# REDUCTION FIRING: THE EFFECT OF COLOUR ON CLAY BODIES AND GLAZES FOR STUDIO POTTERY PRACTICE

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**ABSTRACT**
*This paper deals with reduction firing (the effect on clay and glazes for studio pottery practice) in a sequential order. It tries to explain the concept of reduction and it effect on clay bodies and glazes, describe the procedures involve in the introduction and managing of reduction firing. In this paper, effort was made to state the types of kilns and materials for reduction firing, also the study discussed the purpose of reduction firing as regard colour range. Suggestions are made as guide for effective manipulation of reduction kiln and the safety precaution needed.*

**Introduction**
Reduction firing and Reduction glazes according to Ogunshina (1992:132) is a glaze firing under the influence of carbon dioxide, this is done by smoking the kiln, with candle wax, gas or any combustible materials that can generate $Co_2$ and affect the colours of the clay and glaze materials on the ware.

Hamer (1975) defines Reduction firing and Reduction glazes as:

> *The action of taking oxygen away from metallic oxides of which the potter uses reduction to coax different colors from the same metallic oxide in his clay or glaze, such as black pot from a red clay or metallic luster from a white tin glaze.*

He sees reduction firing and glazes as an achievement which is an intended plans a potter aims at by controlling the atmosphere surrounding his pots during firing and or cooling. By altering the atmosphere, he alters the metallic oxides he is using for his colouring. To achieve reduction, carbon is introduced into the kiln atmosphere. This carbon if hot enough will combine with the oxygen in the atmosphere to form carbon dioxide, that is, when almost all the oxygen present in the kiln atmosphere is used up, then carbon monoxide is achieved or formed.

In a broad outline, Robert (1976) reiterated thus:

> Reduction firing and the effect on clay bodies and glazes is achievable in all types of kilns, for instance, an electric and gas muffles kiln are reduced by introduction of gas, wood or any burnable materials that can generate smoke at the correct time and temperature to the kiln atmosphere.

However, it is pertinent to say that solid, liquid and gaseous fuel kilns are thus partially converted to carbon dioxide by restriction of the flow of secondary air into the combustion chamber.

The following sub topics shall be considered.

- Basic theory of reduction firing

- Effect of reduction on clay bodies
- Effect of reduction on glazes
- Colour range caused by the reaction of reduction on glazes
- Colour from some oxides (iron) in reduction glazes
- Tentative guides for the manipulation of kiln during reduction firing

**Basic Theory of Reduction Firing**

Reduction firing is common among studio practice potters and may not be practicable for industrial production since it is difficult to control the exact colours. The basic theory of reduction firing is a simple one. In an ordinary studio practice setting, different types of fuel, whether gas, oil or wood, when burned, the carbon contained in the fuel combine with oxygen present in the kiln atmosphere chamber to produce the chemical reaction of burning. And the resultant effect of this reaction is heat and carbon dioxide. The chemical equation for combustion according to (Rhodes 1996) is C + 2O – $Co_2$ (Heat)

Taylor and Bull (1986) postulated that reduction takes place when there is insufficient presence of oxygen during combustion; some free carbon in form of black smoke is liberated as well as carbon monoxide, CO.

To ensure an appreciable reduction firing that will have remarkable effects on bodies and glazes, it advisable to monitor the appropriate time of temperature in the kiln when carbon monoxide is chemically active and will seize oxygen from any available source including some oxides in ceramics materials (bodies and glazes). When these ceramics materials are deprived of some oxygen, they are said to be reduced; this may affect its colour on bodies and glazes.

It is much easier to achieve reduction firing in a kiln which burns fuel. This is accomplished when the air supply into the kiln atmosphere is cut down and the draft in the kiln is reduced by closing the primary air pots and damper. In carrying out this, it causes the unburned fuel to remain in the kiln, and thereby producing smoke and dense atmosphere inside the kiln. The degree of reduction can be controlled by varying the amount of air which is allowed to mix with the fuel in the burner.

