Research: Reverse Osmosis

High Brix Syrup Processing – First Two Seasons with Lapierre HyperBrix

Timothy D. Perkins, Abby K. van den Berg, Brian Stowe, and Wade Bosley, University of Vermont Proctor Maple Research Center

Over the past fifteen years, research and demonstration sugaring operations, like many private maple operations, have grown tremendously. In the case of the University of Vermont Proctor Maple Research Center, we have gone from about 1,500 taps in 2004 to nearly 5,000 taps in 2017 and 2018. During that time we upgraded our reverse osmosis (RO) system to a new machine, then added an additional post, and steadily increased our concentration level to near maximum levels supported by the RO. Despite these changes, in 2016 we were occasionally having to boil for extended periods of 8-10+ hours, with repeated switching of sides to control heavy niter deposition. Long-term plans envisioned further expansion to more than 6,000 taps, so the sap processing issues were likely to become more problematic. Although our previous equipment and processing methods had served us well over many years, it was clear that a major shift in processing was needed.

Given our extensive research experience on RO processing and flavor, and the appearance of new RO technology that could concentrate to higher levels, a shift toward this new technology seemed appropriate. Therefore after investigating various options, we entered into a partnership with Lapierre Equipment to utilize the new HyperBrix RO system at UVM PMRC. This paper describes some aspects of our first two seasons of use of this equipment. Given the state of the industry, we define "high brix" maple sap processing as RO machines capable of producing concentrate at 30°Brix or higher.

For sap processing, we used a five-post Lapierre HyperBrix RO (Figure 1) for the 2017 season. A HyperBrix RO is two machines that are combined into one: a low pressure (standard RO) side and a high pressure (HyperBrix) side. The PMRC machine was initially equipped with three membranes on the low concentration side. We expanded this to four membranes before the 2018 season to increase sap processing rates to better match the evaporator, a Lapierre Volcano 2000 (Figure 2). The evaporator consists of a 4′ x 4′ back pan (2 partitions) and a 4′ x 8′ front pan (8 partitions), equipped with a hot-water heating loop in the back pan hood, and a variable-fire Riello oil burner. Our system also came equipped with hoods, a reverse-flow option, front and back pan spray washers, and an electronic auto-defoaming unit.

The goal of the 2017 season was to gain familiarity with processing sap through the RO and evaporator, to explore the limits of operation, and to evaluate different types and com-

binations of membranes. In 2018 we sought to further optimize system operation as well as to continue to evaluate performance of various types and combinations of membranes. This article will address general operational issues of the RO and evaporator, with membrane performance left for another article.

Operating the Lapierre HyperBrix RO is very similar to operating other models of maple RO machines. The controls are essentially very similar, with the exception of duplicate controls for the low pressure and high pressure (HyperBrix) sides of the device. Anyone familiar with general RO operation could quickly learn to operate the machine.

In 2017, we processed over 107,000 gallons of sap (Table 1), averaging 2.15°Brix, producing 9,278 gal of concentrate ranging from 26.2 to 35.6°Brix. Because the concentrate from machine start up and sugar purge, along with liquid from filter press washes were added to the concentrate tank as well, the effective concentrate level in the evaporator feed tank averaged about 25°Brix over the entire season. This produced a total of 2,634 gallons of syrup, thus equating to a concentrate-to-syrup ratio of 3.39 gallons concentrate to produce 1 gallon of syrup.

We boiled 22 times in 2017 (Table 2), totaling 68.8 hours. The longest boil was 5.5 hours, with an average boil time of 3.1 hours. Average evaporation rate was 103.2 gallons per hour, with an average syrup production rate (draw-off rate) over the entire season of 38.3 gallons per hour. This value includes start-up and occasionally switching sides. At peak, we produced 50-55 gallons per hour. The overall total processing rate (evaporation rate + draw-off rate) was 141.5 gallons per hour. Over the season we used 711 gallons of kerosene (kerosene has a slightly lower BTU content than fuel oil,

Figure 1. Lapierre Equipment HyperBrix Reverse Osmosis machine in operation at the Sumner Hill Williams research/demonstration sugarhouse at UVM PMRC in 2018. Note the flow-meters and inline refractometer on lines in the upper right of photo. *Photo Credit: Timothy Perkins, UVM PMRC.*

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but is less susceptible to fuel gelling at cold temperatures), resulting in a fuel-to-syrup ratio of 0.270 gallons kerosene per gallons of syrup produced.

