Index

1. Emergency phone numbers.
   a. What is propane
   b. What to do if you smell propane.
2. General rules for the kiln room
   a. Personal
   b. Operation of the kilns
3. Kiln firing hazards and precautions - Chicago artist resource
4. Pyrometric cones
   a. how to read cones
   b. recommended cone packs
   c. temperature equivalence chart centigrade - resource material from Orton
   d. temperature equivalence chart Fahrenheit - resource material from Orton
5. Overview - Oxidation, Reduction and Partial reduction
   a. Oxidation /Reduction - tech notes from RISD
6. Firing Charts
   a. Bisque Firing
   b. Gas Kiln
7. Overview - Gas kilns
   a. Updraft, down draft, cross draft
   b. Burners systems – venturi, forced-air, pipe burners
   c. Kilns: Theory and practice
   d. Kiln log
8. Stacking – general guidelines
   a. Bisque
   b. Glaze
9. Firing procedures
10. Recipes
EMERGENCY
AND OTHER IMPORTANT PHONE NUMBERS

For all emergencies including injury, ambulance, fire and police  DIAL 8000
Other important numbers:  ASU police ..............2150
                           Infirmary............... 3100
                           Hospital.............262-4100

What is Propane?
Propane is a hydrocarbon (C3H8) and is sometimes referred to as liquefied petroleum gas, LP-gas or LPG. Propane is produced from both natural gas processing and crude oil refining, in roughly equal amounts. It is nontoxic, colorless and virtually odorless. As with natural gas, a strong identifying odor is added so the gas can be readily detected. (See propane education and research council for more safety information.)

What steps should you take if you smell propane?
1. Learn what propane smells like. Propane has a distinctive odor. To help recognize this your instructor will have scratch-and-sniff pamphlets.

2. No flames or sparks! Immediately put out all smoking materials and other open flames. Do not operate lights, appliances, telephones, or cell phones. Flames or sparks from these sources can trigger an explosion or a fire.

3. Open exits and doors windows

4. Leave the area immediately! Get everyone out of the area where you suspect gas is leaking. If the smell continues, evacuate building.

5. Shut off the gas. Turn off the main gas supply valve on your propane tank, if it is safe to do so. To close the valve, turn it to the right (clockwise). The key for the fenced in tanks are located key made and put it in a red box on the wall to the right of the back door of studio.

6. Report the leak. From a nearby building away from the gas leak. Call Sonny /facilities manager and then ASU police (x2150). Have an officer dispatched to determine if they need to call the fire department.

7. When in doubt and gas fumes are excessive pull the fire alarm level as you exit the building.

8. Do not return to the building or area until sonny or fire department has determined it is safe to do so. Stinson 1/08
GENERAL RULES
FOR THE KILN ROOM

Equipment associated with kilns and firings predominately involves safety from extreme heat. No student will be allowed this level of involvement without proper orientation from the Faculty.

PERSONAL
1. Wear required PPE (personal Protection Equipment) – safety glasses/goggles. Ear protection, dust mask/respirator, face shield, gloves as required.
2. Wear closed-toe shoes/boots (no sandals or bare feet).
3. Wear study, full-length pants and no loose clothing (sleeves, ties, etc).
4. Tie long hair back.
5. Never work in the clay studio under the influence of drugs or alcohol.
6. Never operate a kiln if you are ill or over-tired.
7. No smoking in the clay studio. (Breaks may be taken outside).
8. Know the locations of the safety exits and the emergency stop switch for machines.
9. Know the location of the gas main shut off value.
10. Know the location of the controls for the air vents.
11. Know the emergency phone numbers for assistance (see previous page).

OPERATIONS OF KILNS
1. Never use a kiln unless you have been instructed on its use and are clear on the safe and appropriate procedures.
2. Keep the safety equipment in place and in use at all times. Do not remove or override.

Stinson 1/08
3. Appropriate flame retardant and heat resistant gloves and jackets are available for use and recommended for specific types of kiln work.

4. Goggles and other protective eye ware as well as full-face shields are also recommended in specific instances.

5. You are required to be on the premises while the kiln you are in charge of is above red heat.

6. Follow the close out procedures to make sure kiln is completely closed down.

7. Never trust the kiln sitter solely. Check to make sure it is off before leaving the building.

SEE THE OWNER'S MANUAL FOR MORE INFORMATION.

***REPORT BROKEN OR MALFUNCTIONING EQUIPMENT IMMEDIATELY.***

Stinson 1/08
Kiln Firing Hazards And Precautions

Kilns

Electric kilns and fuel-fired kilns are used to heat the pottery to the desired firing temperature. The most common type are the electric kilns. Heating elements heat the kiln as electric current passes through the coils. The temperature rises until the kiln is shut off.

Fuel-fired kilns are heated by burning gas (natural or propane), oil, wood, coke, charcoal or other materials. Propane gas or natural gas is used most often. These kilns can be either located indoors or outdoors. The fuels produce carbon monoxide and other combustion gases. Fuel-fired kilns are usually vented from the top through a chimney.

Firing temperatures can vary from as low as 1,382°F for raku and bisque wares, to as high as 2,372°F for stoneware, and 2,642°F for certain porcelains.

The early stages of bisque firing involves the oxidization of organic clay matter to carbon monoxide and other combustion gases. Sulfur breaks down later producing highly irritating sulfur oxides. Also, nitrates and nitrogen-containing organic matter break down to nitrogen oxides.

Galena, Cornish stone, crude feldspars, low-grade fire clays, fluorspar, gypsum, lepidolite and cryolite can release toxic gases and fumes during glaze firings. Carbonates, chlorides, and fluorides are broken down to releasing carbon dioxide, chlorine, and fluorine gases.

At or above stoneware firing temperature, lead, antimony, cadmium, selenium and precious metals vaporize and the metal fumes can either escape from the kiln, or settle inside the kiln or on ceramic ware in the kiln. Nitrogen oxides and ozone can be generated from oxygen and nitrogen in air.

Hazards
1 Chlorine, fluorine, sulfur dioxide, nitrogen dioxide, and ozone are highly toxic by inhalation. Bisque firings of high-sulfur clay have caused the production of great amounts of choking sulfur dioxide. Other large acute exposures to gases are not common. Inhalation of large amounts of these gases can result in severe acute or chronic lung problems. Long-term inhalation of low levels of these gases can cause chronic bronchitis and emphysema. Fluorine gas can also cause bone and teeth problems.
2 Many metal fumes generated at high temperatures are highly toxic by inhalation. Since lead vaporizes at a relatively low temperature, it is especially hazardous.
3 Carbon monoxide from fuel-fired kilns or the combustion of organic matter in clays is highly toxic by inhalation and can cause oxygen starvation. One symptom of carbon monoxide poisoning is an intense frontal headache, unbelievable by analgesics.

4 Hot kilns produce infrared radiation, which is hazardous to the eyes. There have been reports of cataracts, from years of looking inside the hot kilns.

5 Heat generated by the kiln can cause thermal burns. The Edward Orton Jr. Ceramic Foundation reported that when a kiln was operated at 2370 °F, the surface temperature, was at and above 595 °F, and the temperature one foot away from the peephole was 156 °F.

6 Heat produced by even small electric kilns can cause fires in the presence of combustible materials or flammable liquids.

7 If an electric kiln fails to shut off, the heating elements melt which can cause fires. Gas kilns also generate a lot of heat, and room temperatures often exceed 100 °F.

Precautions

1 Infrared goggles approved by the American National Standards Institute (ANSI) or hand-held welding shields should be worn when looking into the operating kiln. Shade number from 1.7 to 3.0 is recommended, but a darker shade may be required if spots appear in front of one's eyes after looking away from the kiln.

2 Do not use lead compounds at stoneware temperatures since the lead will vaporize.

3 Lumber, paper, solvents, or other combustible and flammable materials should not be stored in kiln areas.

4 Always check that the kiln has shut off.

5 If gas leaks are suspected (e.g. gas odor): shut off gas at the source; shut off power to the kiln room at the circuit breaker; and call the gas company. Test for leaks with nonfat, soapy water or use approved leak-detection solutions.

