As a rough idea, the proportions of these groups in relation to the fusion temperature is as follows:

	Fluxes	Alumina	Silica
Low temperature (950-1000 °C)	1	0,5	1,5-2
High temperature (1250 – 1300 °C)	1	0,5	3-5

## THE FLUXES

### **Lead oxide (PbO)**

It has been one of the first fluxes used since the ancient world. Extremely active in the range of 750-1150 °C, it is the principle (if not the only flux) in most soft glazes that do not contain boron oxide. It gives the glaze a rich, warm and brilliant tone. It has a favorable **coefficient of expansion** for its use in ceramic glazes. Above 1180 °C it volatilizes creating a toxic gas that will ruin the kiln. Due to the toxicity (on which some wrong information have been given creating unreasonable reactions) its use in the last decades has considerably diminished. It is generally used in the form of **frit** and can be very safe if used with proper amount of silica.

*Coefficient of expansion. This is a very important property of glazes and it gives an idea of their ratio of expansion when heated and cooled. It is used in order to give an indication of the resistance to crazing (too much expansion) or to shivering (not enough expansion) in relation also to the clay used and firing temperature. Ideally, at ambient temperature, the glaze should be slightly compressed.*

*Frit. See page n°5*

### **Sodium oxide (Na<sub>2</sub>O)**

It melts at 400 °C. It is a very strong flux that is being used for both low and high temperature. The high coefficient of expansion reduces the resistance to crazing. Besides, the glaze is soft and does not resist time. All the simple compounds of sodium are **soluble**, therefore it has to be used under the form of frit, or “natural” frit (feldspathic minerals). Brightens the colours. The turquoise of Islamic ceramics is based on sodium and copper.

*Solutions and suspensions. A solution can be defined as a molecular mix of two or more substances (sugar that is soluble, dissolves in water). Water and sand instead, if agitated together form a suspension in which the particles float, unaltered. Gradually they will sink in the bottom. Before firing, the glaze is a watery suspension of amorphous particles (without order). As a rule, it is advisable not to introduce soluble components in glazes. In the glazing, these would enter with the water inside the clay provoking (during the firing) alterations that could be dangerous.*

### **Potash oxide (K<sub>2</sub>O)**

It's very similar to sodium oxide. It can be preferred to sodium because it produces a better brilliance, especially, in the presence of lead. It also offers a slightly better fusion range and reacts to colouring oxides in a different way. Introduced in glazes under the form of a feldspathic mineral.

### **Calcium oxide (CaO)**

It fuses at 2200 °C. With other materials it produces **eutectics** which makes it one of the main fluxes for medium-high temperatures. It makes the glaze less viscous and has a low coefficient of expansion that minimizes crazing. It gives hardness and durability. It can be used in high percentages. But if too much, it will develop matt surfaces. Normally, it is introduced as calcium carbonate or dolomite, if the formula includes magnesium oxide. Other materials are: calcium carbonate, calcium fluoride, colemanite or a calcium-boric frit.

*Eutectic. A mix of exact percentages of two or more components, which has a melting point that is lower than any one components.*

**Magnesium oxide (MgO)**

It is generally used at temperature above 1170 °C as secondary flux. It can offer smooth, opaque or matt surfaces. It reduces the coefficient of expansion. It's presence can modify considerably the reaction of the coloring oxides. Introduced in glazes under the form of magnesium carbonate, talc or dolomite.

**Barium oxide (BaO)**

Similar in some ways to calcium oxide. It is used only on temperature above 1130 °C. Like magnesium oxide it can produce smooth and matt surfaces. It modifies the aspect of colorant oxides and sometimes very strongly (copper). If used in excess it will give dry and rough surfaces. Introduced in glazes under the form of carbonate which is very poisonous.

**Lithium oxide (Li<sub>2</sub>O)**

It is very expensive and therefore very little used. It is a very strong flux at all temperature, like sodium and potassium, but it does not produce crazing. Introduced under the form of carbonate or as a mineral in the form of petalite, lapidolate o spodumene.

