THE BENEFITS FROM ELIMINATING ROOF VENTING IN DRY KILNS

John M. Vranizan, P.E.
Carroll, Hatch & Associates, Inc.
Portland, Oregon

INTRODUCTION

The objective of my presentation is to convince users of dry kilns and manufacturers of dry kilns that there are substantial benefits available from altering the design of lumber dry kilns to eliminate roof venting. The benefits that have been demonstrated from this change to the traditional design are:

1. Lower kiln operating costs.
2. Produce more higher quality dried lumber.

I intend to tell you how to vent the kilns in a superior fashion. I will review other changes that are possible when a more controlled venting method is used. I will comment about the effects of the venting change on both thermal and electrical energy needs of a typical kiln.

There will also be discussion on why superior lumber drying results should be expected from the physical changes to the venting system.

The evolution of lumber dry kiln design has progressed slowly since the time after the Civil War when Lafayette Moore decided there was a faster and better way to dry lumber. The forced air circulation system brought with it a need to provide venting of saturated air from the enclosure.

Kiln designers of the early days saw a method of achieving venting as a "tag along" element of the air circulation system. They lined-up holes in the roof on opposite sides of the recirculation fans. Air would blow out of holes on the pressure side and be sucked in holes on the negative side of the fans. When the holes were equipped with lids, the air movement could be controlled by opening and closing the lids. The venting system proved to be cheap and reasonably effective. Mostly it was cheap to build!

In the early 1960's, Lovestead Dry Kiln Company of Tacoma, Washington, introduced "pressure venting". They eliminated roof vents and provided a ducting system to exhaust and deliver vent air. They sold a number of these units, but the concept did not reach design popularity. The company went out of the kiln business and the concept lay dormant for many years.

Two Moore Dry Kiln Company-trained kiln designers embellished the Lovestead concept. In about 1985, driven by the need to address thermal energy conservation, Lyle Carter and Mike Sprague developed a forced dry kiln venting system which featured the ability to recover thermal energy.

It is my opinion that with this innovation, Carter and Sprague have advanced dry kiln design and performance more than any other single improvement since forced air circulation was introduced.

My presentation is, however, not a commercial for their company's specific product. I want to help you analyze why this design change provides a superior drying chamber which produces a better-dried lumber product. If I accomplish my mission, you will go away from this meeting with a desire to improve your own dry kilns.

DISCUSSION

Let us begin the analysis by looking at a cross section of a conventional dry kiln. The example, Figure 1, represents the cross section of a double track kiln with overhead fans and roof vents. We all know that when lumber dries, moisture exits the lumber as vapor.

The psychrometric condition of the drying medium, air, moves toward saturation as it picks up vapor in the drying process. Air must not be allowed to become saturated because then it will loose its ability to continue the drying process. It is necessary to get rid of (vent) some of the almost saturated air and replace it with less saturated (drier) air.

Figure 2 is the same as the cross section shown in Figure 1, with air direction arrows added. This is meant to help clarify the activities that take place.

The out-of-doors is a great place to get dilution air. The air is free. Ambient air is drier than internal kiln air. It is, however, colder than kiln air. So what happens when ambient air is used to replace vent air.

1. Vent air is hot. Heat is lost through venting.
2. Ambient air entering the kiln chills kiln air. Depending upon the location of the vents, ambient air can chill part of the building and cause condensation to take place.
3. Any vapor that has been chilled to water must be reheated into vapor again. (While there is no net heat loss from this effect, it complicates the heat transfer process and contributes to kiln control difficulties.)
4. Some kiln air that was just reheated while passing through the heating coils is vented. This is a heat loss.

In a paper delivered to this group last year, Mr. William Brubaker estimated that 35%-50% of the energy consumed in a kiln is used to convert water in the wood to vapor. I think his estimate may be a low. Realize all of that energy leaves the kiln through the vents. In the drying process there is a great deal of intentional venting.

What about unintentional venting? Vent lids are shaped pieces of metal that cover the hole in the roof. Usually, they are hinged on one side. The vent is opened on command when a force is exerted which causes the lid to rotate on the hinge. When the vent lid is closed it is usually held in position by gravity. By and large there is usually no pressure seal at the vent. Even the smallest pressure difference across the vent opening will result in flow.

In almost every case, a closed vent will be either leaking kiln air or taking in ambient air depending upon which side of the recirculation fan the vent is located. With higher velocity air circulation systems, the leakage problem is exacerbated. High velocities result in higher static pressures across vent lids. Leakage rates can be expected to increase with higher velocities.