Taken directly from:
http://www.chicagoartistsresource.org
Why Use Pyrometric Cones

Cones have been used in firing ceramics for more than 100 years. They are useful because they can determine when a firing is complete, or if the kiln was provided enough heat, or if there is a temperature difference in the kiln, or if a problem occurred during the firing.

What is a Cone?

Cones are slender pyramids made from about 100 carefully controlled compositions. They bend in a repeatable manner over a relatively small temperature range (less than 50°F). The final bending position is a measure of the amount of heat absorbed. We refer to one cone number as being hotter or cooler than another. The coolest cone number is 022 and the hottest is 42. The first cones were numbered from 1 to 20. When cooler cones were developed, an 'O' was placed before the number. So cones cooler than Cone 1 increase from 01 to 02, etc. to 022.

Cone Bending

Both temperature and time and sometimes atmosphere affect the final bending position of a cone. Temperature is the predominant variable. We refer to the temperature as an equivalent temperature, since actual firing conditions may vary somewhat from those in which the cones were originally standardized. Using charts available from Orton, an equivalent temperature can be determined by measuring the final bending position of the Cone, if the heating rate is known. Orton Self-Supporting Cones duplicate their bending behavior with a standard deviation of 2.4 angular degrees or less than ± 2°C.

How are Cones Used?

Cones are used as witness cones located on a kiln shelf near the ware or in a kiln shut off device (e.g. Kiln-Sitter®). The cone bends when glass forms and it becomes soft. The composition of the cone and the amount of heat determine when and how much glass if formed. It is important to note that it is the weight of the sensing rod that causes the cone (or bar) in a Kiln-Sitter® to bend. Changes in weight affect the bending of the cone. A witness cone bends because of gravity acting on it. Therefore, mounting height and angle is important. The higher the cone or the more it leans over at the start, the more gravity affects bending, causing early bending. It is for this reason Orton developed Self-supporting witness cones some 20 years ago, where mounting height and angle is fixed. It typically takes 15 to 25 minutes for a cone to bend, depending upon the cone number. The cone bends slowly at first but once it reaches the halfway point, it bends quickly. When the cone tip reaches a point level with the base, it is considered properly fired; however, the difference between a cone touching the shelf and a cone at the 4 o'clock position is small and rarely affects the fired results.

Why use Cones?

Firing ceramics is much like baking, except temperatures are higher. Ceramics can be fired over a range of temperatures. Some products have a wide firing range while others have a narrow range. Firing to a slightly lower temperature requires the ware to be held for a longer time, just as it would be done if one were baking a turkey. This is because it takes time for the ware to absorb all of the heat needed to properly "cook" the piece. We refer to this absorption of heat as 'heatwork'. When the amount of heatwork for two firings is the same, the pieces will look identical, even if one is fired to a higher temperature for a shorter time and another is fired at a lower temperature for a longer time. Since cones measure heatwork, all manufacturers recommend the cone number to which their product should be fired.
Three Cone System

Many products used today, such as porcelain and lead-free glazes, need to be fired within a 2-cone range. The 3-cone system can be used to determine temperature uniformity and to check the performance of the Kiln-Sitter© or electronic controller. The 3-cone system consists of three consecutively numbered cones:

- Firing Cone - cone recommended by manufacturer of glaze, slip, etc.
- Guide Cone - one cone number cooler than firing cone.
- Guard Cone - one cone number hotter than firing cone.

For example: Cones 017, 018, 019 or Cones 5, 6, 7.

Cones Help Evaluate Kilns

Most kilns have temperature differences from top to bottom. The amount of difference depends on the design of the kiln, age of the heating elements, load distribution in the kiln, and the cone number to which the kiln is fired. Usually, kilns have a greater temperature difference at cooler cone numbers. Use cones on the lower, middle and top shelves to determine how much difference exists during firing. It's best to do this for each type of firing you do i.e. decal, bisque/glaze, porcelain/stoneware.

After firing, observe the 3 cones. If, on the bottom shelf, the Guide cone has only bent half way, then ware is fired one and half cones lower. A Guard cone on the top shelf bent halfway indicates that ware is a half cone hotter and a 2-cone difference exists between the top and bottom of the kiln. If you find a difference, make changes in the way the kiln is loaded and fired to reduce this difference. Adding downdraft venting will also even out temperatures. The kiln can also be upgraded to Orton’s UniTemp™ controller, which keeps the kiln uniform in temperature (see Kiln Controllers).

Checking Kiln Sitter© Performance

The Kiln Sitter© shuts off the kiln when a small cone (or bar) placed under the sensing rod receives enough heat for it to fully bend. Bending is caused by the weight of the sensing rod. Because the cone in the Kiln Sitter© is located at the kiln wall (closer to the heating elements), it frequently receives more heat than witness cones, causing the kiln to shut off early. Using the next hotter cone/bar may be necessary. Use the 3-cone system on a shelf near the Kiln Sitter© to determine if a difference exists between the shelf and Kiln Sitter© cones.

Checking Controller Performance

Electronic controllers allow firing to a temperature (and even a cone number). The controller uses a temperature reading measured by one or more thermocouple(s) placed through the refractory wall of the kiln. A Self-supporting witness cone will check whether the controller is firing accurately. Place the cone in a location near the thermocouple. After the firing, determine if the Firing Cone has bent properly. There should be no more than a half cone difference. Orton encourages the use of electronic controllers; however, we strongly recommend the use of at least one witness cone for every firing to assure that the kiln really did fire to the right cone number. As mentioned earlier, bodies, glazes and decoration products are all formulated to be fired to a cone number, bent to the 90° (6 o’clock) position. Controllers depend upon accurate measurement of temperature and proper programming to fire properly. Most controllers use a Type K thermocouple, which may not give an accurate temperature and which will change after being used. It is not unusual for a Type K thermocouple to have an error of more than 25°F when fired to Cone 6 repeatedly. This is more than a full cone. By using witness cones, you can determine whether the firing was to the right cone number.

Self-supporting Witness Cones

Orton recommends Self-supporting witness cones because they are easier to use and less subject to bending variation. Many people use witness cones every firing and the 3-cone system periodically to check for changes in the kiln. Cones are saved to compare different firings. When more than a half cone difference occurs, it usually indicates a problem exists. This gives you an opportunity to fix the problem or change the way the kiln is being fired to avoid future problems. Cones are the best way to inexpensively monitor your kiln.
PYROMETRIC CONES

Pyrometric cones provide the potter with the most accurate method of measuring what is happening inside the kiln. They are small triangular cones (1 1/8 and 2 5/8 inches in height) made of ceramic materials. Each has a number (022-10), which corresponds to a heat rate/temperature combination that produces it to bend. This enables the potter to determine when the firing is complete.

Reading the cones:
When the cone is at 90 degrees the temperature in the kiln is that of the cone number.

Reading your cones

STINSON 1/08
RECOMMENDED CONES PACKS
**This is only a starting point. Below are recommendations from Lisa Stinson. Consult your class instructor for their recommended cone pack configuration.

**Gas kiln firing**

Cones for a Bisque
012, 010, 08, 06

Cones for Glaze:
Cones for 04
010, 08, 06, 04, 02
Cones for 5/6
010, 08, 06, 04, 02
2, 4, 5, 6, 7
Cones for 9/10
010, 08, 06, 04, 02
2, 4, 6, 8, 9, 10

**Electric kiln firing**

Cones for a Bisque
010, 08, 06

Cones for Glaze:
Cone 04
06, 04, 02
Cones 5/6
5, 6, 7
Cones 9/10
8, 9, 10

Stinson 1/08
### Temperature Equivalent Chart for Orton Pyrometric Cones (°C)

