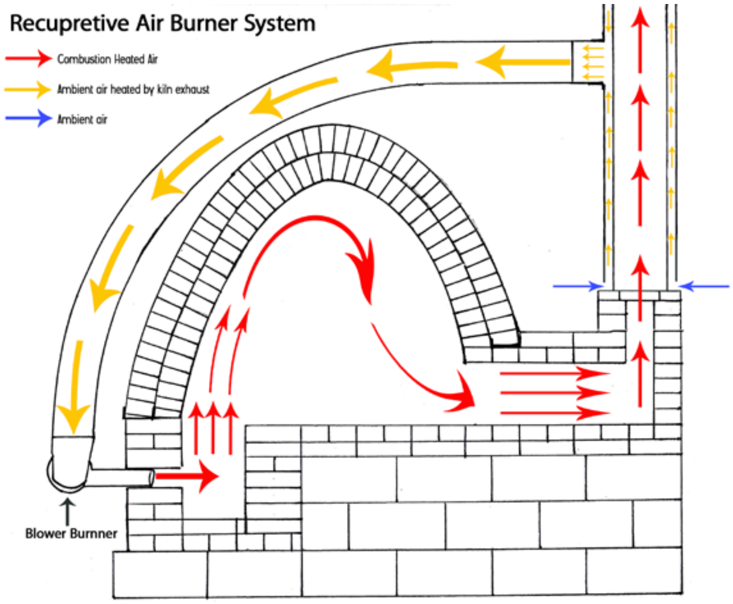
Fuel-Efficient Firing with a Recuperative Air Burner System

Steve Belz shares his research on an environmentally responsible firing system

As a graduate student at Kansas State University and an environmentally conscious ceramist, I recently set for myself the objective of reducing the fuel consumption of our department's natural gas kilns. The opportunity arose to investigate sustainable, energy-efficient kiln modifications and designs when ceramics professor Dylan J Beck and I received a University Small Research Grant in the autumn of 2010. Utilising a recuperative air burner system to increase fuel efficiency, an oxygen (O_2) sensor for atmospheric readings and analysis of firing practices as well as fuel-efficient materials, we achieved a significant reduction in fuel consumption without sacrificing the durability of our kiln or the aesthetics of the ware. Any ceramics artist interested in saving money and time on firings may benefit from our experimentation, since the modifications that we made are applicable to any new or existing kiln.

The base for my research was a 12 cubic foot (.33 cubic metre) soda kiln that we constructed in the autumn of 2010 by employing a catenary arch, cross-draft design and a supply of reclaimed, medium-duty, hard brick. Although reusing the hard brick might initially have seemed consistent with our overall goal of promoting sustainability, the high thermal mass of bricks led to a consumption of nearly 40 percent more fuel by our new soda kiln than by our other relatively low-thermal-mass, soft-brick kilns of comparable size. Due to the higher fuel consumption of the hard-brick kiln, the potential benefits of adding the recuperative air burner system were obviously greater. Fuel consumption could, of course, have been significantly reduced by constructing a soda kiln out of soft brick but that would have necessitated a shielding of those materials from the soda vapour in order to protect them against rapid erosion. When soft brick is used for soda kiln construction, a kiln wash – such as one with which we routinely coat every surface of our shelves (recipe provided at the end of this article) – must be applied to the interior. Regular inspection and maintenance is crucial after each firing, since such coatings are prone to flaking and chipping over time. Kiln debris from this deterioration tends to fall on to wares, leaving dry, white flakes that ruin surfaces. Although we chose to build our soda kiln from hard brick partly because an ample supply was at hand, we also took into consideration the ability of such brick to resist soda-vapour corrosion.



Facing page: ***Figure 1.*** *Assistant Professor Dylan J Beck sprays soda into Kansas State's soda kiln that utilises a recuperative air burner system to reduce fuel consumption. Above:* ***Figure 2.*** *Illustration of soda kiln with recuperative air burner system by the author and Dylan J Beck.*

To obtain our initial data, we regularly fired the new soda kiln over a period of several months to cone 6 (1200ºC) and cone 10 (1300ºC) using six traditional MR-750 Venturi burners (450,000 btu total with seven water column inches). I recorded the consumption of natural gas by checking the service meter before and after each firing. Upon receipt of our research grant, we removed the Venturi burners and installed two Ward blower burners (model #MB200)(426,000 btu total with seven water column inches) with modified high-temperature capable (400ºF [204ºC]) blowers. We did so because blower burners have the capacity to direct otherwise wasted hot air from around the chimney back to the burners.

The recuperative air burner system incorporates a 48-inch (122 cm) section of stainless steel, double-walled chimney pipe located above the damper and below the roof. Exhaust heat exiting the kiln via the internal chimney pipe (12 inch [30 cm] diameter) radiates and heats the air contained by the outer pipe (16 inch [40 cm] diameter). This hot air is then forced by the blowers, via an eight inch (20 cm) diameter, galvanised steel pipe, over the top of the kiln and back to the primary air source of the burners (see figure 2). The warmer the preheated air, the more efficient is the combustion. According to our data, the recuperative air system has consistently produced a 10 percent reduction in natural gas consumption per firing.

