# Retrofitting Tobacco Curing Barns

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Recent research has shown that a class of carcinogenic (cancer-causing) compounds known as tobacco specific nitrosamines (TSNAs) may be formed in flue-cured tobacco leaves during the curing process. These compounds are not found in green (uncured) tobacco. Present research suggests that TSNAs are formed through a chemical reaction between nicotine and other compounds contained in the uncured leaf and various oxides of nitrogen (NOx) found in all combustion gases, regardless of the fuel used. Eliminating NOx compounds in the curing air by using a heat exchanger system has been shown capable of reducing TSNAs to undetectable levels in cured tobacco. The direct-fire curing systems currently in use in most U.S. curing barns are considered to be the major factor contributing to elevated levels of TSNAs in U.S. flue-cured tobacco. Further, there is no known fuel treatment or burner design that can eliminate these nitrogen compounds from combustion gases without the use of a heat exchanger (found in all indirect-fired systems). It is believed that reducing the levels of TSNAs in tobacco products would reduce some of the health concerns associated with tobacco use.

To receive price support for tobacco grown in 2001 and thereafter, producers must retrofit, or change, all barns used to cure the crop to operate with indirect-fired curing systems. An indirect-fired system passes the combustion gases through a heat exchanger and out of the barn, thereby preventing the mixing of flue gases with curing air. Systems with the combustion entirely outside the barn and that conduct the heat to the barn with hot water or steam have proven entirely satisfactory for reducing TSNAs and are acceptable.

Research during the 2000 curing season has shown that converting from direct- to indirect-fired curing can reduce levels of TSNAs in cured leaf to below detectable levels (less than 0.1 part per million).

## Older Barns

Most bulk curing barns built before the mid-1970s were indirect-fired. They had a heat exchanger and flue that directed the combustion gases out of the barn (fuel oil burners). A number of these barns are still in use. Some tobacco samples taken from these older indirect-fired barns during the 2000 curing season were found to have very low to undetectable levels of TSNA. This does not mean that all older heat exchanger barns will produce satisfactory tobacco. Some samples taken from other older indirect-fired barns were found to have TSNA levels approaching those found in direct-fired barns. This suggests that the heat exchangers and flues in these barns may have cracks or holes that allow combustion gases to escape into the barn. This is unacceptable. Growers planning to use older heat exchanger barns should closely inspect them for leaks by using smoke bombs or lights. Your oil or gas dealership representative may be able to help you with this inspection. It is necessary to completely replace the heat exchanger and/or the burners if the old ones are no longer in good working order or cannot be repaired.

## Making Your Own Retrofit

After evaluating the design, price, and availability of commercial retrofits, some growers have built their own or contracted with a local fabrication shop to build units for them. All of these homemade units tested so far have proven satisfactory in lowering the levels of TSNAs in the cured leaf. Additionally, many are relatively efficient in terms of fuel use and apparently have good airflow characteristics. Unfortunately some homemade units have proven uneconomical due to a less than adequate heat exchange area. Stack temperatures (the temperature of the flue gases at a point just as they exit the heat exchanger) have exceeded 1000 F in some cases, allowing most of the heat to escape the barn. Other homemade units have experienced warping and cracking where poor design or material selection did not allow for thermal expansion during firing. If you build your own, be sure to use a design and materials proven reliable in the severe thermal cycling conditions of a curing barn.

## Considerations for Selecting the Right Retrofit for Your Barns

With the many different retrofit designs on the market and the limited time available to make a decision, choosing the best one for your particular situation may be difficult. Further, some companies that contract directly with growers to purchase their tobacco may specify which barn and/or burner system must be used. Other buying companies have stated that they have no preference as long as the system substantially reduces the levels of TSNAs in the tobacco and otherwise complies with the specifications and recommendations of the Tobacco Leadership Group. In either case, growers who anticipate contracting, now or in the future, should ask potential buyers about any such specifications.

Experience during the 2000 curing season has shown that the place to start looking for a suitable retrofit is with the manufacturer of your barns. Presumably, this company will have more detailed information on the heat and airflow characteristics required to give a satisfactory cure with your equipment and should be more willing to offer retrofits for its own equipment. This has not always been possible, however, since some barn manufacturers are no longer in business or are not offering retrofits at this time. If you find yourself in this situation, you may want to closely review the following points.

### Fuel Type

LP (liquified petroleum) gas is a by-product of the natural gas industry and consists primarily of propane and butane. It contains approximately 90,500 Btu per gallon. Fuel oil contains approximately 138,000 Btu per gallon. A gallon of fuel oil contains about one and one half times as much energy as a gallon of LP gas. The cost per gallon of both LP and fuel oil fluctuates from season to season and year to year. Because they may be freely substituted in many applications, they do, however, tend to track each other and cost about the same most of the time. Locally, you may be able to find LP gas cheaper than fuel oil (on a cost-per-Btu basis) this year, but next year may be the opposite. The best prices for either type of fuel are to be had by contract buying in bulk lots.

