# a Change in the air

LIFE AS A STUDIO POTTER comes complete with its own demons. Working alone, day in and day out, one gets to visit with them pretty regularly. I made a list once of the seven deadly sins for potters, and the two big ones, for me, are Fear and Guilt.

I believe in challenges – especially if they lead you to the very depths of the things you want most to avoid. This is what led me to take a look at the idea of "best practices" for potters and ask some questions about our impact on the environment. Perhaps I was about to take a long hard look at things no potter should consider. But I've learned that my work needs to be honest, and I was starting to think I needed to be honest about the process.

I had come face to face with a couple of my seven deadly sins in 1991, when I decided to build my first salt kiln. Fear and guilt churned inside me. What was in that cloud that came out of the chimney when you introduced salt? Investigating my options, I read an article about a stainless steel scrubber that kept any emissions from getting into the air. Everything I learned convinced me that it would take more energy and cause more pollution to produce the stainless steel for the scrubber than it would to fire my small kiln every eight weeks for years. (In fact, I discovered that driving my car for one hour at 70 mph would produce more pollution than a single firing.) Choosing to give up driving during my firing week was the first time I utilized the idea of "trade-offs" to balance my carbon footprint.

In 2006, wanting to inspire my students, challenge myself, and breathe new life into the program I was running for the city of Boulder, I proposed building a wood kiln. I was told I needed a building permit, and that in order to get the building permit I needed to be EPA-compliant within two years. What exactly did that mean? I put out the call to see if anyone knew if their kilns were EPA-compliant. The complete lack of response made me realize that I wasn't the only one living in fear, and maybe with good reason. If kilns get shut down, potters can lose everything.

Sometimes the people you need are right there in front of you. Chris Hicks is a potter and engineer in my Thursday night class. Chris suggested we start a research project to see if kilns could meet air-quality standards. I had recently come back from one of the wood-firing conferences and I knew that potters were trying to manage concerns around firing with wood and wood kiln emissions. Chris contacted the university and that led us to Michael Hannigan, an expert on combustion engineering in the mechanical engineering department, and John Zhai in the environmental design department, both at the University of Colorado. We talked about measuring, quantifying, and reducing or eliminating unwanted emissions from our wood kiln without compromising the firing process or the surface quality of the work. Mike and John sent over a group of graduate students and they started researching the EPA requirements. While they were doing their homework, I read as much as I could about wood firing, but found very little published about the impact potters have on the environment.

By the time the kiln (dubbed "Whale Spirit") was built, my graduate students had good news. There are no EPA regulations for the size and kinds of kilns that potters fire, so technically we were already compliant. We thought about taking the information over to the planning department and being done with the research, but I still wanted to answer some questions.

First, where were we going to get the five or six cords of wood we needed to fire our new 150-

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cubic-foot anagama? We contacted Jeff Sorkin from the U.S. Forest Service and to our delight he joined the research team. In Colorado, thousands of pine trees are currently being killed by a beetle infestation and Jeff hoped we could put the diseased wood to good use. Unfortunately, if we brought the beetle-infested wood to our site, we only had five weeks before the beetle eggs would hatch and spread the infestation. We needed six months to a year to cure the wood before we could use it to fire. It was a great disappointment.

With the first firing scheduled, I needed to find an alternate source of wood. I asked, and wood started appearing at the site from students, tree trimmers, helpful neighbors, and friends. Before I knew it we had accumulated nearly ten cords of wood. (Many potters know about this mysterious support that warms us to our cores.) Shortly after our first firing, however, we were put in touch with other Forest Service and open-space contacts. They had begun to thin the forests, taking out healthy trees in order to fight the spread of the beetles. We became the beneficiary of a steady supply of pine that was going to become waste anyway, and we agreed to continue working with the U.S. Forest Service to try and find ways to use the beetle-killed wood for future firings.

I know we all love our kilns, but this kiln was special. In the very first firing it was even from top to bottom and from side to side. I had fired with several wood-kiln groups in the past and it seemed that we always struggled just to reach temperature. "Whale Spirit" fired like a gift from the gods.

But after seeing the black smoke I began to wrestle with fear and guilt again. I had my research team come to observe the next firing. They explained that I was panicking about *visible* emissions. If you see something, it is fairly heavy and therefore a lot of it will fall to the ground. Visible emissions were a nuisance, but it was far more likely that the unseen gasses might be more problematic.

