

# Guidelines for the Improvement of Combustion Efficiency for Maple Producers

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**I. Retrofitting a wood-fired arch** for more efficient operation (25%-50%) savings are possible. This is due to better mixing of combustion gasses.

A. An over fire air system should be installed to direct high pressure air through a set of nozzles.

1. The fan used for this system should be capable of 3" w.c. pressure minimum. Oil burner fans from 1980 on will usually be a good source for a used fan.
  - a. ½ h.p. on 2.5' wide units such as Grainger # 70747
  - b. 1 h.p. on 3' wide rigs such as Grainger # 7C447
  - c. 1 ½ h.p. on 4' wide rigs such as Grainger # 7D751
  - d. 3 h.p. on 5" wide rigs such as Grainger # 7C561 Be sure to specify single phase, if needed.
  - e. 5 h.p. on 6' wide rigs such as Grainger # 7C562 Be sure to specify single phase, if needed.
2. These fans are noisy and should be totally enclosed under the rig or mounted outdoors.
3. A manifold needs to be constructed to bring the new over fire air in to the fire box. The manifold construction can be accomplished in a few different ways using pipe or duct -- 2" for up to 2.5' wide rigs, 3" for 3' wide rigs, 4" for 4' wide rigs, 6" for 5' wide rigs and 8" for 6' wide rigs.
4. Reusing an existing combustion chamber without removing the refractory bricks will require piping a manifold around the outside of the arch made out of metal airtight, with nozzles emanating every 6" from the manifold through the brick. These nozzles should be 3/8" pipe, and should extend to the face of the brick.

- a. Drilling through brick is difficult and it would probably be easier to remove the top two layers of brick, install the nozzles and reinstall the brick. Plastic type refractory is much easier to reinstall than the bricks would be, as plastic refractory is molded into place like a heavy clay. Its trade name is Max Bond. Be certain to buy air set type plastic refractory, not fire set.
- b. The nozzles should be placed approximately 6” down from the top of the chamber tilted down slightly (10 degrees) and spaced around the entire combustion chamber. It is usually easiest to make a manifold that starts at the back of the combustion chamber then extends around both sides and partway around the front, ending at each side of the firing door.
- c. One row of nozzles will suffice for the combustion chambers up to 3’ wide.
- d. Two rows of nozzles will suffice for 4’, 5’ and 6’ wide combustion chambers.
- e. A damper needs to be incorporated into the system either on the supply side or the intake of the fan, that is easily changed and set into position from almost full closed to full open. It is best to spend some real time on this, so that it can be set from the front of the machine, using a series of levers and rods with a “dog-type” catch. It is possible and very desirable to use an electronically controlled speed control instead of a damper on the motor.
- f. It is important to install a 2” sight glass in the front of the combustion chamber that gets a wide view of the whole chamber (from the top to the bottom). It is common to need to change the setting of the over fire air damper during firing at least once per charge. It is common with this system to have to add wood only once every 15 to 25 minutes.

5. Although it is possible to just add an over fire air system to wood burning evaporators as described above, while still using the original natural draft air and damper for under the grate air control, ideally it is better to provide forced draft air under the grate, as well, with a separate damper control; or a motor speed control.

- a. If your evaporator already has a fan providing air under the grate, it can usually be used as is. It will need either damper control or speed control of the motor. You will find that very little air will be required from the system, except at the end of the 15 to 25 minute wood charging cycle. Frequently, at the end of the cycle, it is advantageous to open the under fire air to a much higher level to burn down the charcoal that is built up, particularly if hard wood is being used as a fuel.

b. If the evaporator just has a damper to control air coming into the combustion chamber and under the grate, make certain that this damper is easily adjusted and set in any position from full open to full close, by a means of levers and rods that can left dogged in position.

c. Existing grate system

1. If the results are not satisfactory using the old grates and damper for under fire air supply, it will be necessary to convert the under fire air supply to forced draft, either by using a separate fan and control, or by teeing off from the over fire air fan system with a duct and damper in it, to feed the under grate air chamber.

2. It will be necessary to seal this chamber air tight so that air doesn't leak out. Ash removal is not a concern with these systems as almost none will remain or fall down into the under grate area when it is pressurized. To accomplish this change remove the grates and seal the area below using brick and high temperature cement or steel or a combination of all (whatever is easiest).