**Zinc oxide (ZnO)**

Used above 1050 °C as a secondary flux. It is particularly useful for it's characteristic in helping crystallization when the glaze cools, producing (especially if used with titanium) matt surfaces. It has a strong effect on colouring oxides, decreases iron colours and gives more brilliance to copper greens. Introduced as an oxide.

**Boron oxide (B<sub>2</sub>O<sub>3</sub>)**

It is a flux, stabilizer and glass former. With a low melting point it is used for low temperatures avoiding the use of high percentage of oxides like potassium, sodium, lithium, etc. that would give rougher surfaces and low resistance to crazing. Normally used on quantities up to 15%. It's great advantage in relation to lead is that it is not considered toxic. But it doesn't give the same richness and warmth as lead.

Normally it is introduced in the glaze as a frit since it's minerals are soluble with the exception of colemanite that unfortunately varies too easily in composition.

**STABILISER****Alumina (Al<sub>2</sub>O<sub>3</sub>)**

Simple mixes of fluxes and silica produce glazes, but these are not satisfactory because they tend to melt suddenly and produces glazes so fluid that they would run down the walls of the pieces and that would also easily crystallize in the cooling. The addition of alumina will make the glaze more stable making it more viscous. It also helps in having a gradual passage from solid to vitreous glaze. Alumina melts at 2050 °C, therefore it makes the glaze more refractory but at the same time it will confer great durability and resistance. The presence and the amount of alumina is one of the major differentiation between glaze and glass. Invariably, glazes will contain a much higher percentage. For low temperatures, alumina is generally introduced in glazes under the form of feldspar. For medium and high temperatures, it is normally introduced under the form of caolin, ball clay (raw firing), hydrated or calcined alumina.

## GLASS FORMER

### Silica (SiO<sub>2</sub>)

In ceramics it is the most fundamental oxide both in clays and glazes. Ceramic glazes consists mainly of silica while the other ingredients are only used to modify in some ways the glaze, to lower the melting temperature, to produce matt or opaque effects etc.

Generally increasing the silica in a glaze we'll obtain the following results:

- i. The melting temperature will rise.
- ii. There will be an increase of the viscosity (fluidity diminishes)
- iii. The glaze resistance to chemical agent will increase.
- iv. Glaze hardness and strength will improve.
- v. It will reduce the coefficient of expansion increasing therefore resistance to crazing.

Quartz and flint are two forms of silica which differ only in geological origin. We can use and exchange one for another. Silica used in ceramics comes from the calcinations and grinding of quartz and flint.

## FRITS

For as far as possible in ceramic glazes, materials are used as found in nature. But sometimes it's difficult to find insoluble or nontoxic forms of the desired oxide; for instance boron oxide, or lead oxide.

The frit offers the possibility to get around these inconveniences. It is produced by the fusion of the wanted oxide (or oxides) with silica and sometimes with alumina.

At a certain temperature, with that specific mix, the chemical structure of the molecule could be non soluble and/or non toxic. When the melt is very fluid it is poured directly into water thus fixing that chemical structure at ambient temperature. The solidification and the thermal shock will break the mass in many fragments which will later ground into dust. But even nature itself has "fritted" some materials like feldspars, colemanite etc.

Lead, boron and alkaline (sodium, potassium and lithium) frits are much used at low temperature. Almost all glazes, prepared industrially, contains frits. At high temperature frits are little used both because they are not necessary and for their cost.

## THE MATERIALS

The oxides used to form a glaze are rarely simple oxides. In most cases these oxides are introduced in the glaze under the form of minerals more or less complex.