**Effect of Reduction on Clay Bodies (Studio Experience)**

Reduction firing does not affect all ceramics clay bodies. Most of the effects characteristic of reduced wares are the result of the changes brought about in a few materials. Clay, alumina and silica as materials constituents of ceramic materials are not appreciably affected by reduction firing. These Oxides are exceptionally stable.

However, the appearance of a clay body can be drastically affected by the atmosphere of the kiln. The major effect in the appearance of clay bodies caused by reduction is the gray or black colour which is as a result of carbon deposit in the pores of the ware during firing and remaining there in the finished product. The basic reduction effect on clay bodies is the change brought about in the iron contained in the clay. The iron oxide is present to some extent in almost all clays turns from brown or tan to gray or black during reduction firing. Again, iron oxide exists in several different combinations and each proportion of iron oxide has characteristic colours as follows:

$Fe_2O_3$ – ferric iron – red
$Fe_3O_4$ – ferro ferric – yellow
FeO – ferrous iron – black    Source (Rhodes. 1996)

(Rhodes. 1996) noted that one of the beauties of some reduction firing effects on clay body is the exceptionally warm gray colour. To obtain the richest form of rust and brown colour on clay body, respectively, the ware must be fired in quite a reducing atmosphere, with the introduction of reductions in the early stages of firing before the clay verification point is met. For instance, in porcelain or white wares, which contain only small amounts of iron oxide, the only vivid effect of reduction is to change the character of the white to a blue-white which is different from the warm whites of oxidation atmospheres.

Also, when reduced stone ware is covered by clear glaze, the body under the glaze shows as cool gray. In white bodies which may be completely iron-free, the blue-gray cast which results from the reduction of small amount of iron has an effect of making the clay white than it was.

**Effect on Reduction on Glazes**

Rhodes (1996) submitted that the reaction of colour glazes to reduction involves several 'transmutation' effects that is, colours result which are the opposite of or are different from those obtained in an oxidizing fire.

In view of the above, leadless glaze, or glass, is not much affected by reducing atmosphere. The oxides in glazes (alumina, Silica, Calcium, barium and potassium) are stable oxides; they do not yield to reduction easily. To carry out reduction on alumina, silica, calcium, barium, sodium and potassium, one requires a very strong reduction beyond the capacity of pottery kilns. Their effective use in pottery is in fully oxidized state (Hamer 1975). Reduced glazes do seem to have a surface quality different from oxidized glazes particularly in the case of mat glazes. The Glazes seem to be smoother, more "buttery" more "lustrous".

**The Colour Range Caused by the Reaction of Reduction on Glazes**

The colours range which is not possible in reduction glazes are more than that of oxidation glazes. Although there are still varieties of possible colours in reduction glazes, among colours which are not possible are green, turquoise and yellow, grape-purples, the reason for the absence of these beautiful colours is that the composite materials tend to react negatively and there by producing colour range from gray, black and brown. (Rhodes. 1996)

He arrived at the above claim by the combination of Chrome and Cobalt though the hues are not quite the same; cobalt however can be made to give a blue-violet. It was on the above submission that the researcher experimented and thus the result on plate 1.

**Color from Oxides (Iron) in Reduction Glazes**

The colours from iron oxide reduction during firing are cool colours of gray, gray-green, blue-green, or olive green. Iron oxide easily yield to reduction firing, and the effect on glazes is it changes from ferric iron ($Fe_2O_3$) to ferrous Iron (FeO) which is characteristically black, gray, or green. The colour produce with the addition of small amount of iron oxide to a glaze fired in reduction is called Celadon. It is a subtle, slightly grayed, cool green in appearance. (Rhodes 1996)

Celadons are known for their beautiful colors when used over a light-body or engobe. And when used over darker stone ware, celadon glaze will produce dark green. Therefore, it is very necessary to know how to develop or compound a celadon glaze for reduction firing. Hamer (1975) gave an insight that a base glaze for celadon colour should be high in feldspar and consequently fairly high in sodium or potassium.

