DEALING INTELLIGENTLY WITH ENERGY IN A HIGH-ENERGY PROCESS

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The process of drying lumber is essentially evaporating water from wood.

Where does all the energy go? In any type of drying, whether it be air drying or kiln drying, the single biggest consumption of energy is the evaporation of water from the wood's surface. For every pound of water evaporated (approximately 1 liquid pint), about 970 BTU's of heat energy is required. If this drying is done in an air-yard, the energy doesn't cost a cent, but we can assign a value to it.

Say 73,000 BF of Ponderosa pine is to be air-dried and 1-1/2 pounds of water are removed from each board foot. This is a total of 109,500 pounds of water (13,600 gallons) which will require a total of 106,220,000 BTU's to evaporate it from the surface of the wood.

Nature gives us this energy free, but if we were to purchase this same amount of energy in the form of fuel, costs would be as follows:

FUEL ENERGY - 106,220,000 BTU's

Natural Gas	$ 531.10	($0.50/Th)
Electricity - Wash.	$ 933.67	($0.03/kWh)
- Ore.	$1,556.11	($0.05/kWh)
- Calif.	$2,178.55	($0.07/kWh)
#2 Diesel	$ 598.42	($0.80/Gal)
Wood Fuel	$ 265.55	($40.00/BDU)

Although nature's energy is free, air-drying takes a lot of time, affords poor control over drying conditions, is subject to seasonal variations, and ties up large amounts of inventory and real estate.

When we dry lumber in a commercial dry kiln, is the amount of energy required for removing the water from wood the same as in air drying? No. It is over twice as much.

Everything considered, the average lumber dry kiln is about 45% efficient. (Figure 1) shows where most of the energy goes.

Table 1 lists these categories in tabular form.

Table 1. Dry Kiln Energy Consumption.

Area	Percentage	Type
Initially heating up (the kiln building and floor)	3% - 5%	U
Heating up the wet wood (to the point of evaporation)	3% - 5%	U
Evaporation of water (from the wood)	35% - 50%	U
Building losses (roof, walls, ends of kiln)	5% - 40%	M, T
Ground losses (through the floor)	1% - 5%	M, T
Heating air/water-vapor mixture (venting losses)	3.5% - 8%	M
Steam spray (for controlling humidity in kiln)	0% - 15%	M, T
Flash loss (beyond traps)	1% - 5%	M
Steam leaks and heat losses (from piping outside the kiln)	0.5% - 2%	M, T
Electrical energy for air circulation (kiln fans)	10% - 15%	M, T

M = Manageable to some extent
U = Uncontrollable
T = Time related

FINDING PRACTICAL WAYS TO REDUCE ENERGY CONSUMPTION

A very wise man once said, "Stop worrying about things over which you have no control". This was good advice. So let's concern ourselves about energy useage we can control or, at least, manage to some extent.

Considering Table 1, above, we can do some value analyses on limiting the energy consumption in the categories which are manageable to some degree. To assign a value to various energy saving modifications which we can make to our kilns, we should first define a "typical" kiln so as to keep everything on an equal basis (see Table 2).

Table 2.

Size of Kiln	Double track by 68 feet long, doors both ends
Species	Ponderosa pine
Lumber Size and Grade	5/4 X R/W R/L Shop & Moulding, green from saw
Length of Schedule	96 hours (100 hour turnaround)
Heat Requirement	2,200 BTU/lb. of water removed
Stickers	3/4" thick
Package Size	50" wide X 50" high
Crib Size	2 packages wide X 3 packages high, 16 feet long
Kiln Capacity	73,000 board feet
Heating System	Steam - Natural gas fired boiler
Steam Source	Natural gas fired boiler, 80% eff.
Humidity Control	Steam spray and roof vents
Fan System	70 HP cross shaft single speed
Natural Gas	$0.50/Therm
Electricity	$0.05/kWh

Net heat energy required to dry the lumber in our "typical" kiln:

(73,000 BF) X (1.5 Lbs. H_2O Removed) X (2,200 BTU/Lb. H_2O)
= 240,900,000 BTU Total/Charge

