ELEVATED AND HIGH-TEMPERATURE DRYING IN THE INLAND EMPIRE

By Robert Beckley

By way of explanation, let me differentiate between elevated and high-temperature drying. By elevated temperatures I am referring to temperatures below the boiling point of water or in practice to 200°. With high-temperature drying I refer to drying using temperatures from 210° to 280°. Most commonly in the Inland Empire, high-temperature drying is, use of maximum temperatures around 240°.

During my discussion of elevated temperature drying, I will be referring to Fir and Pine. Please remember, I am talking about Inland Fir species, whereas with Pine I refer to Ponderosa Pine. The experimentation into elevated drying to which I will refer, was carried on in the Inland Empire.

The Fir in this region carries a low initial moisture content, ranging from 50 to 60%. Ponderosa Pine in the area varies in moisture content, with Sap portions to 200% and Heart from 40 to 50%.

First, let us consider elevated temperature drying. I will mainly discuss results from one plant with which I was personally connected. As is sometimes true, the progress made through elevated temperature drying was brought about by production pressure. Being unable to dry additional production with conventional methods, new schedules had to be developed.

We know the rate at which moisture moves in wood is dependent upon the relative humidity of the surrounding air and the temperature of the wood. The lower the relative humidity, the greater the capillary flow. Low relative humidity also stimulates diffusion by lowering the moisture content at the surface, thereby steepening the moisture gradient. But if the relative humidity is too low during the early stages of the drying of green lumber, excessive end and surface checking may result. The higher the temperature of the wood, the faster will be the rate at which the moisture moves from the wetter interior to the drier surface. But if the temperature is too high, serious defect will occur with a possible reduction of strength of the wood.

Thinking this through, we came up with this premise:-- High temperatures with high relative humidity won't hurt the wood, so heating up the board with 100% or as close to 100% relative humidity as possible in a commercial dry kiln and high temperature should heat the board all the way through. By heating the board all the way through then the drying rate by diffusion should be at a more even rate throughout the full board. In other words, the moisture should begin to move from the center of the board as rapidly as from the surface.

Therefore, in late summer of 1961, realizing there was only one way to find out if our premise was correct, it was decided to try and see what happened. Late in August of 1961, a charge of 6/4 shop was set up to run as follows: Pre-heat at the start of the run to 180 degrees dry bulb and 180 degrees wet bulb for 4 hours, then drop down to 130 degrees dry bulb, 115 degrees wet bulb and run as previous schedules for 144 hours, or 0 to 5 hours preheat, 5 to 72 hours 130-115-130 degrees, 72 to 96 hours 140-120-140, 96 hours to 114 hours 150-125-150, 114 to 144 hours 160-140-160 degrees. This schedule was run and when pulled it was found too dry, about 6 to 7 % or less, but the lumber looked good and there were no visible signs of unusual defect. More charges were then tried at about the same schedule only cutting down on the time. Subsequent charges were run until the time was reduced to 120 hours. At this point, the lumber was still too dry and was showing some stress, so an equalizing period was added to the run, but the drying time was shortened. The total time was contained within the 120 hours.

Needless to say, as soon as certain people heard about this program, they raised some question about it. It was asked, what about brown stain, reduction of strength, surface checking, etc. To satisfy our own thinking and answer these questions, 10 test charges were run and thoroughly checked after surfacing. Some of the charges had pre-heat and some not. After surfacing, it was agreed the lumber with the preheat was the best. Also 10 tests were run; half with pre-heat and one-half without, then sent to a laboratory for strength tests. The result was no difference in strength. The conclusion was then drawn that by pre-heating, the high temperatures did not affect the strength of the wood fibers or boards.

By the end of the year 1961, all lumber at this plant in all grades and specie, were being given some sort of preheat period. The length of this period varied from four to twelve hours, mainly depending upon the density of the wood being dried.

We tried, through green sorting, to place lumber with about the same drying requirements together, and at the same time we tried to separate those of the same grade with different requirements. Such as, in pine common lumber we have essentially three sorts, heart common, sap common, and shorts of 6 and 8'. By using a high pre-heat period on commons we found we loosened the resin around the knots which resulted in degrade. We still used a pre-heat period with 100% relative humidity, but we never exceed a temperature of 160 degrees. With this preheat and then an equalizing run at the end of the schedule, there wasn't degrade due to drying; also the lumber stayed bright and it did not have any more stresses than usual.

In 4/4 pine shop and selects, we separated by length and upon stacking placed full cribs of 14' and 16' shop in one charge, 12' and shorter shop with cribs of 14' and 16' select. The thinking behind this was that short shop and long selects have about the same amount of sap, and will dry comparably. This was done only on a full crib basis and the cribs themselves contained only one grade. Also, we wanted about the same final moisture content for these items. The short select 12' and under was then placed in one charge by itself. This appears to be a sorting menagerie but we found it to work successfully, and the results of more uniform drying were worth the extra effort.