Virtually all manufacturers of softwood dry kilns in the western United States continue to provide kilns with roof vents as the norm.

Now consider the changed cross section of the same kiln we looked at earlier. The changes shown in Figure 3 are:

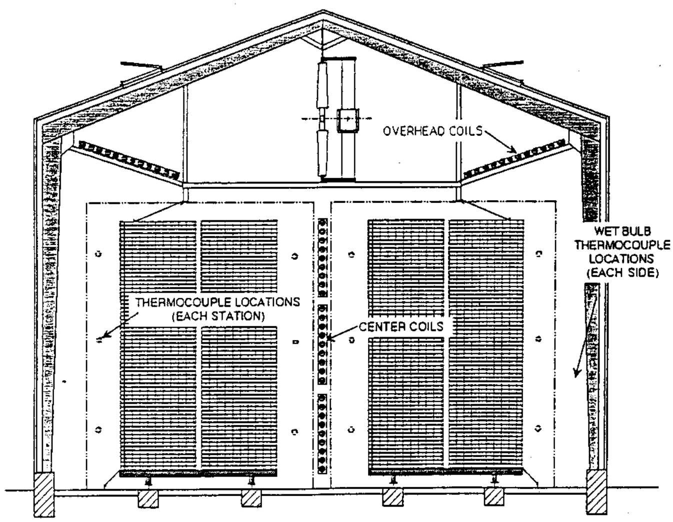

Figure 1. Cross section view of typical double-track kiln.

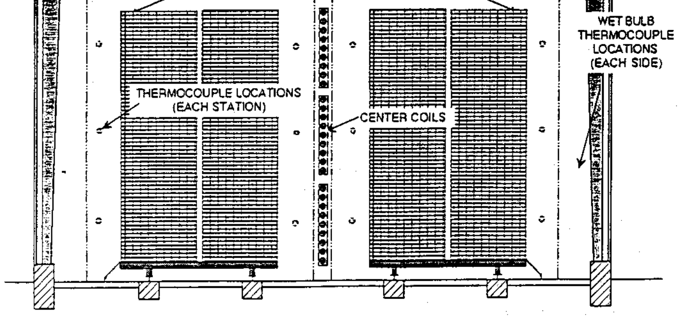

Figure 2. Cross section view of typical double-track kiln showing venting process.

1. Elimination of roof vents.
2. Addition of air delivery/exhaust ducts.

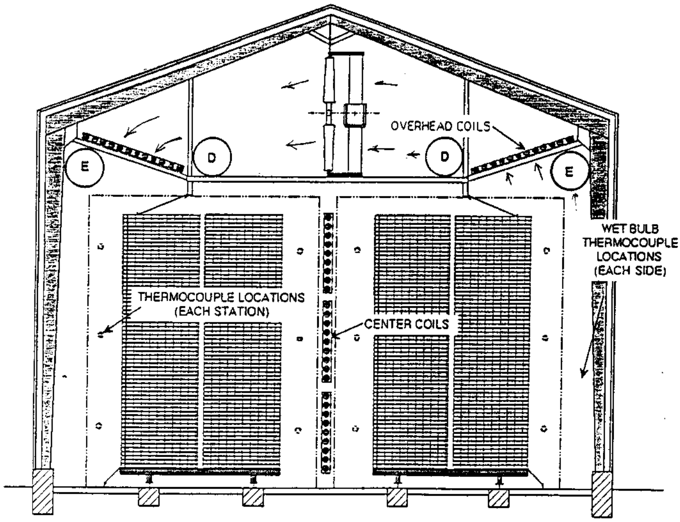

Figure 3. Typical double-track kiln cross section showing exhaust (E) and delivery (D) ducts for forced venting.

With the elimination of roof vents, all of the unintentional venting at the roof vents is eliminated. Thermal losses associated with unintentional venting are also eliminated.

Almost saturated air can now be drawn from the kiln through the exhaust duct. The duct can be sized and shaped so that a uniform amount of air is drawn along the length of the kiln.

The kiln building is of a fixed volume. If air is drawn out of the building, it must be replaced with an equal amount by volume. The delivery duct must also be sized and shaped to deliver dilution air uniformly along the length of the kiln.

If ambient air were introduced in the delivery duct, the duct would be cold relative to kiln air. The duct would sweat because vapor in the kiln air would condense on the duct surface. It would make seem to make sense to heat the dilution air prior to introducing it into the duct. If the air were heated to above wet-bulb temperature little heat transfer will occur between the duct and the kiln air. No condensation will take place.