<table>
<thead>
<tr>
<th>Cone Numbers 022-14</th>
<th>Cone, Self Supporting Cones</th>
<th>Large Cones</th>
<th>Small Cones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>Iron Free</td>
<td>Regular</td>
</tr>
<tr>
<td><strong>Heating Rate, °C</strong></td>
<td><strong>15</strong></td>
<td><strong>60</strong></td>
<td><strong>150</strong></td>
</tr>
<tr>
<td>022</td>
<td>886</td>
<td>N.A</td>
<td>560</td>
</tr>
<tr>
<td>021</td>
<td>880</td>
<td>N.A</td>
<td>550</td>
</tr>
<tr>
<td>020</td>
<td>870</td>
<td>N.A</td>
<td>540</td>
</tr>
<tr>
<td>019</td>
<td>860</td>
<td>576</td>
<td>500</td>
</tr>
<tr>
<td>018</td>
<td>850</td>
<td>565</td>
<td>500</td>
</tr>
<tr>
<td>017</td>
<td>840</td>
<td>555</td>
<td>500</td>
</tr>
<tr>
<td>016</td>
<td>830</td>
<td>545</td>
<td>500</td>
</tr>
<tr>
<td>015</td>
<td>820</td>
<td>535</td>
<td>500</td>
</tr>
<tr>
<td>014</td>
<td>810</td>
<td>530</td>
<td>500</td>
</tr>
<tr>
<td>013</td>
<td>800</td>
<td>515</td>
<td>475</td>
</tr>
<tr>
<td>012</td>
<td>790</td>
<td>510</td>
<td>475</td>
</tr>
<tr>
<td>011</td>
<td>780</td>
<td>500</td>
<td>470</td>
</tr>
<tr>
<td>010</td>
<td>770</td>
<td>495</td>
<td>465</td>
</tr>
<tr>
<td>009</td>
<td>760</td>
<td>490</td>
<td>465</td>
</tr>
<tr>
<td>008</td>
<td>750</td>
<td>485</td>
<td>460</td>
</tr>
<tr>
<td>007</td>
<td>740</td>
<td>480</td>
<td>455</td>
</tr>
<tr>
<td>006</td>
<td>730</td>
<td>475</td>
<td>450</td>
</tr>
<tr>
<td>005</td>
<td>720</td>
<td>470</td>
<td>445</td>
</tr>
<tr>
<td>004</td>
<td>710</td>
<td>465</td>
<td>440</td>
</tr>
<tr>
<td>003</td>
<td>700</td>
<td>460</td>
<td>435</td>
</tr>
<tr>
<td>002</td>
<td>690</td>
<td>455</td>
<td>430</td>
</tr>
<tr>
<td>001</td>
<td>680</td>
<td>450</td>
<td>425</td>
</tr>
</tbody>
</table>

Pyrometric cones have been used to monitor ceramic firings for more than 100 years. They are useful in determining when a firing is complete, if the kiln provided enough heat, if there was a temperature difference in the kiln or if a problem occurred during the firing.

Cones are made from carefully controlled compositions. They bend in a repeatable manner (over a relatively small temperature range - usually less than 40°F). The final bending position is an indication of how much heat was absorbed.

### Behavior of Pyrometric Cones

Typically, it takes 15 to 25 minutes for a cone to bend once it starts. This depends on the cone number. The cone bends slowly at first but once it reaches the half way point (3 o'clock), it bends quickly. When the cone tip reaches a point level with the base, it is considered properly fired. This is the point for which temperature equivalents are determined. Differences between a cone touching the shelf and a cone at the 4 o'clock position are small, usually 1 or 2 degrees.

Temperatures shown on the charts were determined under controlled firing conditions in electric kilns and an air atmosphere. Temperatures are shown for specific heating rates. These heating rates are for the last 100°C or 180°F of the firing. Different heating rates will change the equivalent temperature. The temperature will higher for faster heating rates and lower for slower heating rates.

Cone bending may also be affected by reducing atmospheres or those conta sulfur oxides. Orton recommends the use of Iron-Free cones for all reduction firings (cone 010-3). If a cone is too fast, the cone surface fuses and binders used to make cones form gas that belo the cone. If cones are to be fired rapidly, they should be calcined (pre-fired) before use. Cones should be calcined to about 850°F (455°C) in a reducing atmosphere.

If a cone is soaked at a temperature its equivalent temperature, it will continue to mature, form glass, and be more temperature stable. The time for the cone to bend depends on several factors and as a general rule 1 to 2 hour soak is sufficient to deter the next higher cone number. A soak of 6 hours will be required to deform higher (hotter) cones.

For more information on pyrometric cones, contact Orton or visit us at www.ortonceramic.com.

---

*These tables provide a guide for the selection of cones. The actual bending temperature depends on firing conditions. Once the appropriate cones are selected, excellent, reproducible results can be expected. Temperatures shown are for specific mounted height above base. For Self Supporting - 1 1/4"; for Large - 2"; for Small - 1/2". For Large Cones mounted at 1 1/4" height, use Self Supporting temperatures.*

---

The Edward Orton Jr. Ceramic Foundation  
PO. Box 2760 • Westerville, OH 43086  
(614) 895-2663 • (614) 895-5610  
info@ortonceramic.com  
www.ortonceramic.com
<table>
<thead>
<tr>
<th>Self Supporting Cones</th>
<th>Large Cones</th>
<th>Small Cones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>Iron Free</td>
</tr>
<tr>
<td>022</td>
<td>108</td>
<td>N.A</td>
</tr>
<tr>
<td>024</td>
<td>111</td>
<td>N.A</td>
</tr>
<tr>
<td>026</td>
<td>115</td>
<td>N.A</td>
</tr>
<tr>
<td>019</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>018</td>
<td>N.A</td>
<td>130</td>
</tr>
<tr>
<td>017</td>
<td>N.A</td>
<td>130</td>
</tr>
<tr>
<td>016</td>
<td>130</td>
<td>142</td>
</tr>
<tr>
<td>015</td>
<td>145</td>
<td>150</td>
</tr>
<tr>
<td>014</td>
<td>145</td>
<td>150</td>
</tr>
<tr>
<td>013</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>012</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>011</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>010</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

Pyrometric cones have been used to monitor ceramic firings for more than 100 years. They are useful in determining when a firing is complete, if the kiln provided enough heat, if there was a temperature difference in the kiln or if a problem occurred during the firing.

Cone numbers increase as the temperature increases. If a cone is heated to a higher temperature, it will take longer to reach that temperature. The cone number is the temperature at which the cone is fired. The cone number is determined by the time it takes for the cone to reach a specific temperature after it is placed in the kiln.

Behavior of Pyrometric Cones

Typically, it takes 15 to 25 minutes for a cone to bend once it starts. This depends on the cone number. The cone bends slowly at first but once it reaches the half way point (30 minutes), it bends quickly. When the cone tip reaches a point level with the base, it is considered properly fired. This is the point for which temperature equivalents are determined.

Differences between a cone touching the shelf and a cone at the 4 o'clock position are small, usually 1 or 2 degrees.

Temperatures shown on the charts were determined under controlled firing conditions in electric kilns and an air atmosphere. Temperatures are shown for specific heating rates. These heating rates are for the last 100°C or 180°F of the firing. Different heating rates will change the equivalent temperature. The temperature will be higher for faster heating rates and lower for slower heating rates.

Cone bending may also be affected by reducing atmospheres or those containing sulfur oxides. Orton recommends the use of Iron-Free Co for all reduction firings (cones 010-3). If a cone is heated too fast, the cone surface fuses and binders used to form the cone will be damaged. The cone should be cooled (pre-fired) before use.

For more information on pyrometric cones or Orton, visit us at www.ortonceramic.com


