TEMPERATURE CONTROL FUNDAMENTALS FOR THE LUMBER DRY KILN

by Frank Cook

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Temperature control in the lumber dry kiln is a rather broad and all-inclusive subject and rather thick volumes could be compiled on this, or a presentation would run into hours, if not days, in presenting all of the aspects and influencing factors in their proper relationships.

With your indulgence we will confine ourselves today to some basic definitions and formulas pertaining to heat, and then concentrate on heat and its use in reconditioning lumber.

Such topics as temperature control, proper use and application of steam traps, coil design, hot air duct design, location and distribution of coils or ducts will be presented in other papers, or will be presented in future meetings, as each of these subjects will make a worthy and interesting discussion.

Any discussion of heat and humidity in dry kiln work, whether it be on a practical or purely scientific basis, must of necessity make use of certain terms and the meanings of these terms should be clearly defined so that we all are thinking of the same thing during this discussion.

Heat is a common term, rather hard to define, yet a strict scientific definition states that "heat is a form of energy possessed by all bodies".

Latent heat is that energy required to change the state of a body, such as ice to water and water to steam, whereas sensible heat is the energy required to cause a temperature change. It is this sensible heat that we, as dry kiln operators, use daily in setting kiln schedules, but we are

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consciously or unconsciously working every day with latent heat and the units of measure of this heat, such as b.t.u.'s or horse power. When we encounter trap troubles, improper temperature distribution, or claim we have insufficient steam for running the kilns, we are apt to encounter or be working with both types of heat--that is, both sensible and latent.

As dry kiln people, we are primarily interested in b.t.u.'s and horse power and their application to our every-day needs. A b.t.u. is defined as the amount of heat required to raise the temperature of one pound of pure water 1° Fahrenheit from 62° Fahrenheit, and therefore we are working with sensible heat again.

A boiler horse power per hour is equal to 33,472 b.t.u.'s per hour, but is normally figured at 33,000 b.t.u.'s per hour. A horse power is also considered the amount of energy required to raise and evaporate 33 pounds of water, since we will see later that it takes approximately 1,000 b.t.u.'s to change one pound of water to one pound of steam. Figuring strictly from a scientific basis, it will require 970 b.t.u.'s, but for sake of ease of manipulation we normally round this off to 1,000.

The ability to use these terms and apply them is often considered a technical job, whereas I am sure everyone of us has often wondered how much steam our kilns were using, or how to figure the amount of water that would be available from the kiln condensate for return to the boilers. This can be determined or calculated by using the formula: Horse power per hour equals the gallons of water per minute, times 8, times 60, divided by 33. In this formula 8 represents the number of pounds per gallon, and 60 represents the number of minutes per hour.

We can also determine the number or amount of condensate that is being made available from the kiln by using the formula: Gallons of condensate is

equal to the horse power per hour, times 33, divided by the product of 8 x 60. This formula then gives us the opportunity to determine how much condensate would be available, having a known horse power.

We are also interested in wet and dry bulb readings within a kiln, which is a means of measuring the sensible heat of the dry bulb, and then by measuring the wet bulb we are able to calculate the relative humidity and the equilibrium moisture content, if we desire to use them.

The evaporation of water from the wick surrounding the wet bulb of a thermometer, causes a cooling effect or temperature drop of the thermometer, and this drop is in accordance with the surrounding air's ability to absorb water--hence, wet bulb depression and relative humidity. This relative humidity is not a direct proportion to the increase of the dry bulb temperature with a constant wet bulb reading, but increases tremendously. For example: If we have a dry bulb reading of 130° and a wet bulb of 100°, we have a relative humidity of 35. If we have a dry bulb reading of 150 and a wet bulb of 100, we have a relative humidity of 18. Now, if we were to hold a constant dry bulb at 150, and vary the wet bulb, we find a much greater change. For example, at 110° dry bulb, we have a relative humidity of 28, and at 130° wet bulb we have a relative humidity of 57.

We must remember that the wet bulb reading, or vapor pressure within a kiln, at any one instant will be uniform throughout the kiln; whereas the relative humidity may vary within the kiln, due to variations in the dry bulb. This variation can be caused by several factors, such as condensate on the kiln floor, plugged traps, overflowing water-boxes, or like troubles.

Before passing on to discussion of heat and its application to reconditioning of lumber, we should make a brief comparison of the various qualities of steam, as these will then give us a basic concept of using relative humidity and

water vapor in an effort to relieve stresses in lumber.