Allow for boiler efficiency to determine amount of fuel purchased from gas company:

$$\frac{240,900,000 \text{ BTU to kiln}}{0.80 \text{ boiler efficiency}} = 301,125,000 \text{ BTU/Charge (Gross)}$$

Total electrical energy for the kiln fans will be:

70 HP X 0.746 kW/HP X 0.9 load factor X 96 hours = 4,512 kWh

ENERGY LOSS - BUILDING

Prefab Roofs and Doors

Assume that our "typical" kiln has a wood roof which has gone its distance (and then some). It also has steel framed doors with plywood panel inserts which flop back and forth in the slightest breeze. Building losses could easily be as high as 40% of total energy input. Assume we can reduce energy losses by 15% by installing prefab aluminum/fiberglass insulated roofs and doors. If we're heating the kilns with a gas fired boiler, we would save $225 per charge, or $3.08 per MBF. If this kiln dries 85 charges per year, this would amount to $19,125 per year, or about a 3-year payback on a $63,000 investment.

Lift-Out Rail Sections

In kilns not fitted with lift-out rail sections where the kiln tracks pass under the kiln doors, large openings can exist which can be treated as nothing more than large gaping holes in the kiln housing. As in any hole in the kiln, they act as continuous vents which make it more difficult to maintain humidity, especially during the last half of the kiln run. (However, during the first half of the run, they somewhat aid the venting process.)

It would be difficult to compute the heat lost from rail openings at the door front, as the size of the openings vary greatly, and the amount of airflow within the kiln has a decided effect. The higher the air flow in the kiln, the more air will be forced out of holes on the pressure side of the fans, and a similar amount will be drawn into holes on the suction side. It would not be unreasonable to assume that as much as 1% to 2% of total energy might be lost through rail openings.

Retrofitting older kilns with lift-out rail sections might be expensive, inasmuch as the concrete door thresholds and the doors themselves could require considerable rework to accomplish the change. If new prefab aluminum/fiberglass insulated kiln doors are installed, yes, lift-out rail sections would also be advisable to complement the energy savings in that area.

On new kilns, the added cost of lift-out rail sections is about $2,000; if 1% energy savings is assumed, this is about a 1.5 year payback.

Insulated Vent Lids

Another area often overlooked is the heat which is lost from uninsulated vent lids, especially in the cold winter months. This might amount to 0.5%, or $7.53 per charge. The additional cost for insulating vent lids would be about $1,600 per kiln, for a kiln the size of our "typical" kiln, the payback is approximately 2-1/2 years.

If insulated vent lids are incorporated with a "line shaft" vent actuator system, the vents are kept tightly closed when in the "closed" position, as the actuators pull them shut. Air pressure is used to shut the vents, open them, or hold them in a modulated position (as opposed to systems commonly employed which use air to open, gravity to close.)

Of course, when the kiln is venting, there is no heat loss from the vent lids, but the heat loss then is considered as a venting loss (discussed below).

GROUND LOSSES

If the kiln we are talking about has a gravel or dirt floor, and the area in and around the kiln has a high water table or poor drainage, considerable amounts of moisture (or pools of water) can be present which demand a lot of heat. (Remember, if the water is inside the kiln, it will evaporate, and each pound of water will require heating up and will evaporate at the cost of 970 BTU's per pound of water!) We'll make another assumption--pour a concrete slab floor in the kiln and save 4% in energy costs. This would save $60 per charge energy cost, or about 82 cents per MBM. The payback would be about 1 year and 2 months, but imagine how much nicer it would be to work inside the kiln while pushing in a new kiln charge and doing whatever other work that must be done inside a kiln.

HEATING AIR/WATER-VAPOR MIXTURE - Venting Losses

When we see a kiln drying a charge of lumber in the early stages of the schedule, and when the wood still contains a lot of free water, the visual effects are quite dramatic, especially on a cool morning, or late at night in the presence of nearby yard lighting. Steamy vapor billows out in huge clouds from the venting system and out of every possible crack or opening in the kiln on the pressure side of the fans. The sight of all this happening makes for quite an emotional impact, but the losses are not quite as heavy as the imagination might perceive.

