Kiln Shelf Options

By William Schran

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"KILNS: DESIGN, CONSTRUCTION AND FIRING IN THE 21ST CENTURY"
By Mel Jacobson and Friends

When starting the process of designing a kiln, one should consider the kiln shelves an important factor that may influence the shape and size of the structure. Several factors will have a role in shelf selection.

Kiln shelf size will play a major role in the design of the kiln. There are several standard sizes of square and rectangular shaped shelves. The potter should choose a shelf size that is readily available. One should consider the size of ware, especially diameter, that is made and how the pots will occupy space on a shelf, including the placement of support posts. Maximum weight one can comfortably lift may be important when thinking about the type and size of the shelves.

After kiln shelf size is factored into the design of the kiln, then the type of shelf will be the next consideration. Maximum firing temperature, type of fuel and atmosphere, cost and again, shelf weight, all must be taken into account with shelf selection.

We shall use a standard of 12" X 24" shelf size as comparisons are made of composition, thickness, weight and cost.

One factor many potters often neglect to consider is the amount of energy it takes to heat the pots and the kiln furniture. Often more energy is spent heating the furniture than the pots. We must think about the thermal conductivity of the kiln shelves, also referred to as the K factor. This is explained as the coefficient of thermal conductivity, which is the amount of heat that passes through a unit cube of material in a given time when the difference in temperature difference across the cube is one degree. Simply put, different materials will conduct heat at different rates. The lower the number designation, the more insulating the material is and thus, more energy is required to heat the shelf to a given temperature. Cordierite has a K factor 7 - 10. High alumina shelves are somewhat higher, in the low 20's, while silicon carbide shelves have a number about 100. Silicon carbide nitride bonded shelves are similar to oxide-bonded shelves. Advancer shelves are 85 – 125, depending on the temperature. What does this mean for the potter? It takes considerably more time and energy to heat a cordierite than a silicon carbide shelf. For larger ware, especially larger diameter plates, a faster firing may result in more uneven heating between areas of the pot in contact with the shelf and the upper edge of the pot leading to possible cracking on shelves composed of material with lower thermal conductivity. Once heated, shelves with lower numbers will have a tendency to hold the heat longer, which may be an advantage in slowing the cooling of the kiln.

During this research, each manufacturer or reseller was contacted and asked many questions about the refractories they provide. One question that resulted in unanimous response was: "Should your shelf be rotated (flipped)?" With the only exception being the Advancer shelf, all responded yes, and shelves should be rotated. Due to the number of variable conditions shelves may be subjected to, no specific routine for rotating was suggested. Potters should pay attention and be aware that cordierite is more susceptible to warping than silicon carbide shelves.

Shelves made of Cordierite, a naturally occurring mineral, composed primarily of alumina (33% approx.) and silica (60% approx.) with minor amounts of other minerals, have traditionally been used in top loading electric kilns. The minerals cordierite, mullite and corundum are the primary constituents in the make up of the shelf. Dry pressing under high pressure usually produces these shelves. They exhibit a low coefficient of expansion and are highly resistant to thermal shock, so they are good choices if rapid heating or cooling is desired. On the other hand, they are more susceptible to warping at higher temperatures. In industry, cordierite shelves are generally used where the maximum firing temperature is cone 8. Shelves used up to cone 6 should be at least ¾" thick, and those used to a maximum of cone 10 should be at least 1" thick. A 1" thick shelf will weigh approximately 21 pounds and cost about $30. Shelves composed of cordierite generally have a high porosity rate. Porosity of 13% up to more than 20% has been noted. This means if a glaze drip or run occurs, the glaze can more easily penetrate the surface and melt into the shelf. Glaze must be chipped or ground out of the shelf as each subsequent firing will cause the glaze to penetrate further and may compromise the integrity of the shelf. Kiln wash should be used to protect the surface, using a preferred mix of alumina and kaolin. Cordierite shelves are not recommended for wood or salt firings.