<table>
<thead>
<tr>
<th>Cone</th>
<th>Centigrade</th>
<th>Fahrenheit</th>
<th>Color</th>
<th>What Happens to Clay</th>
<th>Type of Ware and Glazes</th>
</tr>
</thead>
<tbody>
<tr>
<td>_</td>
<td>0</td>
<td>32</td>
<td>_</td>
<td>Water freezes</td>
<td>_</td>
</tr>
<tr>
<td>_</td>
<td>100</td>
<td>212</td>
<td>_</td>
<td>Water boils</td>
<td>_</td>
</tr>
<tr>
<td>_</td>
<td>100–300</td>
<td>212–372</td>
<td>_</td>
<td>Chemical water driven off</td>
<td>_</td>
</tr>
<tr>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>Lowest point where red glow can be seen in the Dark</td>
<td>_</td>
</tr>
<tr>
<td>022</td>
<td>573</td>
<td>1063</td>
<td>_</td>
<td>Quartz inversion</td>
<td>Metallic lustres (gold, platinnum, etc.)</td>
</tr>
<tr>
<td></td>
<td>605</td>
<td>1121</td>
<td>_</td>
<td>Lowest cone temperature</td>
<td></td>
</tr>
<tr>
<td>021</td>
<td>614</td>
<td>1137</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>020</td>
<td>635</td>
<td>1175</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>019</td>
<td>683</td>
<td>1261</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>018</td>
<td>717</td>
<td>1323</td>
<td>Dull</td>
<td>Organic matter in clay burns out</td>
<td></td>
</tr>
<tr>
<td>017</td>
<td>747</td>
<td>1377</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>016</td>
<td>792</td>
<td>1438</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>015</td>
<td>804</td>
<td>1479</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>014</td>
<td>838</td>
<td>1540</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>013</td>
<td>852</td>
<td>1566</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>012</td>
<td>884</td>
<td>1623</td>
<td>Cherry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>011</td>
<td>994</td>
<td>1641</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>010</td>
<td>905</td>
<td>1661</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>009</td>
<td>923</td>
<td>1693</td>
<td>Dark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>008</td>
<td>955</td>
<td>1751</td>
<td>Orange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>007</td>
<td>984</td>
<td>1803</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>006</td>
<td>999</td>
<td>1830</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>005</td>
<td>1031</td>
<td>1888</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004</td>
<td>1060</td>
<td>1940</td>
<td>Orange</td>
<td>Some red clays mature</td>
<td>Average bisque</td>
</tr>
<tr>
<td>003</td>
<td>1101</td>
<td>2014</td>
<td>_</td>
<td></td>
<td>Earthenware</td>
</tr>
<tr>
<td>002</td>
<td>1120</td>
<td>2048</td>
<td>Dark</td>
<td>Buff clays mature</td>
<td>Highfire earthenware</td>
</tr>
<tr>
<td>001</td>
<td>1137</td>
<td>2079</td>
<td>Yellow</td>
<td></td>
<td>Semi-vitreous ware</td>
</tr>
<tr>
<td>1</td>
<td>1154</td>
<td>2109</td>
<td>Yellow</td>
<td>Some red clays melt</td>
<td>Sanitary ware</td>
</tr>
<tr>
<td>2</td>
<td>1162</td>
<td>2124</td>
<td>Yellow</td>
<td></td>
<td>Bone China glazes</td>
</tr>
<tr>
<td>3</td>
<td>1188</td>
<td>2134</td>
<td>Yellow</td>
<td></td>
<td>Lowfire stoneware</td>
</tr>
<tr>
<td>4</td>
<td>1186</td>
<td>2157</td>
<td>Yellow</td>
<td></td>
<td>Salt glazes</td>
</tr>
<tr>
<td>5</td>
<td>1196</td>
<td>2155</td>
<td>_</td>
<td></td>
<td>Stoneware</td>
</tr>
<tr>
<td>6</td>
<td>1222</td>
<td>2252</td>
<td>Bright</td>
<td>Stoneware clays mature</td>
<td>China bodies—bisque</td>
</tr>
<tr>
<td>7</td>
<td>1240</td>
<td>2254</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1263</td>
<td>2255</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1290</td>
<td>2261</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1305</td>
<td>2299</td>
<td>White</td>
<td>Porcelain matures</td>
<td>Porcelain</td>
</tr>
<tr>
<td>11</td>
<td>1315</td>
<td>2309</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1326</td>
<td>2419</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1346</td>
<td>2455</td>
<td>_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1366</td>
<td>2491</td>
<td>_</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The temperature equivalents in this table apply only to large (2½ inch) Orton Pyrometric cones when heated at the rate of 150°F (82°C) per hour in an air atmosphere. The above list represents the temperature range within which studio potters and ceramists generally work. For industrial and scientific purposes, higher temperatures may be needed, with cones going to cone 42, the melting point of pure silica. The color column represents the approximate color of radiant light visible in the kiln.
OVERVIEW
OXIDATION, REDUCTION AND PARTIAL REDUCTION

OXIDATION
Oxidation means MORE AIR TO GAS.

In an oxidation firing more air is let into the kiln than gas. Which means all the gas that enters the kiln will combust and burn.

It is hard to get a complete oxidation atmosphere in a gas kiln. This is why most oxidation glaze firings are done in an electric kiln. Electric kiln rely on the heating of the wire elements, thus the gas/air ratio is not a factor.

The signs of oxidation are:
1  No smell
2  Rumbling sound from the burners
3  Clear inside the kiln
4  Short flame
5  Blue flame
6  No smoke

REDUCTION
Reduction - means MORE GAS TO AIR.

In reduction firings more gas is let into the kiln than air. This means there is gas that cannot immediately burn when it enters the kiln. The gas will actively look for oxygen so that it can burn. It will find this in the clay and in the glazes affecting the surfaces and colors.

The signs of reduction are:
1  Smell
2  No sound from the burners
3  Smokey inside kiln making it hard to see cone packs and pots
4  Long flame
5  Orange to Yellow flame
6  Smoke coming from the spy and around the doors cracks
PARTIAL REDUCTION
This is a point in between oxidation and reduction. The flame is Blue on the inside and yellow/orange on the outside.
OXIDATION AND REDUCTION -
technical notes from RISD

In fuel burning kilns the atmosphere can be easily controlled. Various atmospheres have an important effect on glaze and body colors and textures. (For information on reduction effects, see Clay and Glazes for the Potter by Daniel Rhodes)

In oxidizing fire, plenty of air is let into the burners to oxidize or burn the fuel thoroughly. This air, which enters the burners and mixes with the gas before combustion is called primary air. Air that enters through the burner itself, and adds oxygen to the flame is called secondary air. It is pulled or sucked into the kiln by the pull of the draft. The sign of a clear or oxidizing fire is a clear atmosphere in the kiln, everything being sharply visible. There will be a total lack of visible flame at the damper or coming from the spy holes. the flame at the burners should be burning with a predominantly blue color, with little yellow flame appearing.

If too much air enters the kiln from the secondary air accesses, there may be a cooling effect that prevents the kiln from gaining temperature. Only enough air for proper combustion should be allowed to enter. Even in the case of air which supplies oxygen for combustion, the fraction of nitrogen must be warm and passed through the kiln.

If the kiln appears to be oxidizing, yet no temperature gain is noted, it is probable that too much air is being admitted.

Perfect oxidation is hardly attainable in ceramic kilns. An analysis of the flue gases will always reveal the presences of some carbon dioxide. But, for all practical purposes, if the kiln is burning clear without flame or smoke, an oxidizing effect will be achieved.

If the kiln is oxidizing, a satisfactory rate of climb usually results. To advance the temperature, either the valves are turned up from time to time, or additional burners started. The damper is ordinarily left open, but if the kiln is pulling in too much air, the damper may be partially closed to diminish the draft. To advance the heat, it is good to follow some sort of schedule for a regular pattern of temperature climb. The operation simply involves feeding sufficient fuel in through the burners to maintain the desired rate of climb. Beginning at cone 1, carbon in the wares (and there is always some) burns, and there is an endothermic reaction that may cause a rise in temperature not attributable to the burner settings. Also, at about this heat, radiation from one surface to another seems to make for a more rapid climb.
To reduce, the air supply is cut back. Either the primary air or secondary air supply may be diminished, or both may be cut back until the flames begin to burn with a yellow color. The damper should be closed somewhat until a back pressure develops in the kiln. This will be evidenced by some flame at the spy hole. Flame will be observed at the damper.

Extremely heavy reduction does no good. It is quite unnecessary to have great belching clouds of black smoke coming from the spy holes and chinks in the kiln. The eternal questions are when to reduce and how much to reduce. As a general rule, a neutral to light reduction gives a good color and texture. It will be necessary, however, to experiment with a new kiln to determine just what symptoms of sufficient reduction are. Once a satisfactory firing pattern is arrived at, it can be repeated successfully.

Since reduction involves an excess of unburned carbon in the firing chamber, too much reduction is a waste of fuel. Heavy reduction will usually halt the advance of temperature, or even cause a loss of temperature. If the temperature in the kiln is not advancing, admitting more air at the primary or secondary sources of air will sometimes bring about satisfactory rate of climb.

Reduction in the earlier stages of firing, from 750-900 C.(1382-1652 F.), will cause a deposit of some carbon in the clay being fired, the so-called "body reduction." This may produce warm browns or orange color in stoneware clays. Too much reduction at this stage, however, may cause bloating or cracking, especially if the later of the firing is rapid.