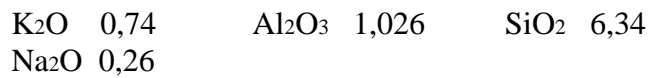
The **feldspar** is one of the most important materials. Used in almost all glazes at high temperature is often the fundamental material that provides the principle flux. Feldspars are composed of alkali (sodium, potassium or lithium single or in combinations) with alumina and silica.

The formulae of feldspar most commonly used are:

Potassium feldspar                       $K_2O \cdot Al_2O_3 \cdot 6SiO_2$

Soda feldspar                                 $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$

From the formula and the proportion of flux, alumina and silica we can see how this material virtually represents a glaze by itself. Most feldspars are mixes that are denominated in relation of their major component. So a conventional formula for a potash feldspar looks like:



Feldspars have a relatively low fusion point and they introduce alkali under insoluble forms (natural frits). Glazes with a high percentage of feldspar have the tendency of crazing (sodium in particular). Often they have a milky semi opaque quality that make them very attractive. Sodium feldspar will give more brilliant and lively colours. When fused, they have a high viscosity that, for example, prevent porcelain from distortion and glazes from running down vertical surfaces.

**Nepheline syenite** ( $\text{K}_2\text{O}.3\text{Na}_2\text{O}.4\text{Al}_2\text{O}_3.9\text{SiO}_2$ ) is a feldspar which contains a high percentage of sodium and potassium in relation to silica. The lower melting point makes it a popular material in the composition of glazes, especially for medium range temperatures. Also very useful in the clay body where a lower maturing temperature is required.

**Clay** is conventionally expressed as follows:  $\text{Al}_2\text{O}_3.2\text{SiO}_2.2\text{H}_2\text{O}$ .

It's used in glazes as a source of alumina and since all glazes require silica, it's content of this oxides goes to the constitution of the glass forming part. Kaolin doesn't contain any iron, so colour of glaze is not effected. Ball clays (secondary clays suitable also for raw firing), stoneware clays and those for low temperature can be used, but inevitably they will affect the colour of the clay.

**Calcium carbonate** ( $\text{CaCO}_3$ ). Used to introduce calcium oxide without any other component. Insoluble.

**Magnesium carbonate** ( $\text{MgCO}_3$ ). For the introduction of magnesium oxide.

**Dolomite** ( $\text{CaCO}_3.\text{MgCO}_3$ ). It's a material which contains both calcium and magnesium carbonates in equal parts and is therefore used if both these bases are required.

**Barium carbonate** ( $\text{BaCO}_3$ ). The normal source for barium oxide. It is poisonous and must be used with great care.

**Talc** ( $3\text{MgO}.4\text{SiO}_2.\text{H}_2\text{O}$ ). It can be used when both magnesium and silica are required. Often it contains calcium impurities which contribute to the fluxing action.

**Colemanite** ( $2\text{CaO}.3\text{B}_2\text{O}_3.5\text{H}_2\text{O}$ ). A natural material which contains calcium and boron oxide in relatively insoluble form. The presence of boron makes it also a stabilizer. Extremely strong flux for all glazes. Less expensive than frits it isn't convenient for the slight solubility. It can develop opalescence and, in the presence of rutile, very attractive dotted surface. It could not stick to the surface and crawl. Used often on American recipes.

**Lead oxide.** Toxic, it can be found under three forms: litharge  $\text{PbO}$ , red lead  $\text{Pb}_3\text{O}_4$  and lead carbonate  $2\text{PbCO}_3.\text{Pb}(\text{OH})_2$ . These are extremely strong oxides (nevertheless due to their toxic nature) they are banned from use as found in nature. As a consequence they are introduced in glazes as a lead frit.

**Zinc oxide.** It is the only source to introduce zinc in a glaze. Zinc oxide shrinks considerably in the firing. It is preferable to use it calcined thus avoiding the possibility of crazing or crawling. In small quantities it is used for low and high temperatures as a secondary flux. Its action on coloring oxide is strong. In medium to high quantities it tends to opacify and make surfaces matt.