After using the pre-heat period for some time and being thoroughly convinced that it would work, further refinement of schedules was necessary.

Looking at the 6/4 shop, 4/4 shop and 4/4 selects schedules it was apparent we were doing something backwards by using the pre-heat period, or getting the lumber hot and then dropping the temperature and humidity to low temperatures and then raising them back higher as the schedule progressed. Therefore, it was decided to use the pre-heat and then take advantage of this temperature and start the drying period at high temperature. We tried this on 6/4 shop first and were real happy with the results.

What we did was this -- We were by this time, on 6/4 shop using a 10-hour initial pre-heat period, leaving our settings at 200 - 202 - 200 degrees until the lumber was hot all the way through. By tests run, we found it only took from 2 to 4 hours after the kiln temperature reached the desired setting, until the boards were hot in the center. We tried to keep the pre-heat period in effect until the point was reached where the board was hot all the way through. After the pre-heat period we then tried this, rather than dropping radically the temperature and humidity, we kept it up to 190 degrees dry bulb and 170 degrees wet bulb for the first drying run and then dropping to 180 degrees dry bulb and 150 degrees wet bulb, progressively dropping the humidity for the balance of the run. Again we found good results with this. Although it appeared this would work, we learned that the schedule must be run accurately. It doesn't take much deviation, which is easy to get with high temperature, to cause serious degrade. Degrade such as surface checking is not common, drying in this manner, when the schedule is run accurately. About the same time we began to use the step-down method, we also inserted an intermittent steaming period in some schedules. This involved, at given times, raising the wet bulb to dry bulb settings for about 1 hour during the drying period, and then going back to the normal run. This is done about every 12 to 20 hours, depending on what is being dried. In the case of 6/4 shop, we found this more effective if used quite often at the beginning of the drying period. The thinking behind this process is to stop the surface drying, allow the center portion of the board to continue moisture movement. Another benefit we have received from this is more even drying, and more uniform final results. We experimented with this process, omitting it, using it less times, and found that by using intermittent steaming, in about the aforementioned method, we improved the quality of the drying and had far less variation at the final result.

We did not inject this process into schedules of any lumber except that which will go through a remanufacturing process, or mainly shop and select. By using this in dry pine selects, we were able to dry 13" and wider without any cupping or defect at all. The combination of pre-heat, intermittent steaming, and final equalizing period gave very good results. By this process, the time required for drying 6/4 shop was reduced from 144 hours to 78; 4/4 select from about 100 hours to 66 hours; 4/4 shop from 100 hours to 60 hours. Besides the reduction in time, a much higher quality of drying and more uniform moisture content was achieved.

After having such good results in pine with pre-heating, it was incorporated into associated species drying also. With fir and Larch, we sorted in the grade by length and to items as close in drying requirements as possible. We separated Fir and Larch 8/4 and 4/4. The Inland Fir we have dried quite readily, but the Larch is real heavy in density, so is slow to dry. In 4/4 Fir and Larch we sort them by specie, but place the heavy sap Fir in the Larch. The Fir and Larch selects are put in one sort. The first pre-heat period used in mixed species was with 8/4 Fir dimension. The length of drying time has not been reduced as great amount as in some other items but the quality and uniformity were better and far less gradient was present.

In 8/4 Larch the pre-heat has worked exceptionally well. Larch is a heavy dense, slow-drying wood and using the old schedules a high gradient was always present. By pre-heating to 200-202-200 degrees and 100% relative Humidity and then retain the high heat at 190 degrees with a 30 degree wet bulb depression, good results have been obtained. The gradient in the final results, by high-temperature drying, are quite low, averaging about 8 to 10%. On the old schedules a 40% gradient was not unusual. Water core is not present or a problem when this method of drying is used. Because the gradient in this larch dimension can be reduced this way, tests were run with good results to determine if this could be dried for laminated beams. This is very possible and would show a minimum of degrade, drying for this purpose. Also, the stress can be removed from dimension by this drying method. In 4/4 Fir and 4/4 Larch commons and selects, all can be dried with the high temperature preheat period with considerable time reduction and without sacrificing quality. By proper sorting and use of the pre-heat and elevated temperatures, the following time reductions were obtained. 8/4 Fir 32 to 24 hours; 8/4 Larch dimension 104 to 66 hours; 4/4 Fir 54 to 20 hours; 4/4 Larch 88 to 60 hours; 4/4 Fir and Larch selects 112 to 60 hours.