While energy is forfeited in the process of venting, some of this loss is avoidable. The use of vent loss minimizer (VLM) control prevents the situation of heating intake air, and then immediately venting some of it out through the exhaust vents downstream (Figure 2).

If you recall from Table 1, venting losses account for 3.5% to 8% of dry kiln energy consumption. VLM will reduce total energy about 2 to 2.5%. Using 2%, annual savings are about $2,560, or $30.12 per charge (41 cents per MBF). The cost to equip our "typical" kiln with VLM is approximately $10,500. The payback is 4.1 years for retrofitting older kilns. But on a new kiln, added cost for VLM is about $5,400, offering a payback of 2.1 years.

Another approach to vent loss energy reduction is to install a vent heat exchanger system which not only avoids some of the loss, but also recovers some of the energy, using it to preheat incoming fresh air. The heat exchanger units are mounted externally at one or both ends of the kiln (or sometimes straddling the kiln roof at the center of its length). The customary roof vents are replaced by a series of four ducts inside the kiln, running the full length, two on each side, and arranged in a way so that exhaust air is taken out before it is reheated (Figure 3), using a blower fan (approximately 40 HP). Preheated inlet air is introduced just ahead of the heating coils and further brought up to dry bulb temperature by the heating coils.

Under ideal conditions, allowing for efficiency, the unit might save up to 6% in venting losses (heat energy), but the cost of electricity to run the 40 HP motor powering the heat exchanger blower fans cannot be ignored. The net energy situation can be shown as follows:

Heat Energy at 6% Savings	$90.34	per charge
Less: Energy to Run Vent Blower Fans	<$42.54>	per charge
Net Savings	$47.80	per charge
Annual Savings	$4,063.00 or 65 cents per MBF	

Capital investment of a vent heat exchanger system retrofit for our "typical" kiln is approximately $120,000, which is high when considering its <u>net</u> energy savings.

When a vent heat exchanger is installed, roof vents are not required, thus reducing any heat loss which may occur from this source (see above, Insulated Vent Lids). And it would seem that any reduction of air circulation during venting would also be eliminated, since no air would exit the roof vents, circumventing the load of lumber being dried. However, a vent heat exchanger necessitates the installation of two inlet ducts approximately 20 inches in diameter, and two exhaust ducts approximately 24 inches in diameter--one of each, on each side of the kiln within the airstream of the circulating air. This probably counteracts any advantage gained from avoiding the use of roof vents.

STEAM SPRAY

The steam spray injects live steam into the kiln atmosphere to maintain a predetermined relative humidity. Obviously, if the kiln housing is not tight or well sealed, its ability to keep moisture vapor inside will be lessened. When the kiln's humidity controls demand steam spray, the system must work harder to provide adequate humidity. So, anything that can be done to eliminate leakage from the kiln building (such as installing a prefab roof and prefab doors) will help to reduce excess energy usage when the steam spray is in operation.

In certain circumstances, there are ways to make a steam spray system perform better. If the boiler supplying steam to your kilns operates at low pressure (below 15 psig), then you have the ideal situation--provided the spray line is adequately sized for your kiln. It could be improved upon slightly if the existing valve is of on/off control, by installing a modulating (or throttling) valve and adapting the control mechanism to provide a modulating signal to the valve.

If a high pressure boiler is supplying steam to the kilns at a pressure of, say, 150 psig, you may have a problem with superheat in the steam. This presents a situation where the steam is very hot and dry when it enters the kiln atmosphere. The consequence is that the spray must work harder (pass more steam) to achieve the same result which would come about with using low pressure steam, but with an added nuisance of driving dry bulb temperatures above setpoint.

Water injection devices spraying water directly into the spray line are an inexpensive approach, but are difficult to control and demand careful attention to maintenance. Excessive water can cause staining on lumber which is in close proximity to the spray line, and minerals in the water can build up and clog the system over a period of time.