3. If possible, it would be helpful to cut the old wood grate air hole or slot sizes in half at this time when reinstalling them.

6. If at the time of conversion your existing grates are in poor condition, it would be worthwhile constructing a new combustion chamber floor at the same level by

a. Pouring a castable (high strength type) refractory floor at the same level as the old grates, leaving at least 3" below the bottom of the new floor. This floor should be at least 3" thick, with 12 3/4" x 3/8" diameter holes per square foot incorporated into the casting. This is a little tricky to do. (The holes taper from the underneath of the grate at 3/4" to the top of the grate at 3/8".) As Un-technical and silly as it sounds, we found that ice cream cones positioned in the right spots make the perfect shape for these holes.

b. Refractory grate blocks can be purchased that have slots in them for the air passage (no ice cream cones needed).

c. Pay close attention to the strength of your new floor, as remember, big heavy chunks of wood get thrown on to it.

d. The first 8" of the floor from the door side should have no air holes.

## B. Stack

1. Be sure you have an easily read (from the front of the evaporator) 200 -

1500 degree F thermometer installed so that you can keep track of your combustion activity, and the evaporator's performance.

2. Manual stack dampers are a bad idea, and if inadvertently closed can cause a catastrophic, fatal explosion.

3. Barometric dampers are very accurate and are safe. They should be at least the full size of the stack's diameter. If the stack is over 30' in height, it is sometimes necessary to install two full-size units. They are expensive to purchase, especially in sizes above 12" diameter. However, if you have the time and you are a capable metal fabricator, they can be made. All a barometric damper is is a precisely made balanced disc on a shaft, with an adjustable weight. They can be square or round (most common). Look at an existing one and copy it if you have the time and the skill.

4. The reason for accurate draft control is to provide the same draft (or suction) on the whole combustion system at all times. Therefore, making your air adjustments at the fan(s) or grates provides the same amount of air at all atmospheric conditions.

5. A draft gauge(available from Dwyer Instruments, and others) is a valuable tool for watching what is going on in your machine. It should be piped into the front of the combustion chamber, and requires a 1/8" p.s. tapped hole. Usually, a good spot for this tap is into the pipe nipple that your 2" combustion chamber sight glass is mounted on. The draft gauge should have a scale of 0 to -3" w.c.

6. The ideal draft setting is -.02 to -.04 w.c. inside the combustion chamber (not the stack) while firing at full bore with a forced draft system. With a combination forced draft over fire air system, and natural draft under fire air system, a higher draft may be necessary. Approximately -.1 to -.3 w.c. at maximum firing rate.

7. If you have time and the skills, considerable efficiency (10-15%) can be realized by making a multiple steel tube heat exchanger in the stack while maintaining the same stack free area and using this heat exchanger to preheat the air going to your new forced draft combustion system from the fan(s). This can be constructed like a fire tube boiler, using multiple pipes welded between two round ends (like an HRT boiler). Flue gas goes through the pipes and combustion air through the chamber around them. Scrounging old used boiler tubes to make a heat exchanger like this is not difficult. (Be sure to plug any holes in the tubes with a quick spot weld.) The tubes are readily available by contacting a boiler pressure vessel repair company (such as Dillon Boiler Repair in Fitchburg, MA or

Vermont Boiler Specialists in So. Burlington, VT). Make arrangements to pick them up at the jobsite where they are working, which will save them the time to transport them to a scrap yard. In today's present scrap steel climate it may be necessary to pay for them but the price should be a fraction of new and will be quickly paid back in fuel savings.

In conclusion, tremendous savings can be realized by providing combustion air in a combination over fire/under fire air system (25 to 50%). It will require some very basic welding or duct work skills to accomplish this work. In addition to the fuel savings, there should be no smoke with a proper system, and the cycle of fuel loading into the furnace time will be considerably extended (generally to once every 15 to 25 minutes).

Commercially made systems that incorporate this type of air introduction are available from most of the major manufacturers. There are very large differences between these, and it would be worthwhile carefully analyzing each manufacturer's product before purchasing one particularly in regard to the amount of heating surface provided for recovering the flue gas heat.