Fourner (1976) says that:

> At least 4 equivalents of calcium should be present and as much as 7 parts of calcium may be used. He went further to say that very simple celadon glazes can be made which contain only feldspar, whiting and a small amount of clay. It is important to note that some barium oxides in the above composition favours a cool green color, if too much barium oxide, magnesia or alumina is used, an opaque glaze will be gray rather than green. But well combination of these simple materials proportionately and tested will give very beautiful glazes if the firing is properly managed

Small amount of iron oxide is required in the entire glaze to produce celadon colour, for example half of 1% gives light green, 1% gives medium tint, 2% gives a dark green. Above 2% will give a very dark green tending toward brown. The process of milling celadon glaze should be through ball milling and it requires a very heavy reduction.

Plate 2 shows that the addition of 2 grams of Cobalt and 1 gram of Iron oxide to a formulated transparent glaze and fired under reduction to about 1200$^oC$ gave a dark blue colour,

**Tentative Guides for the Manipulation of Kiln during Reduction Firing**

Rhodes (1996) noted thus:

There is no outstanding reliable procedures necessary for certain effect in reduction firing. But constant practice needs to be verified and carried out from time to time. There are some questions arising as to why the Chinese, over 1,000 years ago were able to control reduction firing quite well, while we, with all our controls and techniques, have difficulties. The answer is that, in firing kilns to elevated temperatures with wood or other solid fuels, a neutral or slightly reducing atmosphere is normal rather than exceptional.

In wood firing, reduction firing is achieved when the atmospheric conditions in the kiln is near to the ideal temperature for production reduction glaze. If more reduction is required at the end of the firing, the kiln operator needs only a little fuel and close the damper slightly, and if less reduction is required he needs only to use smaller pieces of fuel and see to it that the draft is lively. In fact, if wood is used as fuel, the control and stabilization of the reduction fire is a relatively simple matter. On the other hand, in gas or oil kiln, reduction is accomplished by starving the burners of air and cutting down on the draft through the kiln by partially closing off the damper in the fuel. If the appearance of the inside of the kiln is some how dark and difficult to see through, rather than clear, then reduction is taking place.

Another way to recognize reduction firing is the presence of flame at the damper, which is usually the bottom of the chimney again; another indication of reduction is the appearance of flame at the spy holes. This means that reduction is indicated by the strong back pressure, yellow flame at the spy-holes and heavy flame at the damper.
Electric kiln may yield to reduction firing if well manipulated by potters.

Since many potters prefer the use of electric kilns only, the ideal of achieving reduction in electric kiln is a tempting one. This can be done by introduction of solid fuel of some sort into the kiln during firing. Various fuels have been tried including charcoal, sugar cubes, oil, soaked bandages, and twigs among others. (Rhodes 1996:272)
It is pertinent to note here that all types of kiln have their peculiars and individual characteristics. It is very difficult to base the schedules of reduction firing on clear cut direction. Much depends on the kiln, the kind of ware being fired, the glazes and the effects which are aimed at.

**Conclusion**

This paper has made concerted effort to showcase the experience of studio practice in reduction firing as submitted by some reviewed authorities and was clear that some complexities were inherent in firing glazes. At a glance we have seen that there are unlimited possibilities associated with the development of reduction firing. It is a skill which can be learned only with constant practice in a particular kiln. Reduction is generally considered to be the result of starving the fuel of oxygen during the firing, creating carbon monoxide and hydro carbon gases. This is a very poisonous gas and kiln rooms should be well ventilated. Kiln furniture could be affected by reduction and it is advisable to check with the manufacturers that which is suitable. This paper also gave some studio pottery experience on reduction firing as guild for studio potters.

**Recommendations**

The following steps are however put forward for studio potters who want to engage in reduction

1. Experience shows that reduction firing should begin at $800^{oc}$ so as to allow the carbonaceous vapour to the open body.
2. Reduction firing should not too fast at the beginning and should be low during the end of the firing, this will help in the surface and colour quality.
3. Monitor the cones in order to ensure that the glaze is fully matured and melted.
4. Make sure that the kiln is well sealed after the introduction of carbon monoxide into the kiln atmosphere and there should be a long soaking period during which the temperature must be

**Plate 1:** Blue-violet vase from reduction firing

**Plate 2:** Dark blue colour vase from reduction firing

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