Installing a separate low pressure steam header to serve the steam spray system is the most effective solution. This requires a pressure reducing/desuperheating station to feed the low pressure header, and the steam spray valves and steam spray line must be sized larger to be able to pass the necessary volume of low pressure steam.

Retrofitting an existing kiln installation with a low pressure saturated spray system could cost $10,000 to $20,000 per kiln, depending upon quality of the equipment and individual needs for drying. Determining payback, though, is difficult, inasmuch as so many variables are involved. The actual steam savings are low, perhaps 20 cents per MBF.

The real value of an efficient steam spray system is gained in avoiding degrade from severely checked or split lumber, or lumber which has been poorly equalized or conditioned. Dropping a grade can mean hundreds of dollars per thousand at today's prices.

FLASH LOSS

When steam enters your heating coils in your kiln, heat is given off to maintain dry bulb temperature. For every 900 BTU's (approximately) radiated by the coils, a pound of condensate (water) is formed. The water remains under steam pressure until it passes through the traps to atmosphere. At this time its boiling point lowers and energy is released as flash steam. In a low pressure system operating at an average of 12 psig, 31 BTU's are released for each pound of condensate coming out of the traps. This amounts to about 3.3% of the total energy used for heating the kiln, or about $44.00 per kiln charge, or in the case of our "typical" kiln, 60 cents per MBF.

A high pressure system operating at 100 psig has a flash loss of 129 BTU's per pound, which would amount to $198.00 per charge, or $2.71 per MBF--this is a cost that is $2.11 per MBF higher than low pressure steam!

Although flash loss is a loss we must live with, we have the choice to limit it when a new kiln is purchased or an older kiln is re-piped. Over the long run, the most economical choice at that time is a low pressure steam heating system. Of course, if the kiln happens to be for high temperature schedules, high pressure steam must be used to reach the required temperatures.

There is one thing greater than flash loss through a trap: a malfunctioning trap. Poorly maintained traps which pass raw steam, as well as condensate, can jack up fuel bills astronomically! It is one of the most important areas of maintenance in your entire kiln system, and probably the most neglected, throughout the industry.

STEAM LEAKS AND HEAT LOSSES

Very little needs to be said here about steam and condensate piping outside the kiln. Steam leaks and uninsulated piping eat up unnecessary fuel 24 hours a day, 7 days a week, 52 weeks a year, ad infinitum. An effective maintenance program pays dividends, but is hard to put numbers to. Your leaks and heat losses outside the kiln might amount to 2% (or more) of the total energy to dry a charge. This would amount to $2,560.00 per year, or 41 cents per MBF.

ENERGY FOR AIR CIRCULATION

The mill's electrical power bill is considerable at the dry kilns, if for no other reason than the kilns are up and running over 8,000 hours a year, whereas the rest of the mill is running only 2,000 hours a year, one shift, or 4,000 hours two shifts. Typically, the boiler/dry kiln complex uses about 1/3 of the total electrical power bill for the mill.

If you happen to have a fan system which delivers high air flow, you can bring electrical expenses down appreciably with variable speed controls. There are two approaches: two-speed motors, and inverter drive speed controls.

We know that air demands in drying are highest at the first part of the kiln run, and these demands decrease as drying progresses. We have also found that fan energy consumption can be decreased 30% to 40% using variable speed controls.

Our "typical" kiln, with seven single speed 10 HP fans will consume power costing $225.60 per charge, or $3.09 per MBF. If the kiln had variable speed fan controls, assuming 35% decrease in energy, $78.95 or $1.08 per MBF could be saved on each charge. If an inverter drive speed control is installed, the capital investment would be approximately $28,000. This is about a 4.2 year payback.

The largest gains can be made if the kiln is controlled by a computer which can automatically provide infinite variable speed control throughout the schedule. A word of caution--it is a lot easier to leave the fans on high speed all of the time. Once installed, the variable speed controls must be intelligently managed for maximum return.

EFFECT OF TIME ON ENERGY CONSUMPTION

Refer to Table 1. Time (length of schedule) plays an important role in determining how much energy is used to dry lumber. You will note that in five out of the seven categories which we are able to manage, any means that is used to reduce schedule length can significantly reduce energy consumption.