## **II. Oil Fired Improvements and Standards**

- A. All oil fired units should have burners installed that will produce at least 13% CO<sub>2</sub> with 0 smoke. The higher the CO<sub>2</sub> reading available, the better (with 0 smoke).
- B. Barometric dampers should be fitted to all standard evaporators to provide the same draft in all conditions. This allows the burner to be set to the highest CO<sub>2</sub> possible, saving substantial fuel.
- C. Install a permanent stack thermometer easily viewed, so you can keep track of your evaporator's performance. Don't fire the unit above 850 degrees.
- D. Be certain that an oil pressure gauge is installed that will show nozzle pressure, and a vacuum gauge is installed between the burner pump and the filter.
- E. Obtain an instruction manual for your burner that will help you understand it. This is invaluable.
- F. If your fuel tank is above the burner pump, use a one pipe system.
- G. If your fuel tank is below your burner pump, use a two pipe system. Run the

return to the bottom of the tank, cutting the end of the pipe at a 45 degree angle, right next to the supply to help warm up the oil, as the burner runs. Drill a 1/8" hole in the return line 1" below the tank's top to relieve air and prevent siphoning in case of a line break. Never install a shut-off valve in the return line as one mistake will destroy the oil pump and can very likely cause a catastrophic explosion.

H. Run the supply line to the bottom of the tank cutting its end at a 45 degree angle. This will prevent water buildup in the tank. Be sure to use a slip-through style compression fitting on both lines so that they can be raised easily.

I. It is worth enclosing the fuel tank and keeping it at 50 degrees F. Cold oil adversely affects the burner's operation, and can considerably reduce efficiency (by as much as 15%). Really cold oil (like at the beginning of a season) can cause a burner to be inoperable.

J. Always have at least 2 spare filter cartridges on hand.

K. Always have at least 2 sets of spare nozzles on hand. Nozzles don't necessarily need to be changed yearly. What causes the most trouble with nozzles is sitting through the long off season with oil in them. It is worthwhile removing the burner gun at the end of the season, draining the oil out of it, checking and cleaning the diffuser and electrodes, and leaving it out, which will cut down on the surprisingly frequent occasions of mice making nests inside the burner.

L. Combustion chamber

1. Be certain to have a 2" peep sight located in the combustion chamber, situated to provide a wide angle of view through a tapered hole, particularly so that you can see the bottom of the pan where the flame tips are.

2. The combustion chamber should preferably be made of high temperature brick (hard or soft, but rated for at least 2800 degrees F), or plastic or castable refractory. The commonly used blanket in combustion chambers is a poor choice due to health reasons, both for the sugarmaker and for the possibility of these fibers finding their way into our product. I prefer a V-shaped chamber for single burner applications, as there appears to be slightly better heat reflection to the pans, and less wall area for heat loss.

3. Be certain that you get your oil burner manufacturer's recommendations for combustion chamber's minimum dimensions, and try to add at least 1 inch to those dimensions, in order to avoid the

possibility of flame impingement.

A. Example: if the burner manufacturer lists 12” as a minimum from the center line of the burner to the floor, make sure that you have 13” between the center line of the burner and the floor, the pan, and the side walls.

4. The walls of the chamber should come as close as possible to the edges of the pans, which is tricky but necessary to not lose pan heating surface.

5. All of the surfaces of the top of the arch, which both pans sit upon need to be flat and gasketed. Use a soft fiberfax type rope for this gasket.

6. It is also important to gasket between the front and rear pan to avoid air infiltration at that point. Gasketing of this type is available from Dominion and Grimm, and probably other manufacturers, as well. Dominion’s between-pan-gasket is very well thought out and easily reused.

7. The rear of the combustion chamber should extend approximately 1’ to 2’ past the front pan. Be certain that the length is at least as long as the burner manufacturer’s minimum flame length dimension. Extend the rear wall of the combustion chamber vertically up to within 1” of the bottom of the flue pan, and then keep this dimension underneath the entire flue pan in a flat plane. This will provide much better heat transfer, forcing the very hot flue gases up into the flues where you want the heat transfer to take place.

The surface of the area beneath the flue pan can be done in standard red brick, or even sand, after the first 2’, which should be constructed of materials rated for at least 2000 degrees F.

M. It is possible to make a heat exchanger such as described under wood fired systems to recapture heat from the stack and put it into the combustion air stream. It would be a considerably more complex undertaking than the wood fired set up, and would probably warrant some consulting with a knowledgeable oil burner person.