High Alumina shelves are generally similar to cordierite shelves but contain a higher percentage of alumina, giving them a higher temperature rating (cone 11) and less susceptibility to warping, though rotating of these shelves is still recommended. Dry pressing is used to create these shelves. High alumina shelves are denser than cordierite and somewhat more resistant to glaze drips, but they still may have a porosity of up to 20 % or higher, making the use of kiln wash necessary. High alumina shelves are not recommended for wood or salt firings. A 1" high alumina shelf will weigh 22 pounds and cost about $45.

A recent entry into the list of shelves is the Corelite line produced by Resco Products, Inc. These shelves are extruded with openings through the interior. Resco reports these type of shelves have been used by industrial manufacturers for several years to fire sanitary ware up to cone 9 to save on energy costs. The structural shape of the shelves lightens the weight such that a 12" x 24"x 1" shelf weighs only 12.3 pounds with cost ranging from $38 - $40. The shelves are advertised to be light in weight, ground to be very flat, resistant to warping, thermal shock and less prone to cracking. The shelf composition is a mix of mullite and cordierite, including a high content of alumina (49% approx.) and silica (44% approx.) with about 5% magnesium. As with the cordierite and high alumina shelves, these shelves are not recommended for wood or salt/soda firings. The porosity is 23% to 28%, so the use of kiln wash is highly recommended. Though a company representative stated that these shelves can be fired above cone 10, the specification sheet lists the maximum temperature as 2336°F; so long term use at temperatures at and above cone 10 may be an issue. Flipping of these shelves is suggested.

Silicon Carbide kiln shelves have long been the workhorse of the studio potter firing fuel-burning kilns. Also known as oxide bonded shelves, they are composed primarily of silicon carbide and silica. Silicon carbide shelves generally have a much higher maximum temperature rating than cordierite or high alumina shelves. Dry ram pressing under high pressure is the process used to manufacture most all silicon carbide shelves. Crystolon brand shelves, manufactured by Saint-Gobain, have a composition of silicon carbide: 88% and silicon dioxide: 10% with .5% iron and other minor materials. These are rated to a maximum firing temperature of 2730°F. Ashine Industries, Inc.is one manufacturer that produces silicon carbide shelves in China. Their shelves have a composition of silicon carbide: 90% and silicon dioxide: 6% with .5% silica and other minor materials. These shelves are rated to a maximum temperature of 2370°F. Though these shelves can be fired to higher temperatures and are more resistant to warping, they are more prone to cracking from thermal shock. Some manufacturers, most notably Chinese shelf producers, have begun to introduce expansion cuts in the shelves to address this issue. Silicon carbide shelves generally have a rather high porosity, between 14 % and 18%, so kiln wash is recommended. This porosity does make them more susceptible to warping. When silicon carbide shelves are exposed to oxidation, the silicon carbide structure changes and some bond is lost, causing the shelves to weaken somewhat.

Euclid's sells an oxide bonded silicon carbide shelf made by Ashine Industries that comes with a wash of 98% alumina and 2% bentonite applied at the factory. The shelves made by Ashine also come with expansion cuts to release thermal stress at high temperatures. A 12" x 24" x ½" shelf weighs 14.7 pounds and a 5/8" shelf weighs 16 pounds. The ½" shelf sold by Euclid's lists for $60. The Crystolon, 12" x 24" x 5/8", weighs 17 pounds and lists for about $88 from Smith Sharpe Fire Brick Supply. Thickness of the Crystolon shelf is determined by shelf size, application and load. A larger shelf requires a greater thickness to control warpage during firing. Due to their resistance to corrosive atmospheres, silicon carbide shelves are recommended for wood fired and salt/soda kilns. Smith Sharpe recommends ¾" thick silicon carbide shelves for wood or soda firing.