I am sure all of us have either experienced ourselves, or talked with operators who said that they were unable to properly condition lumber in an economical way, or in a practical length of time, and disregarding all other items, such as type of kiln, building construction, and other like factors, let us look clearly at an extract from a saturated steam table, giving the qualities of saturated steam.

EXTRACT FROM SATURATED STEAM TABLE

Material	Pressure	Temp. °F.	Total Heat BTU/lb.	Volume cu.ft./lb.
Water	0 PSI gauge	212	180	.02
Steam	0 PSI	212	1150.2	26.83
Steam	10 PSI	240	1160.2	16.31
Steam	100 PSI	337	1188.9	3.9

From this table we see that by adding 970 heat units or b.t.u.'s to one pound of water at 212°, we do not change the temperature, but we have changed the liquid to vapor and made a tremendous volume change. By adding additional b.t.u.'s to this one pound steam that is now in vapor state, and increasing the pressure to ten pounds, we increase the temperature but conversely decrease the volume. This again holds true when we add more b.t.u.'s and increase the pressure to 100 pounds pressure.

This chart, or analysis, then bears out

(1) The efficiency of low pressure steam because it is the 970, or approximately 1,000 b.t.u.'s difference between water and steam that does our work with a minimum of loss through flashing when the traps dump.

(2) Pipe size and quantity of pipe must be figured on the steam pressure available in the design of kilns in order to insure proper heat control

(3) Low pressure steam has the best qualities for conditioning, because it has the lowest temperature and thus it will be far easier to get a high wet bulb reading without the sensible heat driving the dry bulb higher and preventing us from getting the wet bulb close to the dry bulb, which is our method of determining relative humidity.

With the aforementioned data in mind, let us now progress to the application of the knowledge to the problem of reconditioning of lumber.

The reconditioning period during a dry kiln schedule, as is generally accepted, is that portion of the lumber dry kiln schedule which utilizes a high wet bulb and high relative humidity in an effort to put moisture back into the kiln or surface of a board. The addition of moisture in the outer area of a board tends to balance the moisture content of the board, and by softening the outer fibers allows them to become semi-plastic and thus relieve the drying stresses, when the outer core is normally trying to shrink around the inner core.

In general, all lumber that is to be remanufactured by resawing or taking a heavy cut off of one edge or surface, should be reconditioned. This reconditioning is necessary in order that the board remains stable by having the same moisture content on all surfaces. Naturally the reconditioning of all lumber put through the dry kiln is a good "quality procedure", but this can only be answered by each individual operator or management policy.

In general, all Shop, Clear, Select and Moulding lumber should be reconditioned. If knowledge as to the end use of the board is available, this should answer the question as to whether the stock should be reconditioned; however, not all Sales Departments or Lumber Brokers advise the producing company of this information, so when in doubt, recondition if you can.

There are many operators who use a series of conditioning periods during

the course of the drying schedule, whereas others use one period only at the end of the run. Those using periodic conditioning periods during the course of the run, do so in the belief that periodic removal of stresses that have resulted up to that period of reconditioning, are easier to remove and that such periodic reconditioning allows a minimum of stress to occur. Those following the principle of using only one final reconditioning period say that only the final reconditioning, at the desired moisture content of the board, is satisfactory and also that periodic reconditioning treatment extends the drying time out of proportion. In either event, we are all interested in obtaining a given wet and dry bulb condition with a minimum of lost time and a maximum of control, and it is to this end that we are all constantly working.

Since the majority of operators are reconditioning their stock in kilns, rather than in separate buildings or chambers, I believe we should give first consideration to their problem.

Most kilns in operation today have adequate circulation and dry bulb control, but many are sadly lacking in--

(1) Tight building construction

(2) Proper building insulation

(3) Tight fitting doors

(4) Tight fitting ventilators

(5) Adequate steam spray equipment and control

It must be remembered that we are interested in a high, water-vapor condition during reconditioning periods, and therefore water, in the liquid state, only tears down the dry bulb condition within the kiln and presents the problem of evaporating this water during the start of the next kiln charge.

A building that is not tightly constructed and has poor insulation, poorly fitting doors and vents, may assist in dissipating heat when the dry

bulb starts to rise, because of the hot steam, but these areas then act as condensors and the dry bulb is lower in these areas, and consequently uncontrolled high humidities will be found in these areas, even though the wet bulb is constant throughout the kiln.