Heavier reduction toward the end of the firing tends to slow the kiln down and give some "soaking," usually beneficial. At this stage, reduction may also favor the development of celedon and copper red glaze colors.

Kilns always tend to re-oxidize on cooling, because they are not really airtight enough to keep the oxygen out. Clay colors are developed toward warm brown by the effect of this re-oxidation on the iron of the body. Some potters give the kiln a brief period of sharply oxidizing fire at the end to "clean it up," but is rather doubtful that this has any real effect.

For reduction firing, best results are obtained in a downdraft kiln that circulates gases to every part of the setting. Kilns burning wood can be reduced by adding an excess of fuel. To maintain temperature advance, and to bring about a pattern of intermittent reduction, this overstoking must be alternated with lighter stoking. Reduction firing may be damaging to the firebrick of the kiln, especially if the brick contains considerable iron. The iron may catalyze the deposition of carbon within the pores of the brick, causing a tendency to disintegrate. In practice, this
is nothing to worry about because in all ordinary reduction firings there is ample opportunity for the carbon to burn during the long cooling period under oxidizing conditions.

http://departments.risd.edu/depts/ceramics/oxidredux.html
Bisque Firing

Most Bisque ware are fired between cone 010 and cone 06 (sometimes as high as cone 04) depending upon the clay body used.

There are two basic things that happen to the clay during a bisque firing: three types of water leave the clay (1. Surface, 2. Pore and 3. Chemical) and organic material and impurities in the clay are burned out.

Critical temperatures
All surface water and pore water will leave the ware at 100 degrees centigrade or 212 Fahrenheit. This is the boiling point of water or when water turns into steam. This is when your piece will blow up! The kiln must be fired slowly at this point. The thicker the piece the slower the kiln should be fired during this period.

Chemical water will leave the ware at 800 degrees to 1200 degrees and when quart inversion takes place. The kiln should be fired slowly during this time.

Some schools do not allow firing bisque in an electric kiln because of the ware and tear on the electric kiln elements.

Firing Graph Below:
All Bisques are Done in Oxidation Atmosphere Only.
Both Gas and Electric kiln can be used to bisque. Note: true oxidation atmosphere can only be obtained in an electric kiln. Some earthenware or other types of high iron bearing clay may require this controlled atmosphere.

<table>
<thead>
<tr>
<th>Room Temp. 100</th>
<th>820-1100</th>
<th>1641</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>Quartz</td>
<td>Cone 010</td>
</tr>
<tr>
<td>Inversion Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Kiln Slowly</td>
<td>raise temp</td>
<td>raise kiln temp</td>
</tr>
<tr>
<td>Evenly</td>
<td>evenly - can go</td>
<td>Faster rate</td>
</tr>
<tr>
<td>(100-200-degree hr)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stinson 1/08
GLAZE FIRING
There are three basic glaze temperatures: cone 04, 5/6 and 9/10. There are two basic atmospheres – oxidation and reduction.

The Electric kiln can be fired at the three different temperature ranges but only be fired in oxidation. (ASU electric kilns are rated to cone 5/6)

The gas kilns can be fired in the three different temperature ranges and both oxidation and reduction. As noted in the RISD tech article gas firing is not a pure oxidation atmosphere but when fired correctly can produce the desired effects.

Below are the general guidelines for firing in a gas kiln. Time, cone, and atmosphere may change according to desired results.

REDUCTION FIRING

CON 10 REDUCTION

<table>
<thead>
<tr>
<th>Room Temp.</th>
<th>Dull Red Heat</th>
<th>Cone 010</th>
<th>Cone 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuartzBody Inversion Reduction</td>
<td>(Slow kiln)</td>
<td>Clear Kiln</td>
<td>(15 min)</td>
</tr>
<tr>
<td>Reduction</td>
<td>(1/2 to 1 hr)</td>
<td>Partial Reduction</td>
<td>(6-8 hrs)</td>
</tr>
</tbody>
</table>

CON 5/6 REDUCTION

<table>
<thead>
<tr>
<th>Room Temp.</th>
<th>Dull Red Heat</th>
<th>Cone 010</th>
<th>Cone 5/6</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuartzBody Inversion Reduction</td>
<td>(Slow kiln)</td>
<td>Clear Kiln</td>
<td>(15 min)</td>
</tr>
<tr>
<td>Reduction</td>
<td>(1/2 to 1 hr)</td>
<td>Partial Reduction</td>
<td>(4-6 hrs)</td>
</tr>
</tbody>
</table>

Stinson 1/08
CONE 04 REDUCTION

Room  Dull Red  Cone  Cone
Temp.  Heat       010         04

Quartz  Body
Inversion  Reduction
(Slow kiln)

Reduction  (1/2 to 1 hr)  Partial Reduction
          (2-4 hrs)

OXIDATION FIRING

CONE 10 OXIDATION

Room  Dull Red  Cone   Cone
Temp.  Heat     10

Quartz  Inversion
        (Slow kiln)

Oxidation  (6-8 hrs)

CONE 5/6 OXIDATION

Room  Dull Red  Cone
Temp.  Heat     5/6

Quartz  Inversion
        (Slow kiln)

Oxidation  (4-6 hrs)

Stinson 1/08
CONE 04 OXIDATION

Room Temp. | Dull Red Heat | Cone 04 Clear Kiln (15 min)
--- | --- | ---
Quartz Inversion (Slow kiln)

Oxidation (2-4 hrs)

BISQUE FIRING — CONE 08-010

Room Temp. | Dull Red Heat | Cone 010-08 Clear Inversion kiln
--- | --- | ---
100 212 | Quartz Inversion (slow kiln)

very slow Oxidation (2-4 hrs)

GOOD LUCK — TAKE NOTES AND USE THESE AS A GUIDELINE FROM WHICH TO START.

Stinson 1/08
OVERVIEW - GAS KILN

There are three types of gas kilns an **UPDRAFT**, **DOWN DRAFT** and a **CROSS DRAFT**.

The difference between the three is simply where the exit flues are located. In an **updraft** heat comes into the kiln and rises to the exit through a flue (hole) in the top. In a **downdraft** kiln the heat enters the kiln, rises to the top, down again, and out through a flue (hole) at the bottom of the kiln and up a chimney. A **cross draft** is similar to a down draft except that the burners and the chimney are on the opposite sides. The flame travels across the kiln and out a chimney.

Each of these kilns are fired slightly different but can produce similar results depending on how you fire.

I have included information on burner systems and technical notes on firing in hopes that readings, lectures and firing time will give you a better understanding of what is happening and how better to control the process.
High Pressure Propane Burner (0-25 psi)

With Components

8. Burner block
7. Giberson Ceramic Burner Head
6. Ransome venturi
5. Gauge (0-30 psi)
4. Needle Valve
3. Pilot light
2. Thermocouple
Main gas
Low pressure safety system for natural gas or propane

1. FM solenoid
2. Gas cock
3. Pressure gauge
4. "UV" monitor & relay
5. Dayton blower 4C442 or other air source
6. Giberson Ceramic Burner Head
7. Burner block
8. "UV" sensor & magnifier
9. Main electric switch
10. Low pressure switch
11. High Pressure Switch

Gas Supply

120 Volts
Kilns: Theory and Practice
By Frank Colson

In order to achieve the desired firing result, a potter must have some understanding of the basic types of fuel kilns. With gas kilns, the effect desired is usually accomplished by means of a so-called "reduction firing" rather than oxidizing a kiln during the firing cycle - the norm with electric kilns. The term "reduction firing" is commonly used in contemporary pottery shop talk, and very simply implies that the oxygen in the atmosphere of a kiln is reduced, thus starving the flame of its natural fuel. Since there is little oxygen within the kiln on which the flame can feed, it goes after particles of minerals and chemicals within the clay and glazes of the pottery. The result is that the iron impurities in the clay body come to the surface and "bleed" on the face of the glaze. Iron glazes turn to green (celadon), while copper-based glazes turn red (reduction red, or "oxblood"); the general effect of the pottery is much different than that obtained with oxidation firing in electric kilns. Some exceptions are when organic materials are placed into an electric kiln to burn depriving the space of oxygen to create a reduction atmosphere. This, of course, is very hard on the heating elements!