**Lithium carbonate** ( $\text{Li}_2\text{CO}_3$ ). Used as source of lithium, it is a strong flux. It encourage brilliant surfaces and helps to correct crazing. It is very expensive, but even in small quantities can be very influential on the glaze characteristics.

**Wood ash.** Ashes from any plant contain a combination of materials that can melt at high temperature producing a glaze of delicate colour due to certain oxides. Ashes vary in composition in relation to the plant or tree and the ground where they have grown. In any case the composition of an ash should fall within the following limits:

Alumina	10-15 %	
Silica	30-70 %	
Potassium oxide	up to 15%	with traces of iron, phosphorous,
Calcium oxide	up to 30%	magnesium and other elements

Most ashes melt in the region of cone 8-10. Alone they produce a rather thin and unattractive glaze. Therefore ash is mixed with feldspar, clay and other minerals, with the percentage of ash from 10 to 60 % in weight. Ashes before use have to be washed and dried.

**Frits.** There are essentially three types: lead, alkaline and boric frits.

Lead frits. The most common are the following:

Lead bisilicate	$\text{PbO}.2\text{SiO}_2$
Lead sesquisilicate	$\text{PbO}.1,5\text{SiO}_2$
Lead monosilicate	$\text{PbO}.\text{SiO}_2$

Alkaline frits. Sodium oxide is always predominant over potassium and lithium. The problem of these frits is that they often craze. We can avoid the problem by introducing some frits with a lower coefficient of expansion thus renouncing partly to the brightness of colours. *See crazing.*

Boric or boron frits. They produce a very smooth surface, without crazing or dotting. The melting interval is very good although the colour response is generally inferior to alkaline frits, especially the sodium ones.

Opacity. *It happens when the light cannot pass through a glass but is reflected by the surface.*

*Opacity is caused by reflecting matter in the glaze or by a matt surface. All glazes can became transparent, or almost, if taken at a sufficiently high temperature.*

*The principle opacifying agents operate by staying in suspension, non dissolved white particles distributed in the glaze. These agents are tin, zirconium, titanium and zinc oxide. The average addition to a soft glaze can be of 10-12 % and rather less for a high temperature glaze. Chrome is a colouring and opacifying oxide.*

*Refractory oxides like alumina can be increased in a glaze in order to give opacity with a matt surface. Small bubbles that couldn't free themselves from the glaze (generally caused by a too thick application) appear as white milky dots. A very slow cooling of the kiln will facilitate the formation of crystals thus producing some opacity (low silica content).*

**Tin oxide** ( $\text{SnO}_2$ ). An opacifier for all temperatures with unique qualities that zirconium or other alternative opacifiers don't possess. It is used on soft glazes for the decoration and colouring of majolica. It tends to crawl. In small doses it seems to help in the development of copper reds. Its use is limited due to the cost.

**Zirconium oxide** ( $\text{ZrO}_2$ ). It can replace partly or totally tin oxide producing hard and brilliant surfaces but not at the same quality of tin oxide. It helps resistance to crazing and it can be used for both low and high temperatures. Much cheaper than tin oxide it is introduced in the form of oxide or silicate.

### Firing basics.

*The elements that condition the results of a glaze are:*

1. *the temperature*
2. *the firing atmosphere (oxidation or reduction)*
3. *the type of clay*
4. *the possible presence of colouring oxides*

*Firing can be done basically in two different atmospheres:*

- a. Neutral or oxidation. *Electric kilns fire only in neutral atmosphere. Oxidation firing happens with combustibles (gas, wood, charcoal, etc.) and sufficient air for a total and clean combustion.*
- b. Reduction. *It happens when, with the regulation of the kiln entrances and exits, the fuel is deprived of part of the air. The carbon liberated from the fuel, not having enough oxygen from the outside, will look for it in the clay and glazes inside the kiln. In these conditions the clay will become more grey and "warmer", due to the reduction of ferric oxide ( $\text{Fe}_2\text{O}_3$ ) into ferrous oxide ( $\text{FeO}$ ). In the glazes the oxides sensitive to reduction are copper oxide that can become red instead of green and ferric oxide that instead of producing browns can give greys, greens and blacks.*