N. Commercially available high efficiency systems are available from different manufacturers that recapture heat usually lost from flue gas. These systems vary greatly and it would be well worthwhile for the buyer to very carefully analyze how each system is made before purchasing a new system. Some manufacturers have more than twice as much heating surface built into the flue gas recapturing system as others, even though the floor print and evaporator size is identical. Even though two different manufacturers have equivalent output capacities for the same size evaporators in these high efficiency models, there is a tremendous

difference in efficiency between manufacturers, due to extra heating surface that is incorporated into one design versus the other.

### **III. Wood Pellet Systems**

A. Wood pellets are an excellent, easily combusted and handled fuel that can be adapted to evaporators. Pellets can be burned by hand (as in shoveled in) or, preferably with stoker type equipment (such as manufactured by the Will-Burt Co.) Over fire air systems such as described in the previous wood burning section are a must for the efficient combustion of pellets. When selecting automatic equipment it is important that you fully understand the size and dimensions of the combustion chamber that are required by the manufacturer.

B. Before investing in wood pellet equipment, it would be very wise to carefully compare the price of them and to be certain that the supply of pellets is available that you will need for the season. It would be prudent to purchase the entire season's requirement well in advance. Wood pellets contain approximately 7,500 btu per pound (sometimes higher), therefore it takes approximately 20 pounds of pellets to equal one gallon of fuel oil.

### **IV. Wood Chips**

A. Wood chips are an excellent fuel "on the job" with purchased or rented chipping machinery (wear your hearing protection). They are also available by tractor trailer loads. Green whole tree wood chips contain approximately 3,500 btu per pound and are difficult to handle. "Mill-type" wood chips contain approximately 5,000 btu per pound and are much more consistent in size, therefore being easier to handle.

B. Be very careful to look into any manufacturer of automatic chip burning equipment's claims and reputation. Be certain to visit an existing working unit before purchasing any system. It is possible to make your own system for burning this excellent fuel. Talk to someone who has done it, like Dave Folino, of Bristol, VT. Use their ideas and learn from their mistakes.

C. Handling wood chips automatically is much more difficult than burning them. There are many types of conveying devices for moving wood chips that don't work very well.

D. Needless to say, using wood, either in chip or stick form is the natural and best fuel for the environment and is in balance with our own woods (in terms of the ash hopefully going back to the land as much as possible as to where the wood came from). It is just as important to burn wood as efficiently as one would burn oil.

## V. Other oils

### A. Vegetable oil and used motor oil

1. Despite rumors to the contrary, there is usually a fair amount of this oil around used from restaurants and garages. Today, you will probably have to pay for it as it is being paid for as of October 8, by the commercial recyclers who used to charge \$1 per gallon to pick it up as recently as one year ago.
2. First, and foremost, it has to be carefully screened and then filtered through a 10 micron filter.
3. It's storage needs to be kept at approximately 75 degrees F, to prevent problems.
4. It's very use wise to let it sit for a month before using it to let the water settle out of it to the bottom of the tank. A drain valve needs to be installed in the tank for this purpose.
5. It is possible to modify a standard #2 oil burner to use this fuel.
  - a. It needs to be heated to approximately 210 degrees F before entering the nozzle(s) in order to be at the same viscosity as #2 oil.
  - b. It's wise to preheat it in the tank and in a constant circulating system to approximately 120 – 150 degrees F before delivering it to the burner system.
  - c. If possible, considerable electrical savings will be realized if waste heat from the evaporator system can be used to preheat the oil. A good safe source of heat to do this is the hot water that comes off of the hood from a sap preheater. Be careful not to send any oil to be heated through a part of the evaporator, where a leak could contaminate the maple process.
  - d. The fuel oil solenoid valves will have to be changed to handle hot oil as the standard ones will not. (Available from Grainger or an oil burner supply house like Sid Harvey's.)
  - e. Electric fuel oil heaters are available from General Fittings Co. Don't use water heater elements and don't make your own electric heater. Improperly made electric fuel oil heaters have the potential for catastrophic explosion.

f. To be safe, hire a qualified heavy oil experienced oil burner person to guide you through this process so that it will be as trouble free and safe, as possible. There is a reason heavy oil burners are as expensive as they are. They are very complicated and generally feature an air atomizing nozzle system.

g. Reasonably priced small air atomizing burners which will burn clean used vegetable oil or motor oil are available from Sandri Co. in Greenfield, MA (Clean-Burn Model). Capacities are available up to approximately 7 gallons per hour per burner. They can, of course, be used in tandem on wider arches, and it is possible they are manufacturing burners that are slightly larger now. Larger air atomizing burners are available if you can be lucky enough to find one being removed from a school or industrial plant that used to use heavy oil. Air atomizing burners are the best design for vegetable or any heavy oils as that is what they are made for. They are prohibitively expensive new.