To illustrate this, consider that evaporating a pound of water (approximately 1 pint) requires about 970 BTU's of heat energy. But because of energy loss in various forms during kiln drying, removal of each pound of water from the wood requires additional heat. Generally speaking, heat requirements for various types of kiln schedules are as follows:

Mild, low temperature schedules	3,000 BTU/lb. water
Elevated, mid-range temperature schedules	2,200 BTU/lb. water
High temperature schedules	1,500 BTU/lb. water

For example, Southern pine dried on high temperature schedules comes out of the kiln in a little less than a day; whereas, some hardwoods which must be dried on mild, low temperature schedules can be in the kiln for weeks--yet the amount of water per board foot to be evaporated might be the same for both species.

The energy losses listed in Table 1 account for most of the difference in the total energy consumed by each of the two species. These losses are continuing whenever the kiln is running.

It stands to reason that any means of shortening a drying schedule can be one of your most effective energy conservation measures.

REDUCING ENERGY WITH MULTIZONE DRYING

In the past, it was customary to operate smaller kilns as a single zone of control. Larger kilns were divided into two zones of control--near end and far end. Times have changed. With the advent of computer control technology, it is now possible to control kilns with many more and smaller zones of control--what we call multizoning. We now can slow down the areas of the kiln which tend to dry too fast, and speed up <u>to optimum rate</u> the sluggish areas which take longer to dry. Gains in drying rate have been achieved with 20% to 50% shorter schedules; however, 25% to 30% seems to be about the norm.

Shortly after introducing multizoning to the industry in 1985, we began to see dramatic reductions in the energy required per board foot to dry lumber in multizoned kilns. Multizoning not only gives you the advantage of saving energy through reducing residence time, but the energy is being concentrated in the lumber which needs it most, and not the areas which tend to dry too rapidly.

A RECAP OF POSSIBLE ENERGY CONSERVATION MEASURES

Table 3 lists types of energy loss and conservation methods for our typical kiln.

Table 3. Recap of Energy Conservation Opportunities.

	$\MBF	Annual For 1 Kiln	Energy Payback
Building Losses - Prefab Roof & Doors	$3.08	$19,125	3.0 yrs.
- Lift-Out Rail Sections	$0.21	$ 1,280	1.5 yrs.
- Insulated Vent Lids	$0.10	$ 650	2.5 yrs.
Concrete Floor in Kiln	$0.82	$ 5,100	1.2 yrs.
Venting Losses - Vent Loss Minimizer			
(old kiln retrofit)	$0.41	$ 2,560	*4.1 yrs.
(new kiln)	$0.41	$ 2,560	*2.1 yrs.
- Vent Heat Exchanger	$0.65	$ 4,063	*29 yrs.
Steam Spray--Change to Low Pressure	$0.20	$ 1,241	** 12 yrs.
Heating System--Low vs. High Pressure (reduction in trap loss)			
(old kiln retrofit)	$2.11	$13,090	3.6 yrs.
(new kiln)	$2.11	$13,090	1.4 yrs.
Eliminate Leaks and Piping Heat Losses	$0.41	$ 2,560	1-3 yrs.
Variable Speed Fans	$1.08	$ 5,710	4.2 yrs.
Multizoning	$4.75	$29,410	*** 3.5 yrs.

*Energy calculations based solely on minimizing heat lost during venting.

**Energy gain from low pressure spray is low, but value gain will be in higher grade recovery.

***Higher grade recovery and increased kiln productivity bring payback down closer to 1 to 2 years.

CONCLUSION

Unless your kilns are relatively new, multizoned and very well maintained, the chances are good that there are energy saving modifications which you can make which will save considerable energy and lower your production costs. With timber becoming more scarce each year, a few changes to your lumber drying facilities can increase your product quality and profitability.

Bibliography:

Wilson, Jim. *Where Energy Goes In Drying.* Forest Research Laboratory, Oregon State University. 1988.