by James E. Houck and Lyrik Y. Pitzman

In certain instances, burning corn was causing corrosion of metal chimneys. Answers were needed to two questions: Why, and what could be done about it?



Beyond a Kernel of Truth

Not surprisingly, corn-burning has increased in popularity due to the abundance of corn in North America, combined with the high cost of fossil fuels and the appeal of domestic renewable energy. Penn State's College of Agricultural Sciences, an independent proponent of corn-burning, lists 32 manufacturers of residential corn heaters on its Web site and many of these manufacturers offer multiple models.

The National Corn Growers Association (NCGA), which represents the interests of U.S. corn growers, boasts 32,000 members. Shelled corn is granular, can be fed from a hopper similar to pellets, and has a respectable heat content of about 7,000 Btus/lb (LHV at 15% moisture). What could be wrong with this picture?

Well, there is a rub. Some stainless-steel chimney systems and their chimney caps have suffered devastating failure after as little as several months of in-home use due to corrosion, apparently from the corn fuel. Further, there have been numerous anecdotal observations that the exhaust from corn-burning is harder on the interior of heaters and chimney systems than wood pellets or, for that matter, just about any other commonly used residential fuel. Is there a "kernel" of truth to there being a problem with corn fuel? The answer is yes.

To get an understanding of what is going on and to develop a more corrosion-resistant venting system for corn-burning, Simpson Dura-Vent sponsored OMNI Environmental Services to conduct some fundamental research. The results of the research tell a clear story. In light of the importance to the hearth industry and consumers, Simpson Dura-Vent authorized the release of the results.

Emissions from the combustion of corn are more acidic and have a higher salt content than those from other common fuels. Some stainless-steel alloys,

Pictured above are examples of the corrosive effects of burning corn.

> **"We had to do something. It was puzzling. Most venting systems that were installed with corn-burners worked fine, but there was a disturbing few that corroded after only a short time in use. We needed to understand the problem and develop a more corrosion-resistant product."**
>
> **– Steve Eberhard**
> **President & CEO**
> **Simpson Dura-Vent**

notably 430, 304 and to a lesser extent 316, corrode when exposed to these acid gases and salts, particularly when the acid gases and salts go into a solution in the water that condenses and accumulates near the terminus of the exhaust system.

Water condensation seems to be exacerbated by (1) long chimney systems that allow the exhaust to cool, (2) a cold climate that also tends to lower the chimney system's temperature near its terminus, (3) lower burn rates, which have commensurate lower chimney temperatures, (4) direct venting systems that tend to cool the exhaust, and (5) high moisture corn. (Shelled corn for fuel use preferably has a moisture content of 15% or less; however, some corn is harvested wet with a moisture content in the range of 22 to 28%.)

Analyses of both the raw, unburned fuel and the emissions upon its burning show that corn produces considerably more nitric acid, sulfuric acid, phosphoric acid, potassium chloride salt, and potassium sulfate salt than, for example, a typical wood-based pellet. Students of botany will understand why.

Mother nature makes seeds chemically different than stalks. Shelled corn is, after all, nothing but seeds and, in contrast, wood sawdust that makes up pellets is from the "stalk" of the plant. Corn, like virtually all seeds, is made up of endosperm, germ and pericarp. The endosperm comprises about 82 percent of the kernel's dry weight and is the source of energy (starch) and protein for the germinating seed. The pericarp is the outer covering that protects the kernel. The germ contains the genetic material.

Seeds have a high protein content compared to the stalk of a plant in part to sustain the plant before it gets established (protein in the endosperm) and in part because the genetic material is made up of DNA, which in turn is made up of proteins. Proteins contain about 16 percent nitrogen, hence corn contains much more nitrogen than wood. (Almost 30 times more when compared to the premium softwood pellets tested here.)