In 2018, we processed nearly 135 thousand gallons of sap (Table 1). Average sap sugar was slightly lower, averaging 2.00°Brix over the season. Concentrate from the initial start-up and sugar purge were diverted back to the sap tank, with only concentrate at the target level sent to the tank for processing. In this way, the range of concentration was kept within fairly tight limits of 34.5-37.5°Brix, averaging 36.0°Brix over the season. Typically, with the 6-post configuration set to concentrate to 36°Brix, about 1,200-1,400 gallons of sap were processed each hour of machine operation, resulting in about 100 gallons of high-brix concentrate per hour. Some warming of the liquid was apparent during concentration, but this was negated by immediate processing in 2017 or through the use of a refrigerated bulk tank in 2018. Boiling in 2018 produced 3,038 gallons of syrup, yielding a concentrate-to-syrup ratio of 2.45 gallons of concentrate for each gallon of syrup produced.

Due to the addition of a refrigerated bulk tank, in 2018 we boiled only 11 times (Table 2), with a maximum boil time of 5.5 hours. Because we only boiled once for every 2.5 sap collection and concentration cycles, the average boil time increased to 3.7 hours. The average evaporation rate rose slightly to 106.8 gallons per hour.

	2017 LAPIERRE HYPERBRIX 4' X 12'		2018 LAPIERRE HYPERBRIX 4' X 12'	
Sap Quantity	107,212	gal	134,819	gal
Average Sap Sugar	2.15	°Brix	2.00	°Brix
Range of Concentration	26.2-35.6	°Brix	34.5-37.5	°Brix
Average Concentration	31.1	°Brix	36.0	°Brix
Effective Concentrate	>25	°Brix	36.0	°Brix
Number of Concentrations	22		27	
Concentrate	9,728	gal	7,443	gal
Concentrate:Syrup Ratio	3.39:1	gal/gal	2.45:1	gal/gal
Syrup Produced	2,634	gal	3,038	gal
Syrup Yield	0.53	gal/tap	0.62	gal/tap

Table 1. General characteristics of sap concentration using the Lapierre HyperBrix in 2017 and 2018.

With the higher level of concentration, syrup production rate increased to 67.7 gallons per hour, with a maximum production rate of ~75 gallons per hour. This produced a total seasonal average processing rate of 180.8 gallons per hour. Only 416 gallons of kerosene were required for the 2018 season, with only 0.137 gallons of kerosene needed to make a gallon of maple syrup. This represents nearly a doubling of fuel efficiency due to the higher concentration levels (36°Brix) used in 2018 compared to the concentration used in 2017 (25°Brix). Given that the concentrate was chilled and stored at 23°F in 2018 before being sent to the back pan, increasing fuel efficiency further by preheating the concentrate before it reaches the back pan is something we will likely explore over the next few seasons.

With the assistance of Efficiency Vermont (www.efficiencyvermont.com), we also monitored electrical usage of the RO during the 2018 season. At the time of this writing the analysis was incomplete, so results will be presented later.

While RO machines are often thought of as energy-saving devices, they also reduce the time spent boiling tremendously. What is less well recognized is the extent to which even small increases in concentration can yield significant time savings in sugarhouse operations. In 2017, sap

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	2017 LAPIERRE HYPERBRIX 4' X 12'		2018 LAPIERRE HYPERBRIX 4' X 12'	
# Boils	22		12	
Total Time Boiling	68.8	hrs	44.9	hrs
Maximum Length of Boil	5.5	hrs	5.5	hrs
Average Length of Boil	3.1	hrs	3.7	hrs
Average Evaporation Rate	103.2	gal/hr	106.8	gal/hr
Syrup Production Rate	38.3	gal/hr	67.7	gal/hr
Max Syrup Production Rate	50-55	gal/hr	~75	gal/hr
Avg Total Processing Rate	141.5	gal/hr	180.8	gal/hr
Fuel (Kerosene) Used	711	gal	416	gal
Fuel:Syrup Ratio	0.270	gal/gal	0.137	gal/gal

Table 2. General evaporation results using the Lapierre Volcano 2000 to process high Brix concentrate in 2017 and 2018.