Since reduction firing requires what most industrial gas servicemen refer to as a "dirty" flame, it is easy to understand why this firing method is more of an art than a set of procedures. Each kiln has its own distinctive firing characteristics. Furthermore, each potter must discover his/her particular kiln's traits and learn to work with them in order to have successful firings. Success cannot be achieved with one firing alone; ten firings of the same kiln may only begin to bring the consistent control that the potter desires.

Most kilns come under two general categories - updraft and downdraft - and each type has its own set of advantages and disadvantages for reduction firing. Almost all fuel-fired kilns built today are designed so as to allow ample flame circulation within and around the stacking chamber. But this was not the case some years ago when "flashing", which occurs due to a flame lick, was not considered an aesthetic attribute on a pot. Because of this, kilns were built with complete baffle chambers around the entire stacking area
so as to prevent flames from even remotely approaching the ware. In some cases, kiln designs provided for each burner flame to pass through a ceramic tube in the kiln, from bottom to top. These kilns were referred to as "muffle kilns", since they muffled the flame and used the heat that radiated through the ceramic tubes to reach the needed temperature. The atmosphere of these kilns was clear and clean, and oxidation firing the only condition. However, with fuel kilns, which are not muffled, freer flame circulation within the stack area allows more direct heat penetration from the flame, and consequently less fuel is required, resulting in savings to the potter. Direct flame exposure also changes the effect of the glazes, creating warm, pleasant differences rarely available with a muffle kiln.

In the last decade, wood has become more and more a kiln heating fuel. Not so much for the purpose of reaching glaze temperatures, but to induce mood ash into the kiln chamber which creates effects onto pots which would otherwise be unobtainable.

Other kinds of heat producing materials; coal, fuel oil, deep fry oils, etc. Can and have been used for kiln firing. Their availability is somewhat restrictive or requires custom built rigging or fireboxes. (The kiln heat generating area).

With today's environmental thinking to eliminate polluting conditions, clean fuels such as methane and grain alcohol are certainly options to consider seriously for kiln firing fuels.

**NEXT: Updraft Kilns**

**Kilns: Theory and Practice: Updraft Kilns**

Most commercially built fuel kilns on the market today are updraft kilns, primarily because of the simplicity of building such a kiln as well as packing and shipping it. An updraft kiln consists of tow basic elements, which contribute to its simplicity of design: the first is a firebox, where most of the flame is concentrated, and which is always located directly under the bottom shelf of the stack area. The second is the flue damper system where the flame exhaust is controlled; this is actually a part of the top of the kiln and consists of little more than
a hole in the roof.

In some cases, the burner system for an updraft kiln is located under the structure, pointing upward. But sometimes the system is on its side or even on the back in a horizontal position. Such a kiln may also have burners within it at floor level. Regardless of the burners' placement, the direction of the flame in an updraft kiln always commences at floor level and goes up through the kiln and out the flue opening at the top. This being so, the problem is to acquire the best efficiency of flame while the flame is in the kiln and to control it for reduction. When the flame enters the kiln at the firebox, it makes its primary circulation. The objective, then, is to hold as much as possible of this flame within the kiln before it is drawn up and out of the flue. This can be done by placing a small wedge shaped brick in front of the burners inside the kiln.

Depending upon where and how such a brick is placed, flame can be directed inward towards the center of the firebox or in another direction of more efficient use. The flame is split up into segments and directed into areas that might not otherwise be covered in the firebox. Burners that enter through sides of the kiln may have such circulation devices, while kilns with burners directed vertically from underneath are often baffled with a refractory plate located a few inches above the burner openings within. In the latter case, the flame, which is dispersed out over the firebox bottom, spreads the heat as evenly as possible. These devices, as well as the density with which the ware is stacked, affect the length of time that the heat of the flame is held within the kiln. With experience in firing as well as stacking a kiln, you will be able to determine the flame's best level of efficiency.

Initial reduction during the firing cycle will depend upon the amount and type of flame that goes into the firebox. If an overabundance of fuel is pushed into the updraft kiln, the draft system will simply accelerate the passage of the flame through the kiln and out the flue, with the result that proper fuel combustion (the right amount of air and raw flame) will take place outside the kiln at the point where the flame leaves the flue. One of several signs indicating combustion going on outside rather than inside the kiln is difficulty in gaining temperature. You can usually notice this by the excess time and fuel consumption required for firing. Another indication will be the
extremely active flame coming out of the flue, often in the form of fiercely waving tails along with a low muffled sound of roaring fire. What is deceiving is that this type of flame will often present a great deal of smoke, leading the potter to believe that a good reduction is taking place. It is - but outside the kiln! If these effects are encountered early in the firing cycle, before cone 6, for instance, there often is a distinct odor of carbon dioxide, which tends to smart the nasal passages and indicates incorrect fuel combustion. The object is then to set up the flame input and the damper control so as to make combustion occur within the kiln. This will bring about a heat rise, thus making possible the conditions needed for a reducing atmosphere.

Unlike a downdraft kiln, an updraft has no chimney stack; its one great advantage in reduction firing, therefore, is that there is a means of seeing and controlling the amount of reduction. Excessive reduction, which also produces excessive backpressure within the kiln, will result in an extensive flame (more than 12 inches) coming out of the top of the flue. Thus the flame you see coming out of the flue and the way you adjust your kiln settings for that flame are the most important factors in a successful firing.

In the early cycle of firing an updraft kiln, (before heat color occurs) the burners are kept soft and low so as to confine the flame within the boundaries of the firebox. Flame from the burners should not be allowed to lick against any pots until after all the chemical water has been removed. (500°F to 900°F) The damper is wide open at this point. Once the temperature has passed beyond 900°F, you may close the damper nearly three quarters while bringing the flame up more and more during the early stages of the firing cycle. The function of this damper position is to hold as much heat in the kiln as possible during the early oxidizing stages of firing. Once color in the kiln has begun, you can pay close attention to the flue.

It is helpful to plan the timing of a firing so that the color within the kiln will coincide with dusk or early evening; darkness will facilitate seeing flame emerge from the flue. If the first flame out of the flue appears blue, this will indicate that the temperature within the kiln is not yet high
enough to prompt proper reduction conditions. At this pint, the damper should be opened substantially, which will result in either a disappearance of any visible flame or a change in color from blue to orange-yellow. As heat continues to build up within the kiln and fuel input continues (up to the point of greatest efficiency, so as not to push fuel through the kiln), the flame coming out of the flue will increase. Once you can see a strong orange color within the kiln - anywhere from cone 8 to cone 1 - reduction should begin. A visible flame should be coming from the flue now: orange, about 12 inches long, and very active. If viewing conditions are good, you may observe a small amount of smoke coming off the top of the flame, and this should indicate that the type of flame going through the kiln is naturally smoky from the burners right through to the flue opening. When you reach the high temperature range of the firing cycle - cone 5 and above - check the kind of flame coming out of the flue often.

Make damper adjustments as needed. The greater the fuel input into the kiln, the more important it is to look at the color and kind of flame coming out of the flue. The backpressure of fuel in the kiln is kept in check by adjusting the flue damper opening. This damper is the primary device for controlling proper combustion, sufficient reduction, and the increase of heat, once the fuel input is at a constant setting.

During the peak of the firing, a secondary characteristic of proper reduction may be observed: the accumulation of slight carbon deposits around the peepholes in the door and around the damper openings.

Summarizing the advantages of an updraft kiln: First and foremost, it is simple to construct, being nothing more than a refractory box in which there is a fuel input in one end and a fuel outlet on the other. Also, with such a kiln, the characteristics of reduction firing can be observed through the entire firing cycle, making it relatively easy to learn reduction-firing techniques that can be controlled with considerable consistency.
Kilns: Theory and Practice: Downdraft Kilns

A distinct advantage of the downdraft kiln is that it uses fuel more efficiently than the updraft. However, firing for reduction is a more complex operation. The downdraft kiln consists of three basic structural elements: The firebox, where fuel combustion takes place; the stack area, where pots are placed; and the kiln stack, which includes the flue damper system. Since the basic principle of a downdraft kiln entails directing flame downward inside the kiln, and not upward, the firebox is usually a separate section, located apart from the pottery stack area. Whereas in some kiln designs the firebox is on one side of the kiln, in other designs it may be split up into two or more areas on opposite sides of the kiln. Sometimes it may be tangent to the kiln in the rear or on the side, but in some cases it is several feet away. The function of this stack is to create a draft for the flame in the firebox so that the flame is drawn through the ware in the stack area. This draft commences either under the kiln floor or on the same level as the floor.