## Heat Exchanger Composition

Commercial heat exchangers for curing barns are presently made of carbon steel, aluminum-coated carbon steel (aluminized steel), one of several grades of stainless steel, or a combination of materials. There are potential benefits and liabilities associated with each. Stainless steel is more resistant to rust and corrosion than carbon steel, so it is less likely to rust or burn out during the expected life of the barn. However, the heat transfer of stainless steel is only about 25 percent that of carbon steel of the same thickness. To compensate for lower heat transfer, a stainless steel heat exchanger would have to be made of thinner material and/or have a greater surface area than one made of carbon steel. On the other hand, a carbon steel heat exchanger could be twice as thick as a stainless steel heat exchanger of the same design and still have better heat transfer characteristics.

A heat exchanger in a bulk curing barn may experience several thousand heating/cooling cycles during a six- or seven-day cure. All metals expand and contract upon heating and cooling, but stainless steel expands and contracts twice as much as carbon steel. Thermal cycling was the prime cause of failure experienced with some stainless steel heat exchangers during the 2000 curing season. No crack failures have been reported with carbon steel heat exchangers. Cracks defeat the purpose of a heat exchanger because they allow combustion gases to enter the curing barn and contact the tobacco. Before you select a heat exchanger, be sure to closely question the manufacturer concerning thermal cycling and any report of cracks. Some tobacco samples taken from indirect-fired barns during the 2000 curing season had elevated levels of TSNAs traced to cracked heat exchangers. Use the same method described above for testing older heat exchanger barns if you suspect a cracked new heat exchanger.

## Airflow

Any heat exchanger will produce some resistance and therefore reduce airflow through the barn to some extent. While most manufacturers have been careful to avoid designs and installations that restrict airflow, the minimal restriction in some cases may lengthen the curing time or contribute to curing problems such as scald, swelled stems, or barn rot. If you have had such problems with a barn before retrofitting, these problems may be more likely after retrofitting. There are only two remedies for poor airflow. The easiest remedy may be to reduce air resistance by reducing the amount of tobacco in the barn. Often even a 5 or 10 percent reduction can have a big effect on the airflow. The other remedy is to increase the airflow. This may be done by increasing the fan rpm or by increasing the angle on the fan blades. In some cases an entirely new, more aggressive fan blade may be necessary. Note that increasing the rpm or fan angle will increase the horsepower and hence amp draw to the fan motor. A competent electrician should check your fan with an amp meter. If it is already at or near the nameplate-rated amperage, you must replace the motor with one of a larger horsepower rating before you change the fan or fan rpm. Operating an electric motor above its rated amperage for even a short period is dangerous and will result in rapid burnout of the motor. Remember that no matter how good the barn, retrofit, or tobacco, if you cannot get air to the tobacco, you cannot cure it. Barn rot, in particular, results in extremely high levels of TSNAs in the cured tobacco and completely negates the effects of retrofitting.

Experience with retrofitted barns during the 2000 curing season has shown that vent settings may need to be altered to maintain the proper wet-bulb temperature. Although few growers reported that the same or slightly less vent opening was required during leaf drying, many needed somewhat more opening to compensate for the air resistance of the heat exchanger. After a cure or two, most growers were comfortable with the new vent settings and pleased with the results.

Heating System Efficiency

The barn heating system consists of a burner and a heat exchanger. The direct-fired gas and oil burners used in curing barns before the retrofit project are very efficient because all the heat produced mixes freely with the curing air. There is no heat exchanger to direct the products of combustion along with some lost portion of the heat out of the barn. Since some heat loss is unavoidable with a heat exchanger, it is very important to gain as much efficiency as possible to control fuel costs. Energy efficiency, by definition, is the percentage of total energy inputted into the system that is put to practical use. In a burner/heat exchanger system, efficiency is complicated by the combination of many interrelated factors.

The Energy Efficiency of the Burner. Combustion is essentially a chemical process. A burner facilitates the conversion of the chemical energy contained in the fuel to heat. All fuels contain a certain and fixed heat content per unit measure. As an example, if an LP gas burner were 100 percent efficient, it would produce 90,500 Btu for each gallon of LP gas burned. In practice, some portion of the fuel passes through the burner unburned and is therefore wasted. A well-designed and -maintained burner limits this waste to no more than one or two percent.

The greatest reason for burner inefficiency is too little or too much air. In theory, a precise quantity of air is required to completely burn a precise quantity of fuel. Because of incomplete mixing, a limited but very important amount of excess air is required to get complete burning and the highest efficiency. When too little air is present, the burner will smoke. The smoke being partially unburned fuel. Smoke not only wastes fuel but can deposit soot inside the heat exchanger, where it acts as insulation. Even a thin coating of soot can considerably reduce heat exchanger efficiency. When too much air is present, the excess air cools the combustion gases and carries heat out before it can be captured by the heat exchanger. Adjusting the correct air-fuel ratio on a burner is essentially the same as adjusting the air-fuel ratio on an engine carburetor. Although an approximately correct burner air-fuel ratio may be set by eye (a blue instead of orange flame), the proper air-fuel ratio can be best achieved with a combustion analyzer. Combustion analyzers range in price from $500 to $5,000, are quick and easy to use, and can save a grower hundreds to thousands of dollars per year in wasted fuel. Some fuel dealers and retrofit manufacturers have these instruments for use in adjusting the burners of retrofitted barns. In addition, your local Cooperative Extension agent has access to combustion analyzers and can test your barns at no cost.