## **VI. Propane and Natural Gas**

A. Although these fuels are not commonly available in sugarhouses, if they are and the price is right, they are a maintenance free excellent choice.

1. A gallon and a half of propane equals a gallon of oil.
2. One thousand cubic feet of natural gas equals 7 gallons of fuel oil.

B. Don't use atmospheric burners, such as are used for finishing pans. Don't make your own gas burner. Atmospheric burners look like stove top or oven burners, have no forced air and are inherently inefficient if used in an evaporator with a very few rare exceptions, such as Gordon Piatt's Blue Line Series (which are still 10% less efficient than a good forced draft burner).

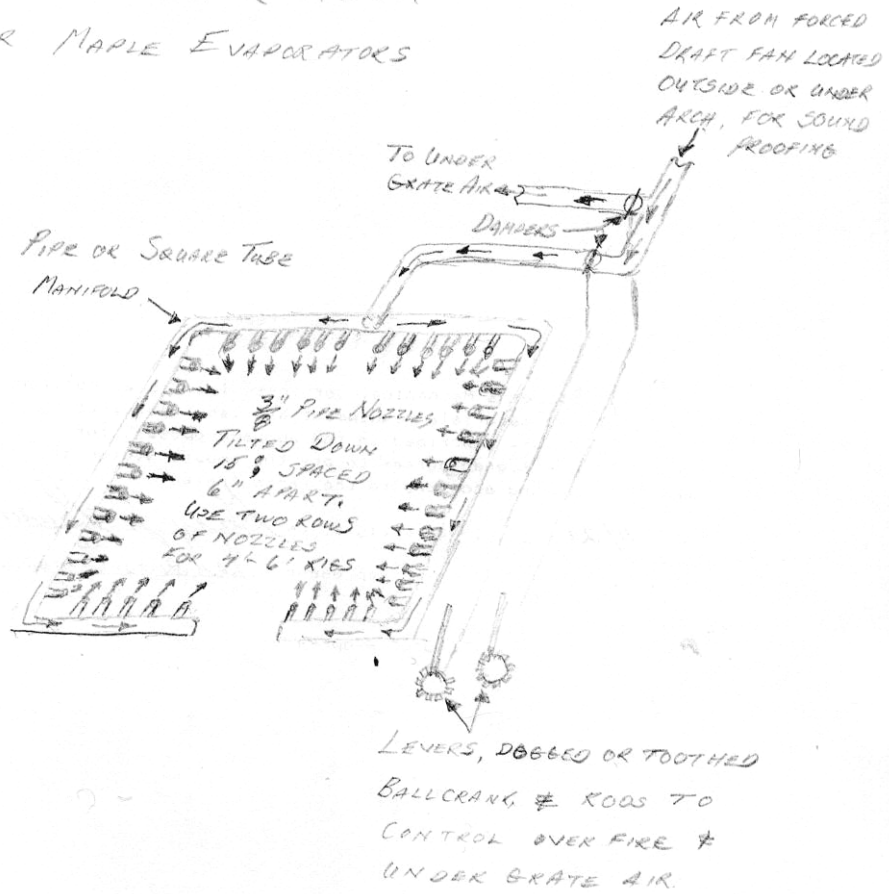
C. There are many manufacturers of good forced draft gas burners.

D. If you are considering firing your evaporator with something other than wood it is worth a call to all the propane suppliers that deliver in your area. Occasionally propane can be bought very cheaply, especially off season and in a

large quantity. Needless to say, you would want to have a tank sized for the entire season or a firm contract with a supplier that would protect you price-wise through the next season.