The other problems associated with introducing chilling air from roof vents will also be eliminated. When the ducts are properly located, the wasteful practice of heating kiln air and venting it immediately is eliminated.

The source of thermal energy for heating dilution air is vent air. Vent air contains many more times the amount of heat than is required to bring ambient air up to minimum acceptable temperature, i.e. greater than wet-bulb temperature. The venting system becomes more complex because of the need for an air-to-air heat exchanger.

What will we expect the heat exchanger to accomplish? The best way to answer that question is with a sketch, Figure 4, that relates desired air properties at various locations within and outside the dry kiln. The properties of air at various points in the system are presented in Table 1.

Table 1 - Psychometric Values of Air at Various Points

Point	D-bulb Temp F	W-bulb Temp F	Hum Ratio $lb_{H2O}/lb_{dry\ air}$	Total Enthalpy Btu/lb	Sensible Enthalpy Btu/lb	Latent Enthalpy Btu/lb
1	40.0	33.6	0.00259	12.4	9.6	2.8
2	156.0	77.6	0.00259	40.4	37.4	2.9
3	165.0	155.0	0.24894	319.6	39.6	280.0
4	156.0	155.0	0.25109	321.0	37.4	283.6
5	156.0	151.9	0.22600	292.9	37.4	255.4

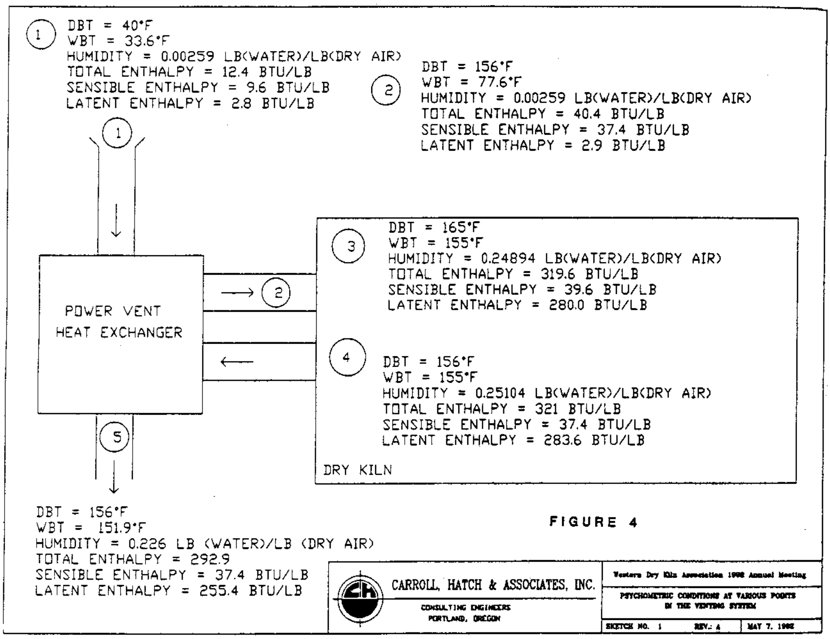

Figure 4. Psychrometric conditions at various points in the venting system.

In this example we want to operate the kiln at 165°F dry-bulb and 155°F wet-bulb. (Point No 3 in Figure 4.) Point 1 is out-of-doors where the air temperature is 40 °F and the relative humidity is 50%. As you are aware, when any two values are defined for a point on the psychrometric chart, the value of other properties at that point are fixed.

As we have stated, ambient air must be heated in excess of 155°F to avoid sweating on the duct in the kiln. Heating takes place as ambient air passes through the heat exchanger. So at point 2 we have raised the dry-bulb temperature and all other values adjust for that single change. The heat exchanger supplied about 28 Btu/lb of incoming dilution air.

As dilution air enters the kiln its total enthalpy is increased dramatically from 40.4 Btu/lb to 319.6 Btu/lb, point 3. This is accomplished by forcing the air to carry the maximum (almost) amount of water vapor which has a much higher specific heat than dry air. The thermal energy necessary to accomplish this effort comes from energy released at the dry kiln heating coils.

Point 4 represents kiln air that is almost saturated. The process moves from point 3 to point 4 as lumber dries. Psychrometric values change little between those two point.