Nitride Bonded Silicon Carbide shelves provide a very strong shelf that is thinner and weighs less than the oxide bonded silicon carbide. A 12" x 24" x 3/8" nitride bonded shelf weighs 11 pounds. Nitride bonded shelves are dry ram pressed, then fired in a nitrogen atmosphere. This produces a shelf that is 75% silicon carbide, 20% silicon nitride, 1% silicon dioxide with the remaining materials being less than 1% each. Ashine Industries is one company that manufactures these shelves in China. The maximum working temperature of these shelves is 2480°F (1360°C). Ashine reports their nitride bonded shelves are fired in a nitrogen atmosphere to 1400°C. As of this writing, Ashine supplies these shelves to Euclid's and Larkin Refractory Solutions. Reports from potters about the early versions of these shelves, that had no expansion cuts, appeared to suffer from thermal cracking more frequently than other shelves. Manufacturers have responded that potters are subjecting these shelves to thermal stress from rapid heating or cooling. Like some silicon carbide shelves, the nitride bonded shelves now have expansion cuts to release thermal stress that might otherwise lead to cracking. Whether these cuts provide sufficient relief from thermal stress is still debated in the industry. Some have suggested the inconsistent quality of the materials or inconsistent firings may be a factor with the cracking issue. Nitride bonded shelves have a porosity of 16%, similar to oxide bonded shelves, so use of kiln wash may be advised.

Advancer® is a patented brand of silicon carbide nitride bonded shelves manufactured by Saint-Gobain Ceramics. The Advancer product line was originally developed in the late 1980's for the commercial porcelain industry in Europe and soon found its way into the sanitary ware market and other technical applications. All Advancers are 5/16" thick. A 12" x 24" Advancer weighs a bit over 9 pounds, providing for faster heating and cooling. Kiln wash is not necessary to protect the surface and glaze accidents can be removed by scraping with a putty knife and as needed, a light application of an angle grinder. The shelf is produced by slip casting using careful quality control of the materials. The shelves are composed of 70% silicon carbide and 30% silicon nitride bond. The maximum firing temperature is 2642°F. The shelves are fired twice, the first time in a nitrogen atmosphere to a top temperature that is proprietary to the company, though is probably in the 2700°F range. A second firing, oxidizing in air, produces a very tight oxide layer. This process produces a shelf that has a porosity of <1%.

Because of this very low porosity, potters must understand a couple of issues with Advancers. Because these shelves are so tight, if they get wet, it is difficult to remove the moisture by evaporation and if they are fired prior to removal of all water they may explode. Saint-Gobain Ceramics published a technical bulletin warning regarding exposure to prolonged moisture penetration, including rain, snow and condensation. These shelves should be stored in a dry enclosed area. This bulletin outlines a specific regiment to follow to slowly heat the shelves to safely remove moisture.

Many porcelain clays may be subject to "plucking" when fired on Advancers. Plucking is a situation where the clay may partially fuse to the shelf, resulting in areas breaking off the foot or bottom of the pot. This issue can be resolved by adding a small amount of alumina to cold wax prior to waxing the bottom or sprinkling a small amount of alumina on the kiln shelf.

Advancers are also subject to issues with uneven thermal gradiant (the temperature across the shelf) that if significant enough may lead to failure. Direct flames on the shelves and crash cooling are instances that may lead to thermal breakage.

Advancer may be used in soda/salt so long as a soda/water solution is not sprayed onto the shelves. They may also be used for wood firings, but must not be in the path of direct flames.
For more detailed information about Advancer, readers are directed to the following links to articles found on the Smith Sharpe web site: www.kilnshelf.com.

Some personal observations:

I have been involved with firing ceramic ware since 1972. I have fired a variety of brands and sizes of electric kilns. I have also participated in building/firing gas fired kilns and have fired a variety of commercially manufactured gas fired kilns. There are manufactured gas kilns that are very well engineered that make firing a fairly simple operation.
In addition to my kiln experiences, I have also used a variety of kiln shelves. Back in the 1970's potters were often limited in their shelf options. Usually ¾" silicon carbide shelves were used in fuel fired kilns and cordierite shelves were the choice for electric kilns.
Potters now have several options, with each type of shelf having advantages and disadvantages.