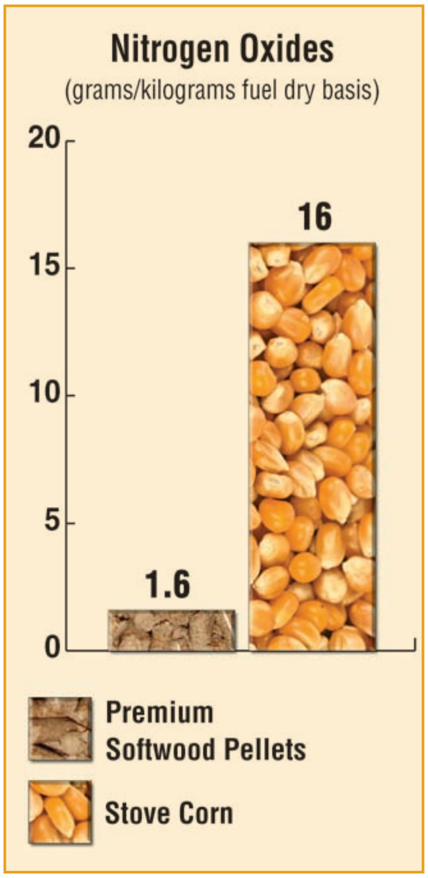
When the corn burns this nitrogen, it turns into nitrogen oxides; when the nitrogen oxides go into solution in condensed water, nitric acid is eventually formed. Similarly, seeds are enriched in phosphorous, sulfur and mineral nutrients as compared to stalk material for the same fundamental physiological reason. The result is that more corrosive salts (namely potassium chloride and potassium sulfate) and corrosive acid gases make it to the surface of the chimney from corn-burning than from wood combustion.

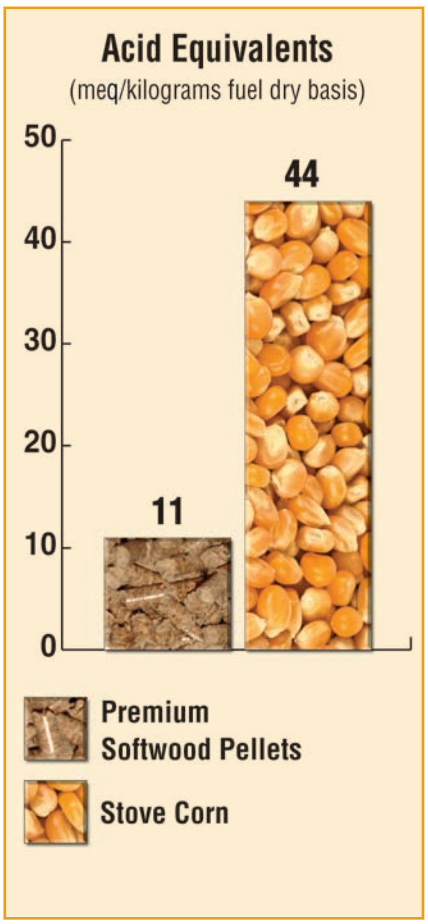
Once it was understood what corrosive agents were being emitted, it was relatively easy to make concentrated synthetic solutions that simulated the chemistry of the condensates from corn-burning emissions. Samples of various metals and alloys were subjected to these solutions at ambient temperature, at 200 °F, and at 570 °F. The ambient temperature tests and the tests at 200 °F were designed to bracket the temperature of the condensate near the terminus of the exhaust system where most corrosion has been seen. The 570 °F test was designed to approximate the maximum expected temperature. (ASTM E1509-04 specifies that the maximum flue gas temperature is 500 °F above ambient for L-vent pipe.)

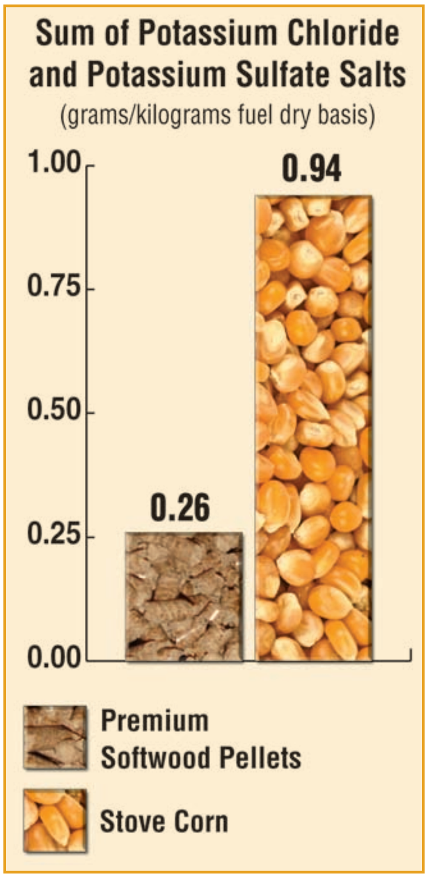
The results of the tests clearly confirmed what has been seen in homes. Namely that 304 and 430 stainless steel corroded; 316 stainless steel showed significant corrosion but not as severe as 304 or 430; pure copper, as expected, was severely damaged and, notably, two superferritic stainless-steel alloys showed high resistance to corrosion and are being considered for a new line of prod-

