

Firing Tips

UNDERSTANDING HEAT TRANSFER

How Heat is Transferred

Heat moves through the kiln from hotter to cooler zones by:

1. convection
2. conduction
3. radiation

Convection

Convection is the first step in the heating process in the kiln. Air is heated as it passes across the warming kiln elements. As the hot air rises and cool air falls, air currents are created which circulate hot air to cooler places in kiln. This heat is transferred to the ware, shelves, etc.

The kiln will not be uniform in temperature at this early stage of firing unless the hot air is pushed through the kiln by mechanical means. Low cone firings such as 022 and 021 depend more heavily on convection for heat transfer.

The most common type of convection we are familiar with is wind chill. The cool air passes across the face and pulls heat from our warmer body, which lowers our skin temperature.

Conduction

When heat moves through a solid, it is conducted. An example would be heat moving through the handle of a saucepan. This is a slow way to heat, but the handle will eventually get hot.

In a kiln, conduction moves heat from the inside to the outside of the kiln and from the outside to the inside of the ware. Conduction is the main way we get uniform heating in the kiln. This is a slow process and if we fire too fast, the inside of our ware will receive too little heat and not fire properly.

Radiation

At the beginning of the firing, the elements are the hottest part of the kiln. The heat from the elements radiates out - like the sun warming us on a cool day. Eventually the firebrick and the ware will also get hot and will radiate heat as well.

As the temperature increases, more and more of the heat is transferred by radiation from the heating elements. For uniform heating, is important that all surfaces of the ware be exposed to heating elements, even partially.


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4. Time and temperature profile during the burn out period

Both time and temperature are important for proper burn out of the carbon. Some carbons require much higher temperatures than others. Oxidation should be completed below red heat (1400°F).

Carbon burns out from the surface first. As more oxygen penetrates the body, then more carbon is reacted to form the CO or CO₂ gas and the burn out process continues. If there is sufficient time, temperature and oxygen, then complete burn out occurs. If these conditions do not exist, the resulting incomplete burn out is referred to as black coring (where the center of the piece has a black or gray cast).

Incomplete Burn Out

Incomplete burn out can result in several firing problems including:

1. Bloating of the ware

If the temperature is hot enough, the outside of the piece will seal up before all the gases can escape. As the body becomes plastic due to glass forming, gases trapped inside the body expand with heat and cause bloating and sometimes cracking of the ware.

2. Glaze defects, such as pinholes

The escaping gases will push through the glaze surface and cause bubbles which pop. If these do not heal, then pinholes will result.

3. Appearance of fired bisque

Where carbon burn out is incomplete, the piece will have a grayish cast (white bodies) or may have a greenish cast (red bodies). The body will also be more porous and weak.

Preventing Incomplete Burnout

1. Slow down the firing.
2. Be sure the kiln is vented adequately so there is sufficient oxygen.
3. Load the kiln with burn out requirements in mind.

Leave plenty of space between ware and shelves. Do not stack ware. Use tile and plate stackers and invert pieces on top of one another to help conserve space and insure proper burnout.

Want to learn more?

Read more about carbon related glaze and body defects in the Orton Firing Line and Technical Tips publications. Each issue is packed full of articles to help you learn more about firing. Members of the Orton Firing Institute receive these publications at no charge. Single copies are available to non-members at a per issue rate. Orton's 80 minute video, *Key Principles of Successful Firing*, is also an excellent resource on firing.

For information on Orton products, see your Orton dealer or distributor. For information on the Firing Institute or publications, contact

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