## COLOURING OXIDES

**Iron oxide** ( $\text{Fe}_2\text{O}_3$  ferric, red). The range offered by iron oxide is quite wide. It goes from honey or yellow-brown to brown, red brown and black. In reduction atmosphere it can give greys, grey-blues, greens and black. In lead glazes, iron has the tendency to give warmer colours than in the alkaline glazes where it will give cooler tints.

Iron oxide is also a flux and it lowers, even considerably, the melting temperature of glazes for medium and high temperature. This is especially true in reduction where it becomes ferrous ( $\text{FeO}$ , black).

In the presence of zinc iron oxide will give a dimmed aspect while titanium oxide ( $\text{TiO}_2$ ) appear to increase considerably the colouring strength. Another oxide that inhibits color because of its bleaching action is calcium oxide ( $\text{CaO}$ ) although it is useful for the production of celadons.

Due to the wide range of colours that it can produce and for its stability even at low temperatures, iron oxide is perhaps the most used pigment.

**Copper oxide** ( $\text{CuO}$ ). A medium strength oxide. It is used to produce apple greens in glazes fired in oxidation or neutral atmosphere. Under reduction it's possible to obtain very beautiful reds known as copper reds. In high alkaline glazes, for example a glaze with barium carbonate, the addition of 3-5 % will offer attractive blue turquoises. Zinc and boron will obstruct this effect.

Above around 1050 °C copper oxide will start to volatilize and will increase this phenomenon as the temperature rises to the point of affecting the colour of the other glazes.

Due to its fluxing power, copper (as iron and cobalt) if introduced to a glaze will reduce its melting temperature.

**Cobalt oxide** ( $\text{Co}_3\text{O}_4$ ). The base of all blues. Most potent and rarely used on quantities above 1%. In alkaline glazes produces extremely brilliant blues. When a glaze contains magnesium oxide we will obtain blue-purples. Cobalt oxide is a strong flux not subject to reduction.

At high temperatures combinations of magnesium and cobalt oxides can develop dotted effects in reds, pinks and purple but they are difficult to control.

**Chrome oxide** ( $\text{Cr}_2\text{O}_3$ ). Generally chrome develops a green opaque colour in some ways darker than the transparent green from copper. On glazes with a high content of lead and low in alumina, it is possible to obtain a brilliant red-orange with the addition of 1-2 % of chrome oxide.

In combination with the zinc it gives a brown colour while with tin oxide it can develop the famous chrome-tin reds.

At high temperature it becomes volatile and can “flash” the objects in the surrounding if they contain tin in the glaze. It is not a flux.

**Manganese oxide** ( $\text{MnO}_2$ ). It's one of the weaker colouring oxides. In lead glazes it tends to develop browns while in the alkaline it encourages violets. It's an energetic flux at low temperature. With other oxides it is used to produce blacks. At high temperatures mixes of only manganese and copper can produce opaque and golden surfaces.

**Nickel oxide** ( $\text{NiO}$ ). It produces rather weak brown-kaki and brown-greens. Often used as an agent to modify the tonality of colours obtained with other pigments, as an example the combination nickel-chrome to produce pleasant, soft gray-greens.

**Vanadium oxide** ( $\text{V}_2\text{O}_5$ ). It is very expensive. In combination with tin it is used commercially to produce yellows. Vanadium in glazes tends to create spots of diverse tonality, characteristic used in order to develop special effects.

**Titanium oxide** ( $\text{TiO}_2$ ). It is very expensive and like vanadium moves the glazes giving the glazes diverse tonalities. Sometimes used as an opacifier.