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Reducing the visible particulates was relatively easy. An old device called a cyclone can be installed on the top of a chimney; the velocity of the flame swirls the particulates, burning more of them, collecting unburned particulates, and reducing what is released into the air. There are also catalytic converters that filter out particulates. Either of these options would reduce the visible smoke, but they are expensive to build or buy and would have to be retrofitted to work on a kiln. Having been a potter for thirty years, it has been my experience that potters often live on the edge. Getting potters to keep a special device in working order seemed an unrealistic goal. I wanted to find other ways to address the issue, knowing we could always come back to a catalytic converter or a cyclone if we had to.

Visible emissions are a problem because if your neighbors see the smoke, they might complain. If they

smell the smoke, they will complain. And you can be sure that if the smoke is entering their space, they will complain loudly. Most kilns are threatened because of a nuisance complaint. But I also had to ask myself: what if carbon monoxide could enter your neighbor's space. Could it be harmful?

Without a lot of funding for the research project, it was up to us to find ways to quantify the emissions and look for a way to reduce or eliminate the problem. Like most potters who fire with wood, we watched the chimney to call the next stoke. When the smoke was gone, it was time to feed the firebox. We took time to record each stoke and write down how black the smoke was and how long it lasted. Regulatory departments use an opacity test to regulate air quality emissions. In Colorado you cannot exceed twenty percent opacity. Because we produce smoke intermittently, we would average the opacity over a 24-hour period.

Our chimney has a spark arrester, a square box placed about fifteen inches above the chimney. It has two different screens welded in place to keep large sparks from coming off the stack. The idea is that all sparks need to be completely out before they hit the ground, to avoid the chance of starting a ground fire. This gave us a visual marker to see how far up the particulates would rise into the air after they left the chimney, how dark the smoke was above the spark arrester, and how thick the smoke appeared between the spark arrester and the chimney. We used a system of white to gray, dark gray to black, for our records. A constant dark gray would be twenty percent opacity. Over a 24-hour period we recorded our emissions in fifteen-second intervals for six minutes after every stoke. We also recorded the weather, documenting humidity, wind, rain and snow, as well as the amount of wood in each stoke and how quickly the temperature increased each hour.

Keep in mind, I had built an anagama, enticed a group of students and potters from the community to help me fire it, and now I was asking them to record every stoke and keep detailed records of the entire firing. I expected them to revolt, but to my surprise they dedicated themselves to the task.

During the first year, we fired five times, experimenting with several ways to reduce the smoke. First we changed our stoking pattern, putting in less wood more often. This turned the black smoke to gray, and if we paid close attention we could eliminate the plume completely. With this new pattern we were still able to adjust the temperature as before and used the same amount of wood in the same 100 hours.

We then introduced air into the chimney at the floor level, using a leaf-blower set on idle and turned on after each stoke, like an afterburner. This also worked, with the same amount of wood and the same firing schedule. The big difference was that we were using fossil fuel to run the leaf blower. We felt confident that we could reduce or eliminate the visible emissions, and decided to adopt the new stoking pattern for future firings.

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reduced and had similar ash accumulation as those from the firings with visible smoke. This confirmed that black smoke doesn't mean reduction; it means waste. We could achieve our desired results without producing excessive black smoke. We had learned a great deal. Now it was time to try to gather more accurate information.

I met with the research group and asked them to list all of our emissions and pollution concerns. In our discussion they kept saying that wood had zero net emissions. What exactly did that mean? We were putting $CO_2$ back into the air. How could we claim zero $CO_2$? Here's how:

We all know that carbon has an impact on the environment. What I hadn't understood was that although firing with wood gives off carbon, it is carbon that would be released into the atmosphere anyway. A tree absorbs carbon and gives off oxygen during its life; this is a good thing. When the tree dies and rots, or if it is burned, it releases the exact amount of carbon it absorbed. This balance has been going on since the beginning of time. But when we bring up fossil fuels from deep in the earth, we release carbon that has been sequestered for millions of years. In a sense, it has been forgotten and is no longer part of the natural exchange. So when using wood, you fire carbon neutral, but when you use fossil fuels you are adding unbalanced carbon to the air and contributing to greenhouse gasses.