In our school gas fired kiln I have begun a long term testing of all of the shelves I have written about.
We have been using Advancer shelves in the kiln for about 2 years. We have never applied kiln wash to the shelves. We have experienced many glaze run issues and have even had a low fire clay pot mistakenly included in a cone 10 firing. In all instances most all of the glaze pops off with a putty knife. A quick application of an angle grinder removes any remaining glaze. I have noticed the shelves will pluck pieces of the kiln post that remain attached to the shelf and require the use of the angle grinder. Coating the post ends with alumina may resolve this. I have not observed any warping of the Advancers.

The old silicon carbide shelves are warped from years of firing and not flipping them. They are very heavy and are held in reserve to finish loading a firing if needed. I will be flipping these shelves to see if they will flatten out over time. Some have small cracks, but have been that way for many years, and the cracks have not enlarged.

The oxide bonded silicon carbide shelf that came from the factory with a coat of kiln wash seems to be holding up well, though after two firings it came out of the kiln with a rather glossy surface on the unwashed areas. Whether this is due to oxidation of the silicon carbide creating a glassy surface is unknown.

We decided not to apply kiln wash to the nitride bonded silicon carbide shelf to test how resistant the shelf might be to glaze accidents. The one glaze run that occurred so far came off fairly easily with the angle grinder. Porcelain clays are subject to plucking on these shelves. After 3 firings I have noted a slight warping of the shelf. I will continue to monitor this very carefully.

The shelf manufactured by Resco, that has the openings through it, seems to be holding up well in the cone 10 firings. I did notice the shelf color has darkened and the surface seems to be more vitrified. Some glaze drips have gotten through a layer of kiln wash, into the shelf that required removal with an angle grinder. This has resulted in small areas of the shelf being ground away. I am pleased to see this product on the market as I think this may be a good alternative for folks with larger top loading kilns that need something lighter in weight than the 1" thick solid cordierite shelves.

I would like to thank all of the individuals and companies that have provided me with valuable information, product samples and full shelves for testing in cone 10 reduction firings:

Jon Walls, Euclid's Elements/Euclid Kilns, http://www.euclids.com/ 1-800-296-5456 ex 223 jwalls@pshcanada.com oxide and nitride bonded silicon carbide shelves and more, Jon also put me in touch with his supplier:

Peter Wu, Ashine Industries Inc., http://www.ashine.com/ 416-493-5187 ashine@ashine.com manufacturer in China of oxide and nitride bonded silicon carbide shelves

Jim Wunch, Larkin Refractory Solutions, http://www.larkinfurnace.com/, 678-336-7090 lrs@larkinrefractory.com supplier of oxide and nitride bonded silicon carbide shelves and other refractories

Sue, Bailey Ceramics Supply and Bailey Pottery Equipment Corp, http://www.baileypottery.com/ 800-431-6067 info@baileypottery.com high alumina, cordierite, oxide and nitride bonded shelves

Kevin Frederes and Eric Nedreberg, Resco Products Inc, http://www.rescoproducts.com/ 888-283-5505, Kevin.Frederes@rescoproducts.com , eirc.nedreberg@rescoproducts.com producer of Corelite high alumina cordierite shelves

Jon Pacini, Laguna Clay Co, http://www.lagunaclay.com/ and http://www.axner.com/ 800 4-LAGUNA, 800-843-7057, jpacini@lagunaclay.com
supplier of cordierite, oxide and nitride bonded shelves, Advancer shelves

Dona Turbes and Marshall Browne, Smith-Sharpe Fire Brick Supply, http://www.kilnshelf.com/ 866-545-6743, dona@ssfbs.com , marshall@ssfbs.com
Primary supplier of Advancer and Crystolon shelves and other refractory materials

Mike Arbini, Saint-Gobain Ceramics, http://www.refractories.saint-gobain.com/ 817-545-2867, Michael.a.arbini@saint-gobain.com
Producer of Advancer and Crystolon shelves and other advanced refractories