**Uranium oxide**

**Cadmium oxide**

**Selenium oxide** Are three important oxides but their use is limited due to their toxicity. The ready-made glazes that use them must show the content of these two compounds and cannot be used for the inside of pottery where food is served.

## COMBINATIONS OF OXIDES

Some of the most attractive colour tonalities derive from the combination of two or more oxides. Let us for example examine the sophisticated colours that can be obtained mixing cobalt with iron, or manganese, or vanadium, etc with the more crude colours that we can produce when using cobalt by itself.

Generally the colour that two different oxides will deliver is somehow foreseeable. There are some exceptions like the pinks from chrome-tin, the green-grey from nickel-chrome, the greys from nickel-manganese, the grey-blues from nickel-cobalt and grey-browns from nickel-vanadium.

Combinations can in any case be born as a consequence of interaction between glazes like when a coloured glaze is applied over another containing different pigments, or over a slip.

The combination can be very diverse and consequently this technique often brings non foreseeable results but often very attractive especially at high temperatures.

Slips containing iron oxide (up to (20 %)) are often used with good results. When these effects are required, oxides are preferable to pigments.

## PIGMENTS

Some colours are possible to obtain only when the materials that that constitute them are calcined or prepared as frit. Examples are the vivid reds obtained with combinations of fritted cadmium and selenium oxides and pinks at high temperature obtained from iron and zirconium oxides.

Pigments found in commerce are mixes of pigments (normally oxides) with other materials. The whole is then calcined in order to combine them chemically and in the end finally ground.

The use of coloured pigments offer to the ceramic world a wider and more stable (within certain temperatures) palette than it would be possible using the oxides by themselves.

In any case, even if some can be excellent even at high temperature, others can contain ingredients that limit their use only to low temperature.

The colour produced by a pigment can naturally be modified with others oxides or minerals.

*To calcine. To disintegrate with heat: the strong heating of a material provoke a physical and chemical alteration. This is also the way to eliminate composition water.*

## UNDER GLAZE PIGMENTS

These products, which sometimes can be used in alternative to pigments, consist normally not only of colouring oxides but also of a flux in order to stick the pigment to the surface of the clay, of accessory materials to modify the colour and of refractory materials to control the fusibility.

## FAULTS AND REMEDIES IN GLAZES

When the glaze and the clay are heated they will expand. In cooling they will shrink. The ideal situation is when clay shrinks a bit more than the glaze; in this way the glaze remains in a slight compression.

**Crazing.** It happens when the glaze shrinks more than the clay and manifest itself as small fracture lines. On a vitrified clay (stoneware or porcelain) crazing doesn't constitute a problem but it does in low temperature firings because the liquids can infiltrate the objects. Generally crazing is finer in transparent and brilliant glazes than on matt glazes. To cure crazing there are a series of solutions:

- i. Reduce the thickness of the glaze.
- ii. Lower the fluxes in relation to the silica.
- iii. Where possible use boron oxide.
- iv. For low temperatures increase the biscuit temperature.
- v. Increase silica in the body.

In some circumstances (raku, high temperature) crazing can be seen as a possible way for decoration and therefore it is wanted. In these case it is called "crackle".

**Shivering.** In this case the glaze shrinks less than the clay and it is too much compressed with the result that it detach itself from the piece, especially on borders. To cure the following can be tried:

- i. Increase the flux
- ii. Use a stronger flux.
- iii. Diminish the silica (5-10 %)

**Crawling.** This occurs when the glaze surface breaks in the firing and forms beads leaving part of the clay unglazed. Possible cures are:

- i. Change or modify the plastic clays.
- ii. Keep the biscuit clean from dust or grease.
- iii. Using a finer layer of glaze. In the event that you want a double glazing do not let the first layer dry too much.
- iv. Reduce the presence of opacifiers.
- v. If using colemanite, substitute it with calcium borate, such as, gerstley borate.

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