Many operators have found good use of cooling periods or water sprays very helpful in reducing the ambian temperature of the lumber and kiln, prior to starting the reconditioning period. While they accomplish the end result, they have certain inherent disadvantages such as:

(1) Lost kiln production time during cooling.

(2) Increased steam consumption after cooling to obtain the desired wet and dry bulb readings.

(3) Maintenance of water-spray equipment, which is a continual source of cleaning the orifices and problems.

(4) Tearing down an otherwise controlled dry bulb temperature.

(5) Placing a surplus of liquid water on the kiln interior, which retards the drying of the following charge.

Those operators having exhaust steam at 10 to 25 pounds pressure available, should not encounter any problems in securing proper conditioning within the kiln, provided that they have thoroughly tight, well-insulated buildings, and a properly designed steam spray system, including proper size diaphragm valve, spray pipe and spray line trap.

Those of us having only steam at a pressure of 100 to 150 p.si. available find ourselves continually fighting a rising dry bulb condition during steaming or reconditioning periods. This is due to having steam at between 350 and 370° Fahrenheit, which, even though saturated, contains a surplus of heat for our needs.

During the past few years many various and sundry experiments have been carried on in the field in an effort to improve wet bulb, and consequently reconditioning control.

Many have turned to specially constructed steaming or reconditioning rooms to reduce kiln time and improve conditioning.

Water has been injected into steam spray lines in an effort to cool steam or kill the surplus heat, and results have improved slightly under certain optimum conditions, but as a general rule, this has not been a satisfactory answer.

The most promising results have occurred where a large diameter pipe is used as an accumulator for 10 to 20 pounds steam. This pipe is hooked directly to the individual kiln steam spray lines and steam is admitted to the kiln through an instrument operated diaphragm valve. The source of steam for this accumulator can be exhaust or flash steam from trap action or turbines, with the provision for additional steam from the main steam supply being admitted to this accumulator through a reduction or pressure controlling valve when needed. Provision must be made for killing the surplus or super-heat steam of this reduced steam by either water venturis or like means. This 100 P.S.I. steam at 337° F. can be reduced to 10 pounds steam, which has a normal temperature of 240° Fahrenheit; however, simply reducing the steam pressure has not changed the temperature, although it has changed the volume and pressure. Thus we have approximately 100° F. of surplus heat that we must get rid of. This can be done by using a water injection, which means that water is used to kill this flash, or the line can be left uninsulated, which is a means of radiating this surplus heat.

This accumulator can either be a large diameter pipe hung across the control room, or can be an oversize tank such as an old boiler shell.

Naturally the larger the size of the accumulator, the better as to volume is the holding capacity of this unit, as volume is a critical component of such a system. We have learned from the previous discussion the large volume differential between 110 pounds steam and this cannot be overlooked.

The killing or elimination of the superheat, as previously discussed, is a critical problem, but if done in an oversize pipe or tank, adequate provisions can be made whereas surplus water, in the liquid state, will not be carried into the kiln and where heating efficiency is not eliminated.

Several installations in this area have this type of steam spray equipment, such as the Ralph L. Smith Lumber Company at Anderson, and the U. S. Plywood Corporation, Bear Creek Division, at Anderson.

I would like to point out at this stage that no definite set of rules or conditions concerning the attainment of a desired wet and dry bulb condition can be made because, again such factors as:

(1) Size of kiln in comparison to size of spray line

(2) Tightness of building construction

(3) Type of building construction as to insulation

(4) Quality of steam available

all have a direct bearing on proper attainment in control of reconditioning schedules.

Several operating companies have, after analysis, found that the reconditioning problem has caused them excess lost kiln drying production time and, therefore, have turned to specially constructed rooms wherein lumber is removed from the actual kiln rooms and placed in these rooms for reconditioning.

Although it may appear on the surface to be an ideal answer, careful

consideration must be given to the cost of such a unit, its efficiency as compared to using present kiln facilities, and the cost of rehandling lumber from the kiln units to and from the reconditioning units.

Assuming it is found practical to use special reconditioning units, let us see what their requirements must be.

The size of these units will, of course, be dependent on the cost of the size of the actual kiln drying units, the production of stock that is to be reconditioned, and the amount of stock to be placed in the unit for actual reconditioning, and the length of the reconditioning period.

