ENERGY USE IN MAPLE OPERATIONS

Last year's high oil prices caused many sugarmakers to look for ways to become more energy efficient in order to reduce costs. Today's low prices have brought temporary relief, but it seems inevitable that the cost of oil and other forms of energy will rise again. Becoming more energy efficient is also just another part of the desire of most people involved in agriculture to be good stewards of the land. This month's column summarizes a presentation that I gave recently on energy efficiency in maple production; next month I intend to continue with information about new and alternative energy saving methods and fuels for sugarmakers.

One of the primary energy consumers in a maple operation is the arch, and the input of heat needed to turn sap into syrup can be described in terms of a British Thermal Unit (Btu), which is a common unit of heat in many appliances. It takes about 400,000 Btu to convert cold sap at 2% brix into a gallon of syrup. The calculation goes like this: one Btu is the amount of heat necessary to raise 1 lb of water 1 degree F, so it takes about 170 Btu to raise 1 lb of water from 40 degrees to the boiling point, depending on your elevation. Next, to convert hot sap to steam, requires much more energy because it represents a phase change—liquid to vapor. An additional 970 Btu per lb in needed to do this. A gallon of water weighs 8.33 lbs, so it takes (172 + 970) x 8.33 or about 9512 Btu to convert a gallon of cold sap to steam. If the sap is at 2% brix, then by the rule of 86 it takes 86/2 or 43 gallons of sap to make a gallon of syrup, of which 42 gallons is boiled off. 42 x 9512 is about 400,000.

Where does the 400,000 Btu needed to make each gallon of syrup come from? For most sugarmakers, it comes from either # 2 fuel oil, which contains 139,000 Btu per gallon, or from firewood, which contains around 20 million Btu per cord when it is properly seasoned. Estimating the amount of Btu in a cord of wood is not entirely straightforward, because different woods have different heat values and many sugarmakers burn a mixture of hard and soft wood. In addition any moisture in the firewood has to be boiled off, which requires the heat input described above. Thus while wood that is wet has the same energy content per cord as wood that is dry, getting rid of the water in the wet wood will use up some of the wood's energy that otherwise would be applied to the bottom of the pans.

Knowing the amount of heat contained in the fuels we burn does not tell us how much of each we will use to make syrup. This is where efficiency comes in. In a typical oil-fired evaporator, about 70% of the heat from the burning oil actually goes toward heating the sap—most of the rest goes up the chimney. Since 70% of 139,000 is 97,300, it would take about 4.1 gallons of oil (400,000/97,300) to make a gallon of syrup, starting with 2% sap. At $2.50 per gallon, this amounts to over $10 worth of oil in each gallon of syrup.

Wood-fired arches are generally much less efficient than 70%; in fact, a plain evaporator with an un-insulated front and no forced draft is around 30% efficient. This means that of the 20 million Btu in the cord of wood, 70% goes up the chimney as smoke and unburned hydrocarbons, or in heating the sugarhouse, and only 30% actually heats the sap. At this efficiency, a typical dry cord of wood is enough to make about 15 gallons of syrup. Purchased at $100 per cord, firewood for the arch wood costs close to $7 per gallon if 2% sap was being boiled. While many maple producers consider firewood obtained from their sugarbush as free, this only holds true if you consider your labor and the equipment to process wood as free and ignore the fact that you could have sold the firewood instead of burning it yourself.

The other form of energy that most producers consume during sugaring is electricity, which is used primarily to run motors which turn pumps. The largest motors are those attached to the vacuum pump and the reverse osmosis (RO) machine. Electricity prices vary considerably across the maple region, with the highest prices in New England, and the lowest in the Midwest. Current prices, which are expected to rise as contracts are renegotiated, range from about 8 to 18 cents per kilowatt hour and prove to be quite inexpensive for maple production. Using Vermont rates (about 13 cents per kilowatt hour), the cost of electricity to run a vacuum pump for the season, shutting it off only when freezing, is probably less than 50 cents per gallon of syrup, while the cost of electricity to run an RO for the season is probably less than 20 cents per gallon of syrup.

So how does a producer become more efficient and reduce these costs. Reducing electricity expenses by switching to more efficient motors, or to variable speed drives for vacuum pump motors may produce savings for some producers, but the payback time may be quite long unless one is using large motors for vacuum. The real savings should come with reduced fuel use in the evaporator. From the calculations above, it should be clear that the 400,000 Btu needed to convert cold, 2% sap to a gallon of syrup can be reduced by 1) pre-heating the sap, and more importantly 2) pre-concentrating the sap. Concentrating sap using electricity (in an RO) is generally much cheaper than concentrating in the evaporator, although an RO is expensive to buy and not simple to maintain. Many producers are attempting to drive their evaporator costs to a minimum by concentrating in the RO as high as possible. Look for 2008 and 2009 research results from the Proctor Maple Research Center that describe effects on flavor and other properties when concentrating, particularly at very high levels. #1 can be done in a sap preheater, which reduces the Btu's required by the amount needed to heat the sap (which can thus reduce fuel use by a maximum of about 15%) but does not reduce the greater amount needed to convert hot liquid to steam. The steam recovery devices that sit on the flue pan both heat the sap and concentrate it, so they can provide a considerable improvement in efficiency.

Finally, the arch can be made more efficient by additions that cause more of the heat in the fuel to actually boil the sap, rather than escape up the chimney. Air-tight fronts, blowers, secondary air, barometric dampers on oil-fired rigs—there are many ways to improve an existing arch. You can find a description of some of these methods in the document "Guidelines for the improvement of combustion efficiency for maple producers" by Harry Atkinson and Lisa Marchetti on the Proctor Maple website, at http://www.uvm.edu/~pmrc/Combustion.pdf. Given the current oil prices, the payback time for some energy savings conversions may be considerable; however, with improved efficiency, sugarmakers can say they are doing their part to combat global warming, and taking a step towards the long term sustainability of not only their operation, but the planet.

Only about a third of the energy released by burning wood actually heats the sap in an old-fashioned evaporator—the rest heats the sugarhouse or goes up the stack.