	2017	2018 without Bulk Tank	2018 with Bulk Tank
Number of Concentrations	22	27	27
Concentrate Level	25 Brix	36 Brix	36 Brix
Number of Boils	22	27	11
Time Boiling	68.8 hrs	44.9 hrs	44.9 hrs
Clean-up Time (2.5 hrs/boil)	55.0 hrs	67.5 hrs	27.5 hrs
Total Time (boil + clean)	123.8 hrs	112.4 hrs	72.4 hrs
Syrup Produced	2,634 gal	3,038 gal	3,038 gal
Syrup Prod Rate (Total SH hrs)	21.3 gal/hr	27.0 gal/hr	42.0 gal/hr
Time Savings (for 3,000 gal)	0 hrs	29.7 hrs	69.4 hrs

Table 3. Time efficiency results for high-brix evaporation in 2017 and 2018.

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runs required 22 concentrations to an average effective level of 25°Brix and 22 boils, totaling 68.8 hours (Table 3). Since clean-up after each boil requires 2.5 hours, total sugarhouse operation time in 2017 was 123.8 hours for 2,634 gallons of syrup produced, or 21.3 gallons of syrup per hour of operation. In 2018, had we not used a refrigerated bulk tank, concentrating to 36°Brix on 27 occasions would have produced 27 boils totaling 44.9 hours for 3,038 gallons of syrup, or 27.0 gallons syrup produced hourly, resulting in a time efficiency increase of 26.8%, equating to a time savings of nearly 30 hours over 3,000 gallons, or three hours per week over the 10 week season. By using a refrigerated bulk tank to reduce the number of times we boiled, we aved even more time. In actuality, we boiled only 11 times in 2018 (2.5 concentrations/boil), with 44.9 hours of evaporator time and 27.5 hours of cleaning time totaling 72.4 hours of sugarhouse operational time to produce 3,038 gallons of syrup. The syrup production rate was therefore 42.0 gallons per hour of sugarhouse time, with a total time savings of 69.4 hrs in 10 weeks, or almost seven hours additional of worktime saved each week. The combination of concentrating to a higher Brix level and using a bulk tank increased time efficiency in the sugarhouse by almost 100%. This leaves considerably more time to work in the woods in keeping vacuum levels, and thus sap yields, high.

In both the 2017 and 2018 seasons, we used caustic soap to wash the membranes after each use, followed by a permeate rinse. Based upon benchmarks, this seemed to keep flow rates acceptably high throughout both seasons. Niter seemed to be light-moderate both years, with a pan rinse and permeate soak sufficing after most boils, and pan acid used only 1-2 times during each season. The heat loop in the back pan produced 500 gallons or more of hot permeate water each boil. Syrup grade was good each year, perhaps a little lighter than what we normally produced in 2017, but very light throughout 2018. Light syrup seemed to be common in our area in 2018, but may have also been due to several changes we made in our operation (refrigerated bulk tank, new sap filtering regime). Due to the

high rate of syrup production in 2018, we moved to filtering immediately off a draw-off tank rather than using a finishing pan. This also resulted in significant time savings and probably accounts for some of the increase in light transmittance. Syrup flavor was excellent both years, with no off-flavors attributable to processing being evident.

Figure 2. The Lapierre Volcano 2000 4' x 12' evaporator in the Sumner Hill Williams Sugarhouse at UVM PMRC in spring 2017. From left-right, Donald Lapierre (Lapierre Equipment), Dr. Timothy Perkins (UVM PMRC), Dr. Abby van den Berg (UVM PMRC), Jeff Goulet (Lapierre Equipment), Carl Lapierre (Lapierre Equipment), and Brian Stowe (UVM PMRC). *Photo Credit: Peter Gregg, The Maple News.*

In summary, moving to high brix sap processing with the Lapierre Equipment HyperBrix RO and Volcano 2000 evaporator has proved to be an excellent fit to the UVM PMRC operation, and has resulted in significant improvements in energy and time savings without compromising our high standards for syrup quality. This equipment will also serve as a platform for continued research on sap processing.

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Spout/Tubing Sanitation Publication to be available in June

The UVM Proctor Maple Research Center and Cornell Maple Program conducted a multi-year joint research project investigating spout and tubing sanitation methods. The full research report will be released in June 2018, with summaries to be published in upcoming editions of the Maple Syrup Digest and the Maple News. To receive a PDF copy of the full report when it is released, please email Timothy.Perkins@uvm.edu