The height of the stack or chimney, plus its diameter, must be directly related to the size of the kiln if the proper draft is to be created. For the purpose of reduction, fuel backpressure within the kiln is controlled with the damper, which is located at the bottom of the kiln stack. The damper is handled in much the same way as for updraft kilns, but it is important to understand other characteristics of a downdraft kiln in order to control reduction during the firing cycle.

Since the firebox in a downdraft kiln is normally separate from the pottery stack area, you must allow time in the early portion of the firing cycle for the firebox area to be heated. This must be done before the ware area will reach any substantial temperature. At the onset of a firing it may be difficult to acquire even a little draft within the kiln to draw the flame up from the burners because the kiln stack
may be at some distance from the firebox. One actual advantage of such a firebox arrangement, however, is that the ware is protected from being licked by flame in the early part of the firing cycle. Once heat has begun to build up within the kiln, a substantial draft will usually occur if the damper is wide open. As heat continues to build up, with the damper set to maintain the greatest fuel efficiency as described earlier, you must watch for the signs of reduction conditions.

The first indication of reduction is in the kiln atmosphere itself. If when you look into the kiln, the inside is hazy or foggy, this means there is smoke inside the chamber and indicates reduction. It is difficult to observe obvious signs of reduction in a downdraft kiln, particularly in the early firing stages. In order to make these signs plainer, however, you can close down the damper control, thus creating a little more backpressure than necessary. When you do this, a forceful carbonization will take place around the peephole, and if you open a peephole (particularly a top peep), a forceful smoky flame will leap out. At this point, the backpressure should be let up a little by opening the damper slightly while you observe the nature of the flame from the peeps. The top peep should have a warm yellow-orange flame about six inches long with a very slight smoky tip. The middle peep should be the same color, but only about three inches long. The bottom peep will often be neutral - that is, there will neither be a draft (which can be checked by holding a lit match in front of the hole), nor a flame coming out of it to indicate any great backpressure. These conditions should be maintained by making damper adjustments as the heat buildup increases within the kiln and you reach the desired temperature. If at any point during the firing cycle you are uncertain about how reduction conditions are progressing, you can close the damper down a bit to overcompensate for reduction and then readjust by backing off the damper once again.

In making adjustments for reduction effects during a firing, keep in mind that the kiln must have at least a half hour to make adjustment. It is therefore easy to misjudge what is taking place during the firing if you make damper or fuel adjustments at intervals of less than thirty minutes. In fact, in many cases it is wiser to wait at least an hour between adjustments, but this depends on the size of the kiln, since
large kilns take considerably more time to readjust to a setting than small kilns. Perhaps the greatest frustration you can experience in attempting to make a reduction firing comes when you anticipate what the kiln will do without giving it a chance to show its own traits. As already mentioned, it usually takes more than several firings to learn a fuel kiln's traits and to be able to make predictions that will contribute to the control needed for firing. After you have fired a kiln many times, your experience contributes to the predictability of a firing cycle, which, in turn, leads to your needing to give less attention to each firing. Each subsequent firing will then fall into a pattern, which may vary only slightly, according to the manner in which pots are stacked.

In reviewing the advantages of the downdraft kiln, note that although this type is a more complex structure to build and involves a great deal of labor and materials, the way it holds heat by passing the flame down through the ware and out of the floor is very efficient. It is more difficult to reduce with this type of kiln until you have learned and can predict its firing characteristics.

I have tried to make no specific recommendations as to what temperatures begin reduction or oxidation or at what point glazes or clay body are reduced, but have attempted to show instead how to set up the conditions for reduction firing with two basic types of kilns, the updraft and the downdraft.

Since the kiln itself is a retaining box for heat, a system that will generate heat must be provided. You must understand burners and the basic types of fuels that burners use in order to reach a given temperature within the kiln. As already noted, kilns constructed with ceramic fiber materials provide such excellent insulation that the heat input needed is considerably less than for conventional brick kilns and there is a resulting saving of fuel.

NEXT: Combustion

Kilns: Theory and Practice: Combustion

Combustion, the process of combining oxygen with fuel, results in
the release of heat. In order to achieve proper combustion, air and fuel are mixed together in a ration that does not leave excess fuel unburnt or deprive the fuel of an opportunity to burn at its maximum rate. The correct proportion is ten parts of air to one part of fuel. An inadequate quantity of fuel in the mixture results in oxidation because the oxygen in the air is not totally consumed while excess fuel results in a "rich mixture" (or an insufficient amount of oxygen), creating a carbonizing atmosphere and incomplete burning of fuel.

The ignition which initiates combustion occurs when the oxidation reaction (a flame) is induced by an external heat source and the reaction itself releases heat faster than the heat, which is lost to its surroundings. Or, to put it in another way, after introduction of the external heat source, the heat from the oxidation reaction ignites in what is referred to as "spontaneous combustion".

All measurements of heat are based upon B.t.u. (British Thermal Unit) - the quantity of heat necessary to raise one pound of water one degree Fahrenheit. The amount of B.t.u given off by any natural or liquid gas burner is determined by the size of the orifice. The orifice allows a given amount of fuel to pass into the burner chamber, where the fuel is combined with air, and where, when ignited, it creates a flame. A flame may be defined as a zone in which the combustion reaction is occurring at such a rate as to produce visible radiation. The flame front is that place along which combustion starts. When the correct conditions take place, the flame front appears to be stationary, because the flame is moving toward the end of the burner with the same speed that the fuel-air mixture is coming out.

If the fuel-air mixture is fed into the burner at too fast a rate, the flame may blow off. This is identified as a "pop off" of the flame from the lip of the burner, which leaves a gap between the rear end of the flame and the front end of the burner. If the fuel-air mixture is fed into the burner too slow, the flame may have a "flashback" into the burner. In some extreme cases the flame may flash back as far as the mixing point just above the orifice hole, causing the burner itself, which gets extremely hot, to become the heat chamber for the flame instead of the kiln.

Atmospheric burners using natural or liquid gas have two important
and basic components, which are necessary for successful operation: primary and secondary air control. Although these components are also necessary factors in burners using dense and hard fuels, they are more identifiable in burners using gas fuels, where they are easier to control.

When the primary air combines with the flame at the ignition point of the burner, the cooler air is heated, and as a result the flame increases in velocity, creating a forceful driving flame at the burner tip. This basic principle, known as the Venturi effect, is the same one that powers a jet engine on a 747. The secondary air is that which combines with the flame at the tip of the burner where proper combustion is taking place and is being driven into the kiln. An excessive amount of secondary air at this location creates a "cool" flame going into the kiln, and insufficient secondary air creates a flame lacking in proper combustion, which results in a reducing or smoky flame.

Primary air is controlled by the air shutter located near the orifice head - secondary air by the position of the burner head in the burner port.

For any given burner, a change in the fuel-mixture pressure or the amount of primary air will affect the flame shape. Increase in fuel pressure will broaden the flame in most burners while an increase in the primary air will shorten the flame (assuming the input rate remains the same). But the design of the burner has much more effect upon flame length and shape than either of these operating variables. Good mixing, produced by a high degree of turbulence and velocity, creates a short bushy flame, whereas poor (delayed) mixing and low velocity result in a long, slender flame. Interestingly, burners may be ignited at the point of their external heat termination (the end of the burner). If the position of the burner is correct, initial combustion occurs only at this point, often leaving the internal area of the burner totally without flame. Although this creates a soft flowing flame rather than one, which has velocity, this flame serves its purpose well by creating a reduction atmosphere within the kiln and still providing necessary heat rise.

Another type of burner which does not operate by using atmospheric
air as a part of its mixing procedure is the forced-air burner. This type of burner does not require a secondary air intake since the air is being forced into the burner chamber by mechanical means. With this burner, a much greater fuel input into the chamber of the burner is possible, and its flame, which is very forceful, enables a massive amount of B.t.u. to be thrust into the kiln chamber.