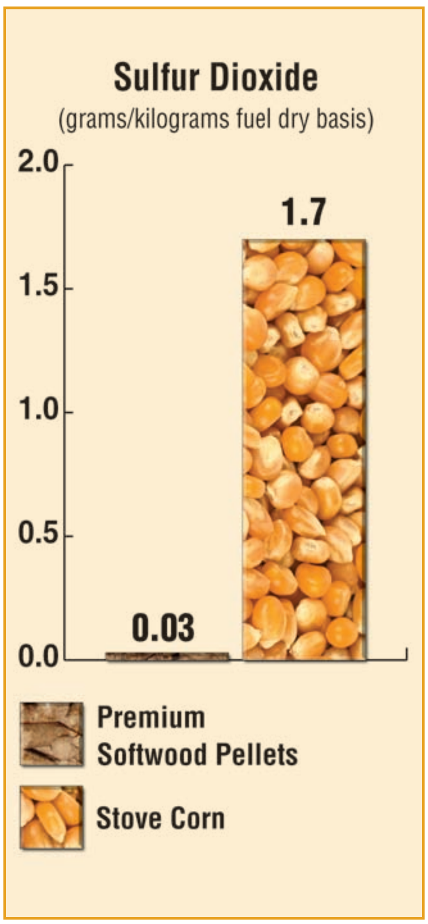
Stove Corn and Premium Softwood Pellet Fuel Comparison

Component	Percent in Fuel		Comparison of Potential Corrosion Effect
	Premium Softwood Pellets	Stove Corn	
Moisture	5.3%	12.8%	Typical corn fuel has more water as compared to most wood pellet fuels. If all else is equal there is more condensation to provide a corrosive environment.
Inorganic Material (ash)	0.15%	1.4%	Corn fuel has almost 10 times more ash than wood pellets. More corrosive water-soluble salts, notably potassium chloride and potassium sulfate are contained in the ash.
Sulfur	0.01%	0.10%	Corn fuel has 10 times more sulfur than wood pellets. The consequent formation of sulfuric acid and soluble sulfate salts in condensed water is higher.
Nitrogen	0.04%	1.16%	Corn fuel has 29 times more nitrogen than wood pellets. The consequent formation of nitric acid and nitrate salts in condensed water is higher.
Phosphorous	0.007%	0.26%	Corn fuel has 37 times more phosphorous than wood pellets. The formation of phosphoric acid and phosphate salts is higher.









The Corrosion Potential of Other Seeds

Conceptually there is little difference in terms of chemistry and the related corrosion potential between corn "seeds" and other seeds such as wheat, sunflower, barley and cherry pits that have been used for fuel. In fact, studies with livestock rations have shown that wheat and barley have even more protein and commensurately more nitrogen than corn.

There is also an additional corrosion issue if feed grain fortified with additives or material for use as planting seeds that is coated with pesticides or fertilizer is inadvertently and inappropriately used as a fuel. Almost in all cases, the additives would exacerbate the corrosion potential of the fuel.

Finally, it should be noted that there is a financial incentive to burn old, treated seed since its "shelf life" is about 18 months and, once it has expired, it has little value – it is not very viable as a seed and it can't be fed to animals due to its additives.

ucts designed for corn-burning.

Meanwhile, before new chimney systems are available, owners are encouraged to follow "best practices" to minimize corrosion. These include avoiding burning wet corn, avoiding fortified feed corn or treated seed corn, avoiding burning at the lowest rate for an extended length of time and, if remodeling or a new installation are planned, minimizing the length of the chimney system if possible.

About the authors: Dr. James E. Houck is president of OMNI Environmental Services. Lyrik Y. Pitzman is an environmental scientist. They can be reached at (503) 643-3788, houck@omni-test.com or pitzman@omni-environmental.com. Visit www.omni-environmental.com for related technical publications and services.