The Energy Efficiency of the Heat Exchanger. The energy efficiency of the heat exchanger is the percentage of the total heat entering from the burner that is extracted (exchanged) for practical use inside the barn. For the heat to be exchanged from the burning flue gases, it must pass through the walls of the heat exchanger. Many factors influence the exchange capacity and hence the efficiency of the heat exchanger. These include shape and size of the heat exchanger, its material type and thickness, the rate of hot gases flowing inside the heat exchanger, and the rate of air flowing over the outside surfaces of the heat exchanger.

Additionally, the rate of heat generation (Btu/hr) by the burner greatly influences the efficiency of a particular heat exchanger. A burner operating at a high capacity can easily overwhelm a modest heat exchanger designed for a smaller burner. Most modern fuel oil and LP gas burners are adjustable in capacity (Btu/hr) over a considerable range. For the most efficient operation, balance the burner and heat exchanger. The burner/heat exchanger system will operate most efficiently when the burner is operating at the lowest capacity that will allow the barn to maintain the desired temperature. The early part of leaf drying (barn temperature between 125 F and 135 F) is the part of the cure when the barn requires the most heat. Adjust the heat output of the burner so that the burner is operating nearly continually during this time. For example, a burner that is on for a minute and off for several minutes is probably operating at too high Btu/hr setting and inefficiently overwhelming the heat exchanger. Further, in the short time the burner is operating, the heat exchanger may be getting too hot, inducing severe thermal stresses in the metal and ultimately shortening its life.

Curing Efficiency

While heating system efficiency is the combined efficiency of the burner and heat exchanger, curing efficiency takes into consideration the entire process of tobacco curing. In essence, barn efficiency is the bottom line that is often conveniently expressed in terms of pounds of tobacco cured per gallon of oil or gas consumed. Considerable research has established that, on average, a well-maintained and -operated direct-fired barn will cure approximately 9 pounds of cured leaf per gallon of LP gas (or approximately 13 pounds per gallon of fuel oil). These numbers may vary considerably even in the same barn over a curing season because they are affected by such factors as barn loading rates, stalk position, weather conditions, the condition of the tobacco, and variations in vent settings, among others.

Because some of the heat is lost up the stack with a heat exchanger, a burner/heat exchanger delivering the same amount of heat (in terms of Btu/hr) to the curing barn as was delivered by a direct-fired system will necessarily require more fuel. In fact, during the 1999 and 2000 curing seasons, many growers did report using slightly more fuel. Others, however, reported no increase in fuel use or even that their retrofitted barns used less fuel. There are several possible explanations, with the most likely being that many of the direct-fired burners needed maintenance and adjustments.

One of the quickest and easiest ways to check the efficiency of a burner and heat exchanger is to measure the temperature of the flue gases. To get an accurate reading, you can make a small hole (about 5/16-inch) in the flue at a point just as it comes from the heat exchanger. This opening may be conveniently plugged after the test with a short 3/8-inch bolt. Because the hot flue gases quickly cool as they pass up the stack, taking the temperature at the top will give an erroneously low temperature. Likewise, simply measuring the temperature of the metal flue itself will yield a temperature much lower than that of the flue gases. With the barn warmed to a moderate temperature (140 F) and the Btu/hr output of the burner adjusted so that it can complete the cure in a reasonable time, the ideal stack temperature should be 350 F to 400 F. If you measure the stack temperature before the barn warms up or if the Btu/hr output of the burner is adjusted too low, the reading may be in error.

Careful Installation is Important

Not all retrofits will properly fit all barns. Proper selection, planning, and installation should reduce the probability of poor airflow and of too little or too much heat, as well as the possibility of explosions and barn fires. Some heat exchanger surfaces may exceed 1200 F, but wood ignites at approximately 450 F. It is very important to make sure that all wood is a safe distance from heated metal surfaces.

Since the purpose of indirect-fired curing systems is to prevent contact of combustion gases with the tobacco in the barn, do not allow exhaust fumes from burners, boilers, tractors, and other equipment to enter the curing chamber. When the intake vents are open, the barn fan can pull the exhaust fumes into the barn and possibly result in increased TSNA levels. Because these exhaust gases have mixed with outside air, the effect on TSNA levels would not be as great as would be expected with direct-fired burners. Nevertheless, this source could be eliminated or reduced by using smokestacks or flues that release the gases well above the barn roof, and by not allowing tractors or other equipment to operate for extended periods near the intake vents of the barn.