The other point the research team kept making was that carbon monoxide indicates incomplete combustion. An obvious statement, but it made me realize I didn't want to waste fuel or cause an unhealthy environment for the stokers. We were getting more complete combustion when we changed our stoking pattern, but how much CO was still coming off the stack? The research team decided to take some samples from the stack to quantify our CO and $CO_2$ emissions and get an idea of the number of particulates leaving the kiln. John Downs, one of the graduate students, found a way to pull air from the chimney and run it through a measuring device to give us some actual numbers. For the first time, we would be able to measure exactly how much CO and $CO_2$ were present around the kiln.

With John's measuring device we were able to determine that the average particulate matter was 10 micrometers in diameter, with a density of 1 g/cm^3 (one gram per hour). While the density did vary and the particulates were reduced as the temperature increased, the number of particulates never exceeded air quality standards. Keep in mind, however, that the EPA is regulating industry. Small potters' kilns do not give off enough emissions to be of concern or be measured; the air quality or regulatory agencies are concerned with tons per year, not grams per firing. No studio potter will ever reach that quantity of pollutants. This doesn't mean we shouldn't do our best; it simply means we are very, very small in the scheme of things.

In Colorado it rarely rains, but we had one firing we called "the underwater firing" because it poured for the entire 100 hours, resulting in a "backwash" situation. ("Whale Spirit" was accurately named.) During this firing, the water concentration made the CO accumulate around the kiln instead of dispersing and dissipating. Our readings revealed that the moisture in the air had given us unsafe CO levels in the atmosphere. During the next couple of firings we monitored the air, but never experienced the high levels of CO around the kiln area again. This confirmed that weather conditions could affect our kiln site and stokers. Being aware of how far the CO, $CO_2$, and all the particulates were traveling led us to the next test.

Jeff Sorkin arranged an air quality test. We set monitoring stations around our kiln, following the predominant wind patterns. We put one monitor within ten feet of our kiln and one on top of the building near the kiln, and then moved them out to cover around 500 feet. The monitoring devices

recorded the air quality throughout the entire firing. We never exceeded safe levels of CO, $CO_2$ or particulates, and all of the readings were within normal air quality standards.

We were thrilled. We had successfully reduced the visible smoke, and we were finally able to say that we met air-quality standards.

This preliminary testing has led me to ask, what is the best way for us to fire? Electricity, natural gas, and propane seem more efficient in their use. Certainly natural gas is one of the cleanest fuels, giving off very few particulates, and electricity has no emissions when used, but is that the whole story? My initial thought was that electric kilns are the least polluting; certainly they would pass the opacity test. But electricity depends on where it comes from. If you are lucky enough to get your electricity from wind-generated power or a hydro plant, then it is a fairly clean option. However, most of our electricity comes from coal, and the process of making electricity from coal is three times more polluting than using natural gas or propane, not to mention the impact on the towns and cities that mine the coal and produce the electricity.

What about natural gas and propane? Both are fossil fuels, and both add carbon to the air, contributing to greenhouse gasses. What's more, the EPA explained that natural gas has over 1,000 $CO_2$ leaks just getting the natural gas to the customer. Using wood, which is carbon neutral, may turn out to be one of our best options. Because it is a renewable fuel and starts with zero net emissions, it has the benefit of a much smaller carbon footprint, but if we don't make an effort to achieve complete combustion or reduce the particulates, it contributes pollution in its own way. The most important thing is to find the right surface for your work, then to fire as efficiently as you can and find ways to reduce your energy use.

We are currently working on a carbon footprint calculator to help potters determine which fuel source is best for them, whether we should bisque fire or single fire, and what, if any, energy savings we see if we drop our temperature from cone 10 to 7 or 8. We also want to understand what trade-offs could be made to offset the impact of firing. How can we change our studio practices to avoid adding to our landfills or contaminating our water supplies?

As I look back over my list of the seven deadly sins for potters I realize there just may be an eighth – the sin of insulation. Insulating myself from the world around me kept me in fear. Stepping out into the community with intention, belief, and an open mind released me. We need to think globally and realize that every little change we make adds up. Learning the facts and living in truth will set us free.