It should be noted that burners designed for operation at sea level may not work as efficiently at high altitude, where there is less oxygen in the air.

Oil burners of various types work most efficiently with a forced-air blower system. However, some oil burners are designed to operate without forced air and yet are able to provide an extremely powerful flame, as if forced air were being used. An example of this type is the oil burner which operates by converting oil into a vapor under pressure before it is released at the orifice opening. Naturally, this burner does not require any electrical means to create its forceful flame.

After you have acquired a basic understanding of burners, it is important you become aware of the effect that flame has upon that area of the kiln where heat input is being initiated - the area universally referred to as the "firebox".

The firebox is the heat energy source for the entire kiln; it is the motor which makes the kiln go! Firebox shape and sizes may differ, according to the type of kiln. Downdraft kilns normally contain well defined fireboxes where the massive buildup of flame goes on before the flame thrusts its heat up into the ware chamber. Updraft kilns usually have the area below the bottom ware shelf as the firebox, although there are exceptions to this arrangement. In both cases, the fireboxes takes the greatest beating during the firing cycles, since it is subjected to thermal shock at the firing's onset. It must also withstand higher temperatures than the rest of the kiln because of its generating source and continuous flame impingement. Kilns made of bricks - whether they be refractory or insulating - constantly need repair in the firebox area because of these factors. The bricks here show considerable expansion and contraction compared to other parts of the kiln, and it is necessary to "beef up" this area for durability.
is required. However, as already indicated, with kilns that use ceramic fibers as a hot face covering on the internal walls of the firebox, the material is unaffected by either thermal shock or flame impingement. Also, most of the characteristics of firebox abuse, such as expansion and contraction, are eliminated since the material does not expand. Ceramic fibers do contract slightly (about 2 to 3 percent) if they are taken higher than their given hot-face working temperatures and therefore, if the internal surface of a kiln contains a ceramic-fiber face rated at 2,300°F in the firebox area and heat generated during the firing exceeds this temperature, the material will shrink slightly and become somewhat brittle. It will not, however, expand again once it has contracted. One solution to slight contraction might be to use a higher rated ceramic fiber in the firebox area. For example, some specialized ceramic fibers made of zircon have working temperatures as high as 4,500°F, but they are extremely expensive and not worth the cost since the lower rated and more available alumina-silica fibers provide the same protection in the firebox area once they have contracted.

Natural gas is the cleanest of all natural fuels, followed by propane, butane, and then the oils. Natural gas is lighter than air and therefore problems with burner carbonization rarely occur during the low preheat periods of kiln firings. Liquid gases, however, which are heavier than air, even in a state of vaporization, often present carbonization problems during the preheat period unless the kiln is started at a high, rapid level of heat input. Orifices in liquefied petroleum gas burners are often too large to present some carbonization, both on the inside of the burner as well as in the firebox during the low heat prefireing cycles. This factor is all the more evident with oil burners, and one must be aware that carbon residue may be building up inside the burner itself, particularly on the inside nozzle end. The buildup can be very slight; however, after many firings, the carbon builds up significantly to actually constrict the opening of the burner. The result is the operation of a smaller burner than the one that was originally the proper size. Frequently this occurs with homemade burners which use the gas manifold as the burner mount; the orifice is in the manifold and the carbon can constrict the size
of the orifice, thus cutting down substantially on the required B.t.u. input of heat to the kiln.

When carbonization takes place within the firebox itself - often directly in front of the burner - it is of little consequence to any of the functioning areas of the kiln or the burners because as the heat increases and the temperature becomes extreme (above 1,000°F), all carbonization, regardless of how thick, will burn off by the end of the firing cycle. One exception to this rule would be a kiln which has vertical burners situated directly under the burner port leading into the firebox - that is, a kiln where the firebox is a ceiling suspended directly over the burner.

If carbonization builds up substantially on the face of the firebox over the burner, heavy accumulated pieces of carbon can scale off and fall into the throat of the burner, causing a deflection of the flame and resulting in a very unsatisfactory flame shape entering the kiln. Once lodged into the throat of the burner during the early firing stages, the carbon refuse will not burn away since there is little heat generated within the burner itself. Fortunately, carbonization does not affect the new materials themselves since, as already mentioned, they are inert. Conventional materials such as insulating characteristics may be modified by heavy carbonization.

HOME

http://www.r2d2u.com/html%20coage

/klaintheory.htm
<table>
<thead>
<tr>
<th>TIME</th>
<th>PILOTS</th>
<th>MAIN GAS</th>
<th>PASS-DAMPER</th>
<th>POS-DAMPER</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LOADING/STACKING

General Guidelines

1. Check the floor of the kiln to make sure where the posts are and that it is free from broken shards.
2. An evenly stack kiln will fire more evenly. Look at the ware you are to stack and make a plan.
3. It is best to use a taller shelve at the bottom of the kiln to help allow for even heat distribution.
4. Place post on kiln shelve first –then place ware.
5. Allow an open space around the elements and the top of the kiln (aprox 2") to allow for even heat flow.
6. Make sure all the furniture (posts) are directly above the ones below. Post to post.
7. Place cone in the sitter – follow wall chart as a guide.
8. Always have a sight cone.

Bisque

1. Rim to rim foot to foot
2. Three pieces on top of each other maximum.
3. Do not place thin-rimed pieces on the rim. (I do not put anything on its rim.)
4. Handle with care – clay is at its most fragile state when it is bone dry.
5. Use common sense when stacking heavy work with light work.

Glaze

1. Glaze is a type of Glass – things cannot touch each other.
2. Be careful your hands do not pick up any glaze and transfer it to another piece.
3. Try to handle the work only once.
4. Leave space around each piece (1/8” inch).
5. If you are re-firing leave up to 2” around each piece. Place these pieces in the middle and bottom of the kiln.

Stinson 1/08
FIRING PROCEDURES

1. Persons firing kilns are responsible for:
   a. Loading and unloading the kiln
   b. Clean and washing kiln shelves
   c. Vacuum out the kiln
   d. Returning all fired ware to carts
   e. Returning all kiln furniture to their proper place
   f. Cleaning area in and around kiln

2. The team should meet and confirm firing times.

3. Each team member will keep a log of the firing schedule.

4. Do not change the kiln without consulting with log and writing what you did down for the next person. If it is not your firing you need to consult with the team leader before making any changes.

5. Be sure to use safety equipment.
   a. gloves
   b. safety glasses
   c. protective equipment

6. Use the three-post system for supporting the kiln shelves and position the posts similarly for each succeeding shelf.

7. Never leave an unattended kiln once it reaches dull read heat.

8. Never trust the kiln sitter - ALWAYS check to make sure the kiln is OFF before leaving.

9. furniture - use the bricks for the gas kiln and the kiln post for the electric kilns.

IF YOU HAVE QUESTIONS ASK.  

Stinson 1/08
RECIPES

KILN WASH FOR ELECTRIC/REDUCTION KILNS

50      KAOLIN
50      FLINT

*mix to consistency of a glaze

KILN WASH FOR SALT/SODA/WOOD KILNS

50      KAOLIN
50      ALUMINA HYDRATE

*mix to consistency of a glaze

WADING FOR SALT/SODA/WOOD

50      KAOLIN
50      ALUMINA HYDRATE

*mix to consistency of clay
ELECTRIC KILNS

ELECTRIC KILNS CAN ONLY FIRE IN AN OXIDATION ATMOSPHERE

Small cones are used in the electric kilns. Suggested cone packs are listed in the pyrometric cone section.

All of the kilns at ASU have a computer program.

I have listed both instructions on the manual and the controller programs for your reference. We will use this schedule if our controller is out for repair.

Manual Kiln schedule

3-Day Schedule

Load kiln .............................................. Late afternoon

1 element on low
(with lid cracked) .................................. Over night

2 elements on low
(with lid cracked) .................................. 9:00 am

Shut Lid .............................................. 10:00 am

3 elements on low .................................. 11:00 am

All elements on medium ......................... 1:00 pm

All elements on high .............................. 2:00 pm
(or when you see color in the kiln)

Watch for the cones to bend.
This is when the kiln should be turned off.

This is a standard schedule. If your work is very wet or very thick you may want to go slower. If your work is very thin and dry you can go faster. Remember the critical times and the kiln rate of climb.

Stinson 1/08