I have many of the schedule charts used in this program, which any of you are free to look at. I would caution anyone starting such a program to go easy in the beginning. There are many plants in the Inland Empire now drying with a pre-heat period. There are still many people who do not believe it does any good. I can only speak of the results, which have been verified by many people. By this drying method, additional capacity can be achieved by a small or little capital investment. The kilns used for the results I speak of were originally piped for low pressure steam. Later, they were fed by steam pressures up to 60#. This naturally was an advantage as it allowed faster heat up times. Also, these kilns had venturies installed for better humidity control. Any modern kiln could have this additional equipment for very little cost.

Since the original work with elevated temperature, this plant has continued drying studies, working with drying curves and brown stain. To establish the most desirable drying curves, a set of scales were built, to allow weighing of kiln samples from the control room, during the drying schedule without disturbing the drying program. These scales were accurate and simple enough to allow weighing of the samples hourly. Drying curves were established by schedule manipulation to allow for continuous moisture movement. These curves ran as far as possible in a straight line from original moisture content to desired final moisture content.

Lengthy studies were made with Brown stain in shop lumber. Some progress in control of brown stain was achieved. Final results drew two conclusions which I'm sure are nothing new -- No. 1 -- Higher temperatures do accentuate Brown stain; No. 2 - Fresh logs, with Ponderosa Pine are the best protection against brown stain. This is truer in the Inland Empire than in other areas for some strange reason, however, in working with a chemical engineer, it was found that brown stain could be worked to the surface of lumber when the great majority of it, and all in some cases, could be surfaced off in normal surfacing.

High-Temperature Drying

In high-temperature drying for the Inland Empire, there is still much to be learned. Because of variation of drying subjects from kiln to kiln and area to area, each operation must be handled somewhat differently.

Original high-temperature drying, first used overseas, was on products of much similarity. However, we in the Inland Empire have not been so lucky. As you know, we must work with material with moisture contents ranging from 50% to 200% or more.

In the Inland Empire the following species have been dried with high-temperature: White Fir, Hemlock, Fir, Larch, White Pine, Lodgepole Pine and Ponderosa Pine. Regarding Ponderosa Pine, where black knots are prevalent, excessive knot loss occurs in high temperatures. With the other species mentioned, those operators with high-temperature facilities have been having successful results.

Average drying times have generally been about 50% of conventional schedules, and in some cases even less.

These are some representative schedules presently being used in high-temperature kilns.

SCHEDULE

White Fir Dimension

Hours	D.B.	W.B.	
0-4	200°	200°	Spray Closed
4-8	200	200	Spray Open
8-16	220	200	
16-24	230	200	
24-31	240	200	
31-38	240	190	
38-48	200	190	

White Fir Dimension Sap

Hours	D.B.	W.B.
0-5	225°	205°
5-9	225	190
9-13	240	200
13-17	240	205
17-21	240	210
21-26	240	200
26-31	240	190

White Fir Dimension Water Core

Hours	D.B.	W.B.
0-8	205°	210°
8-16	240	190
16-24	240	180
24-32	240	170
32-38	210	200

White Fir Dimension Mill Run

Hours	D. B.	W. B.
0-8	200°	180°
8-40	220	170

Dimension Mill Run - White Fir

0-10	240°	220°
10-16	240	200
16-24	240	210
24-28	240	200
28-44	240	210

Inland Fir Dimension

0-4	240°	210°
4-8	240	150
8-10	240	210
10-16	240	150
16-18	200	200

Fir and Larch Dimension
Cam Controlled

0-4	210°	200°
4-12	Drop from	
	210	190
	to	
	210	160

Total time - 28 hours

Fir and Larch Dimension

0-6	230°	210°
6-12	230	200
12-18	230	190
18-25	230	180
25-28	230	210

Larch Dimension

0-8	205°	210°
8-16	240	180
16-17	205	205
17-25	240	170
25-26	205	205
26-34	240	160
34-40	200	200

Idaho White Pine - Water Core

0-10	240°	210°
10-13	220	200
13-18	220	190
18-22	220	185
22-34	220	210

Idaho White Pine - Mill Run

Hours	D. B.	W. B.
0-5	190°	180°
5-10	200	180
10-14	210	180
14-17	220	180
17-23	230	180
23-28	210	200

Idaho White Pine 4, 6 & 8" Mill Run

0-6	190°	180°
6-12	200	180
12-18	200	170
18-30	200	160
30-36	205	195

Idaho White Pine 10" & 12" Mill Run

0-6	190°	180°
6-12	200	180
12-28	200	170
28-36	205	195

4/4 Ponderosa Pine Commons

0-6	210°	200°
6-12	210	190
12-21	210	180
21-24	210	200

4/4 Fir & Larch Common

0-6	210°	200°
6-12	210	190
12-18	210	180
18-20	210	205

4/4 Spruce Commons

0-8	220°	210°
8-10	220	200
10-13	220	190
13-18	200	190

CONVENTIONAL DRYING SCHEDULES

6/4 Ponderosa Pine Shop

0-20	190°	180°
20-30	170	140
30-50	180	150
50-65	180	140
65-78	180	180

6/4 Ponderosa Pine Shop

Hours	D. B.	W. B.
0-10	200°	201°
10-26	190	165
26-27	190	190
27-40	180	150
40-41	180	180
41-56	170	135
56-57	170	170
57-68	170	125
78-88	180	180