Normally the reconditioning unit should hold one complete kiln charge in order to handle stock having been subjected to comparable kiln drying conditions and stresses. If the kilns all consisted of large double track units, it might then be practical to consider a unit holding just half the kiln charge; however, as pointed out, the actual size of the unit must be determined by a thorough investigation of the problem confronting each individual particular concern.

Building construction for these special chambers must, of necessity, be tight to prevent loss of heat and vapor pressure. Slight holes in the eave joints or around the doors would again lower the dry bulb reading and give unbalanced relative humidity within the unit.

Special consideration must be given to having a water-proofed building and well-insulated building to prevent heat loss and in an effort to guard against building deterioration, due to the rotting of wood timbers or the rusting of metal members. We have all seen the deterioration of wood kilns around the eave joints and ventilators, due to the continual working of the wood members caused by large variations in both the wet and dry bulbs. We

have also seen the affect of wood acids on metals within kilns, but, of course, this is primarily dependent upon the species of lumber being handled.

Now with a well-constructed building, let us see what equipment needs are required to give us controlled conditions.

Air circulation is required in order to properly control dry bulb conditions and prevent hot-spots from occurring near the ceiling or in those areas containing the heat coils, if found necessary, or the steam spray lines.

As in a dry kiln the wet bulb or water-vapor pressure will be uniform and, therefore, the circulation is for dry bulb conditions alone.

Since this circulation is for proper distribution of dry bulb conditions and need not be used for actual drying of the lumber, the high volumes and velocities normally found in modern kilns are not required. Although circulation is required, its importance is much less than in kilns; therefore, it can be obtained either by relatively fewer and smaller fans, or can even be attained by proper design of the steam spray jets that emit steam to the units. The design and installation of jets for the purpose of circulation requires careful consideration and planning and the easiest approach is through the use of fans.

Control of water-vapor is the prime target of this unit and therefore we must find a means of introducing and controlling this vapor in the conditioning unit. Those of us operating steam heated kilns have this required vapor available in the form of steam, and as long as we can control the steam, as previously discussed, it is through this controlled steam that we in turn control water-vapor.

The use of low temperature saturated steam is our goal, so, as in the case of controlling this steam within dry kilns, here again we must control the steam or water-vapor as to volume, temperature, and prevent liquid water

or condensate gaining entrance into the conditioning room and upsetting the designed dry bulb settings.

As in the case of regular dry kilns, we must control the dry bulb. Depending upon the species being handled, location and climatic areas of the plant, the desired wet and dry bulb settings, the requirements as to heating coils within such a unit must be analyzed from that particular installation. Some operators have found that by using 100 pound pressure steam through one spray line and 10 pound pressure steam through another spray, they can control both wet and dry bulbs. This is done by having a control instrument hooked so that the dry bulb control and set handles the high pressure, or 100 pound pressure steam, and the wet bulb control of the instrument is hooked to the 10 pound pressure steam. The dry bulb setting then controls the 100 pound pressure steam, which, although has some water-vapor, has a surplus of heat. The wet bulb control then controls the low pressure steam which is relatively low in heat but high in water-vapor.

Some may wonder why we consider control over the dry bulb necessary, because aren't we primarily interested in high humidities which, in turn, mean getting the wet bulb as close as possible to the dry bulb. Control of the wet and dry bulbs independently is a prerequisite to proper reconditioning as some species will develop stain or drying defects if left uncontrolled with too high a reconditioning schedule, or length of time. These defects can manifest themselves primarily in reverse case-hardening and some types of stain.

Controlling instruments are a worthy help to the operating personnel because they allow him to ask for a set of conditions, give him a record of actual conditions and, if properly installed, will attain the desired conditions. Normally ventilators and their automatic control will not be required in reconditioning. This again, however, is only true if we have

positive control on the wet and dry bulb and stock has been dried below 20%. However, a positive answer as to the necessity of vents and their control would again be dependent on other designed features of the reconditioning unit.

Reconditioning of lumber has to date been a prerequisite of properly seasoned lumber and it is with this in view that proper controls and equipment must be designed and installed to allow this controlled reconditioning with a minimum of maintenance and a maximum of production. Many problems surrounding the reconditioning can be solved by maintaining accurate records of the condition of the lumber prior to and during actual reconditioning, as well as a practical analysis of the actual operating conditions within the unit.

Qualified personnel in the field of kiln design should be called upon to assist in these problems, if necessary.

Thank you very much.

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