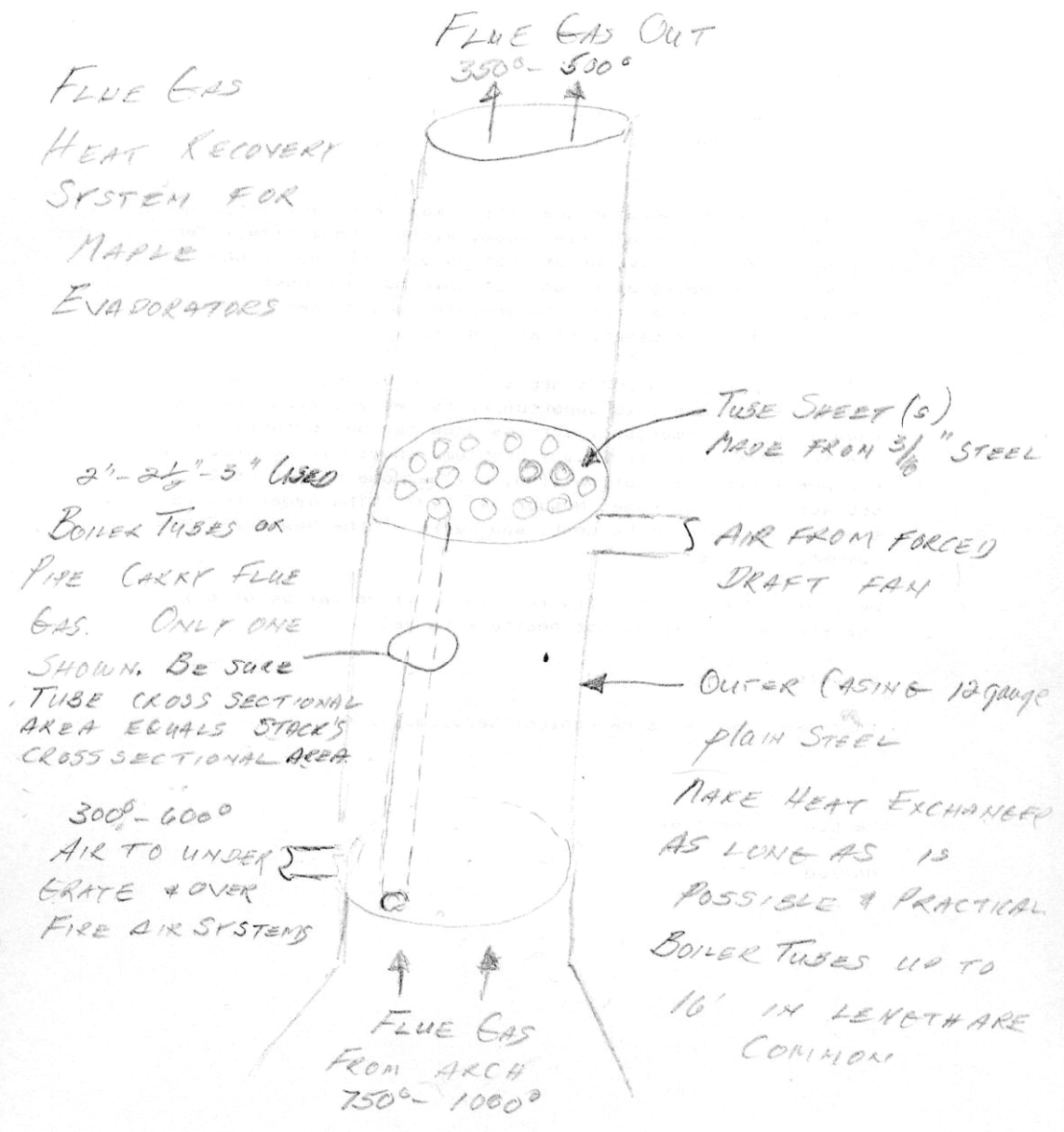
In summary, the bottom line is that as sugarmakers we need to and should be leaders in energy conservation. What we do is naturally very energy intensive, both in terms of electricity and fuel. Using fuel as efficiently as possible is good for our wallets, our product's image, and as a shining light of what a small group of innovative farmers can do with limited resources.

### OVER FIRE AIR SYSTEM FOR MAPLE EVAPORATORS



THANOR BOUTRES COOP.  
ALAN ATKINSON & LISA WARENETT

FLUE GAS  
HEAT RECOVERY  
SYSTEM FOR  
MAPLE  
EVAPORATORS



THUNDERBOLT RES. CORP.  
HARRY ATKINSON & LISA MARCINETTI