When designing any recuperative air burner system, one should carefully consider several key questions. First, what part of the kiln radiates the hottest air to be captured by a heat exchanger? The answer will vary but most kilns can be easily modified at the chimney, just above the damper. We chose to install our heat exchanger at the chimney in order to make reinstallation easier on the next kiln through a simple re-ducting of the eight inch (20 cm) supply pipe to the burners. In other situations, however, it might be best to install the heat exchanger above the arch of the kiln or around the firebox. I suspect that a modest increase in pre-combustion air temperatures could even be achieved by simply enclosing the area around the burners with a sheet metal box. Calculations should, of course, be made to ensure that the holes in the sheet metal are equivalent in area to the holes for the burner ports in order to ensure that the burners

Specifications for recuperated air burner system
• Burners Ward blower burner model MB200 with special 400ºF blowers.
• Cubic Feet a Minute (CFM) of air for each blower: 129 CFM max.
• Btu of each burner: 213,000 at seven water column inches.
• Supply pipe: eight inch diameter Double walled chimney pipe: inner = 12 inch diameter, outer = 16 inch diameter.

Top left: ***Figure 6.*** *The soda kiln's intake and exit ports were built oversized and to standard size brick dimensions for easy modification of the burners.*
Above: ***Figure 5.*** *Assistant Professor Dylan J Beck and Graduate Student Jarred Pfeiffer admiring the test arch for the soda kiln. 2010.*
Centre left: ***Figure 7.*** *The first layer of the arch completed.*
Below left: ***Figure 9***. *Completed kiln with recuperative air burner system.*
Below: ***Figure 10.*** *Close up of Ward MB-200 blower burners and the preheated air duct.*

receive ample oxygen for efficient combustion.

A second key question is: How will the radiated heat be returned to the burners? The hot air must be moved by means of a fan if high levels of efficiency are to be achieved but the fan can either push the preheated air or pull it. The more cost-effective method of pushing the air can be achieved with a standard blower. Pulling the preheated air requires the installation of more costly, specialised blowers capable of withstanding temperatures above 180ºF (82ºC). We purchased the 400ºF (204ºC) blowers due to cost and because the quantity of air that they were capable of moving was adequate for the volume of our kiln.

My research also included a comparison of rates of fuel consumption during cone 10 (1300ºC) and cone 6 (1200ºC) soda firings, both of which were 10 percent lower than before we installed the recuperative burner system. The cone 10 (1300ºC) firings, however, consistently consumed 20 percent more fuel than the cone 6 (1200ºC) firings due to the fact that the burners were on full power for an average of two hours longer. This information is particularly useful for those who are interested in saving fuel and shortening their firing time while making only a small financial investment. After testing cone 10 (1300ºC) clay bodies and glazes and lowering them to cone 6 (1200ºC) or switching to existing cone 6 (1200ºC) clay and glazes, one could easily cut the firing time by a couple of hours and save roughly 20 percent on fuel costs. Changing from cone 10 (1300ºC) firing to cone 6 (1200ºC) firing in combination with the use of a recuperative air burner system could increase savings to 30 percent of prior cone 10 (1300ºC) fuel costs. If one is working with stoneware clay bodies, I would argue that essentially the same surfaces and ware durability can be achieved at cone 6 (1200ºC) as at cone 10 (1300ºC), in soda as well as in other gas reduction firings (see figure 3 and 4).

Top: ***Figure 4.*** *Jarred Pfieffer.* ***Bulbous.*** *2011. 6 x 7 x 7 in. (15 x 17 x 17 cm.) Fired to cone 6 (1200°C), soda fired stoneware.*
Above: ***Figure 3.*** *Chris Graber.* ***Jar****. 2010. 25 x 22 x 22 in. (63 x 56 x 56 cm.) Fired to cone 10 (1300°C) soda fired stoneware.*

The oxygen sensor made possible a precise control of the atmosphere in our kiln and helped us to reproduce positive results. During the early stages of a firing, many potters tend to produce overly oxidised atmospheres, unnecessarily cooling the flames. A neutral atmosphere produces the greatest temperature rise while expending the least amount of fuel. Later in the firing, some potters reduce too heavily, wasting unburned fuel that escapes through the chimney. These problems can be avoided through the use of an oxygen sensor, which provides precise readings of the atmosphere inside the kiln regardless of external weather conditions.

My research has focused on the fuel consumption of kilns and some of the efficient materials, devices and practices that are available to potters today. An oxygen sensor, by providing a precise reading of the atmosphere in the kiln, allows the operator to reproduce positive results and to use no more than the necessary amount of fuel. Fuel consumption can also be reduced by roughly 20 percent simply by lowering the firing temperature from cone 10 (1300ºC) to cone 6 (1200ºC). Adding a recuperative burner system, as we did, can reduce fuel consumption by an additional 10 percent when the recuperated air temperature is 290ºF (143ºC) and fuel savings as great as 30 percent may be attainable when recuperated air temperature reaches 1000ºF (537ºC) (Rebello. 1980.). A recuperative air system holds great potential for fuel consumption reduction and widespread practical use, both in retrofits and in new kilns. Combining the system with other strategies yields the greatest energy savings and, in my experience, does not entail any sacrifice of desired aesthetic results.

Kiln Wash Recipe

Edgar Plastic Kaolin (EPK)	*25%*
Kaolin (calcined)	*25%*
Alumina Hydrate	*50%*

Apply with a brush in thin even coats, perpendicular to each other.

Citation
Rebello, Kohnken and Phipps, "Estimation of Fuel Savings by Recuperation of Furnace Exhausts to Preheat Combustion Air". (Proceedings from the Second Industrial Energy Technology Conference, Houston, Texas, US, 13–16 April, 1980.) Pp 301–308.

After many years as a potter and carpenter in Colorado, Steve Belz returned to school to focus on sculpture and to pursue a Master of Fine Arts Degree. He is currently in his final year of graduate school at Kansas State University.