4/4 Ponderosa Pine Select

0-10	196°	200°
10-15	180	165
15-22	180	160
22-28	180	155
28-29	180	180
29-38	180	150
38-48	180	145
48-49	180	180
49-66	180	140
66-74	180	180

4/4 Ponderosa Pine Shop

0-8	198°	200°
8-14	180	160
14-20	180	155
20-28	180	150
28-29	180	180
29-40	180	145
40-41	180	180
41-52	180	140
52-60	180	180

4/4 Ponderosa Pine Heart

0-6	160°	165°
6-14	160	140
14-22	160	135
22-30	160	165

4/4 Ponderosa Pine Sap

0-6	160°	165°
6-30	160	-0-
30-36	160	160

8/4 Fir Dimension

0-8	195°	200°
8-20	180	150
20-28	190	150

4/4 Fir & Larch Select

Hour	D. B.	W. B.
0-8	196°	200°
8-23	190	160
23-24	190	190
24-37	190	155
37-38	190	190
38-48	190	150
48-60	190	195

8/4 Fir Dimension

0-8	195°	200°
8-24	190	150

4/4 Fir Common

Hour	D. B.	W. B.
0-6	190°	195°
6-12	180	150
12-18	185	150
18-28	190	190

4/4 Larch Common

0-8	198°	200°
8-30	180	150
30-31	180	180
31-46	190	150
46-56	190	190

8/4 Larch Dimension

Hour	D. B.	W. B.
0-10	198°	200°
10-30	190	160
30-31	190	190
31-40	190	150
40-41	190	190
41-54	190	150
54-66	190	190

For some reason, there at first, was some dark secret about high-temperature kiln equipment. I believe this misconception has since been resolved. So far as we presently know, there is not a magic point, temperature-wise, whereas lumber automatically dries faster. The drying rate is conversely proportional to the temperature used. For most practical purposes maximum temperatures used have been about 240°. However, high temperature drying can be achieved at any temperature above the boiling point, which in most areas of the Inland Empire is around 210°.

At this time, I believe successful high-temperature drying has to accompany a pre-steaming period. Without such a pre-steaming period, length to be determined for species being dried, degrade possibilities are too great. Also, it is my belief that a pre-steaming period tends to plasticize the board and soften it to some extent, which allows drying without crook and cup associated with other fast-drying and wide spreads. This appears to be especially true with some Pines dried with high temperatures.

In working with high-temperature kilns, with recording potentiometers, we have found wide temperature drops across the loads during early drying stages. I believe for this reason, operators have been able to dry with much wider recorded spreads in the schedule. As the lumber approaches the fiber saturation point, this temperature drop is lessened. Some element of control beyond the instrument is achieved here which is not apparent to the operator. This wide temperature drop through the load is again noticeable, early in drying stages, in the opposite direction after reversal. This is one other reason shorter reversal times are necessary with high-temperature drying.

Most operators starting out with high-temperature drying experience two problems; First-overdrying, and Second - wide variation in final moisture content. By schedule changes, these things can be overcome. We must remember that we haven't been working with high-temperature drying too long. How long did it take to establish good schedules for conventional drying? I think we must remember in high-temperature drying this one important fact. Even with conventional drying we know we could dry faster but we suffered degrade. We now have some new tools to work with but let us not throw out the window everything that has been learned about drying through the years. Conditioning periods, equalization and steaming periods, are still much needed. They may take a different complexion with high-temperature drying compared to conventional drying, but they are still necessary. I believe that with both elevated temperature and high-temperature drying, pre-steaming should be used.

High-temperature drying equipment really isn't too new. Fin pipe is still used, fans and good air circulation are a must. Traps are still used. New developments in the types of equipment have been utilized. Drying equipment and building materials are better today than they have ever been. The diversity of equipment available is tremendous.

Studies are presently being conducted to present better information for establishing high-temperature schedules. Some of the things we need to learn are: how much moisture so many pounds of air will absorb at given air velocities; given average temperatures; given average humidities inside buildings used for kilns. We should know how much loss we have out the buildings. We must learn more about venting and how much venting is necessary.

At this time, I would encourage anyone who is handling dimensional items to thoroughly investigate high temperature drying. We are learning more about it every day and certainly haven't reached its limits to date. There are many benefits to be achieved, both economic and quality-wise. Some lumber items can be dried to better advantage with high temperatures than through conventional means.

If we could combine natures forces in the following -- Mountain States dry air with Midwest humidity, add Death Valley heat and a Texas Tornado with a Florida hurricane for reversal, we would have drying problems licked.