Vent air passes from point 4 to point 5 as this air moves through the heat exchanger. From the psychrometric data, you will note that the dry-bulb temperature remains constant (sensible enthalpy stays the same) but the wet-bulb temperature drops (latent enthalpy value drops). The exhaust air gives up about 28 Btu/lb to match the heat that was absorbed on the other side of the heat exchanger by the dilution air.

Some of the vapor in the exhaust air will condense and release heat. There will be a steady stream of liquid flowing out of the heat exchanger as the venting process continues.

Now what has taken place? Air moving into the kiln (point 1 to point 3) received an increase in energy of 307.2 (319.6 - 12.4) Btu/lb. Of that amount, 28 Btu/lb came from the heat exchange. This represents 9.1% of the thermal energ y required. We conclude the heat exchanger helps reduce the fuel bill by that amount.

Now comes the dilemma. Operating experience for dry kilns equipped with forced venting and heat recovery systems experience a thermal energy requirement reduction of 25% in some cases and even as high as 40% or more in other cases.

Before installing forced venting with heat recovery, Frank Lumber Company in Mill City, Oregon, typically struggled to get through winter with enough steam to service their battery of seven kilns. After installing the system, that company was able to add kiln capacity and service it along with the original battery from the same steam system that was thought to be overtaxed.

At this meeting you will hear of other examples that have dramatically reduced thermal requirements. In those examples the mill managers have conducted careful tests. The story is the same: major thermal energy reductions!

How can this significant savings happen if heat recovery accounts for only 9% of the fuel savings? The answer must be in prevention. The systems do not recover great quantities of heat, they prevent the heat from being lost in the first place!

My conclusion, after studying this dilemma, is to encourage kiln operators to get rid of roof vents and the attendant losses associated with those vents. Kiln thermal energy requirements can be reduced by 25% to 40%. After looking at the overall results that are taking place and looking at the thermodynamic activities in the kiln and venting systems, a person is forced to reach the conclusion I have stated herein. The systems do not recover great quantities of heat, they prevent the heat from being lost in the first place!

It that all there is? No! There is more, and to many of you, the best is yet to come.

Getting rid of roof vents results in truly making the kiln building tight. Temperatures, wet and dry-bulb, can be controlled more precisely. There are fewer upsets to cause grief with a control system. The result of better control is a more uniform drying environment in the kiln.

Uniform drying environment results in the ability of the kiln to deliver lumber with tighter moisture content spreads. Target value of desired moisture content can be more precise.

Degrade as a result of kiln drying has been reduced substantially in dry kilns equipped with forced venting and heat exchangers. The reduction in degrade is probably a more serious incentive to kiln operators than are energy savings.

Are there any downside effects of the forced venting system? There may be. Forced venting requires that the air moving in and out of the kiln through the heat exchanger be moved by way of a fan or fans. Electrical energy is required to drive the fan.

The fan may operate on a start/stop basis or a damper system will be necessary to provide ability to vary flow. Those of you who are willing to do it right, will invest in a variable speed drive control for the forced vent fan. This will allow you to precisely control venting to a higher degree than with a fan damper control.

Schedule lengths may be different. There are examples where schedules have been shortened by several hours with the use of forced venting. There are other examples where schedules are slightly longer. Where schedules are shorte ned there will be electrical savings in addition to the thermal savings. Where schedules are lengthened, there will be electrical energy penalties.

Those of you who are serious about electrical conservation should already have equipped your kiln fan drives with variable speed controls. It was eight years ago that I addressed this group and told you about the benefits available in electrical energy savings for fan speed control.

Many of you have adopted this feature and have experienced electrical energy savings. You also should be experiencing the added benefit of improved drying quality due to the elimination of surface hardening that results from high velocity, hot air impinging on almost dry lumber in the kiln.

I understand some of you haven't made that fan speed control improvement. I don't expect to them here in another six years!

CONCLUSION

This industry was never known to rush into technological advancements. This industry is known for being reluctant to spend capital. This industry in the western part of the United States is in big trouble with respect to timber supply. This industry better make the most of what you have with which to work.

Forced venting with heat recovery is a most significant advancement in kiln design technology. With this advancement the industry has the opportunity to save significant amounts of energy while at the same time improving its ability to produce higher quality lumber.

You dry kiln manufacturers ought to offer this technological improvement as standard equipment. You buyers of kiln equipment ought to be ready to pay more for equipment that does more.

I suggest that dry kiln operations who survive over the next five years will be those operations who have decided to embrace this proven technology. I say goodbye to you who will not recognize reality. I do hope to see you all in five more years.