



# Practicalities in Air Drying Lumber

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The drying of lumber is an important process that is required for the efficient use of wood products. A freshly harvested tree will have a significant amount of moisture trapped within the wood cells. For example, a 17 foot log that is 18 inches in diameter at breast height with several inches of sapwood can have approximately 130 gallons of water in its cells. This water represents more than half the total weight of the log. Any lumber manufactured from such a green log will have a high moisture content making it unsuitable for many applications. Proper gluing and finishing are not possible until the moisture content is reduced to an appropriate level. Other advantages of drying include weight reduction, increased strength, and greater resistance against biological deterioration due to fungi and insects. This fact sheet summarizes some of the practical aspects related to air drying lumber.

While kiln drying is usually necessary for lumber to reach the low moisture content needed for bonding or finishing, it is possible to reduce moisture content significantly by air-drying, which involves exposing piled lumber to ambient outdoor conditions.

The main objective of air drying is to evaporate as much moisture from the lumber as possible. Unlike kiln drying, air drying offers little control of the rate of drying and the final moisture content. With air drying, lumber is typically left on stickers in the yard until a moisture content of approximately 20 percent is reached. Drying rate and time depend on environmental conditions such as air circulation rate, temperature, and relative humidity of the outdoor air. The required air-drying time is longer for all species than kiln drying time. Table 1 displays average air-drying time for lumber of various species with one inch thickness. Air drying is ideal for lumber that is going to be used for a high moisture content application, or as a pre-drying method for kiln drying. Although drying parameters in air drying are not as fully controlled as they are in kiln drying, the relationship between the quality of dry lumber and the drying process should not be overlooked. Lumber quality and drying time are directly related to the beginning moisture content of the lumber and to the moisture content difference between that of the wood and the surrounding environment. Wood loses and gains moisture in an effort to reach equilibrium with the surrounding environment. Moisture content of wood at this point is called the equilibrium moisture content (EMC) and is a function of the relative humidity of the surrounding air. Relative humidity is the ratio of the amount of water vapor present in a quantity of air to the maximum amount of water

vapor air can hold at the same temperature. Relative humidity is measured using a hygrometer that consists of both wet and dry bulb thermometers. Wet bulb temperature will usually be lower than that of the dry bulb due to evaporation, which takes place on the damp wick of the wet bulb. Based on the difference between these two temperatures, relative humidity can be determined from Table 2. For example, if the wet bulb and dry bulb temperatures are 70°F and 75°F, respectively, the relative humidity will be 78 percent.

## Stacking of the lumber in air drying

The first step in ensuring quality lumber from any drying operation is proper stacking. Improper stacking can lead to a variety of problems such as warping, twisting, bowing, staining, and increased drying time. Lumber should be sorted based on grade, initial moisture content, species, thickness, and length before stacking to reduce drying time and reduce degradation. Sorting for thickness is important to ensure uniform air flow over the stack and reduce drying defects such as cupping and twisting.

Sorted lumber should be then stacked on a level foundation of large cants that will provide adequate airflow from beneath and allow for access by lifting equipment. Care should be used to maintain space between boards so that the air flow is optimized. Hard maple, beech, oak, or Douglas fir is often used to make stickers ranging from 0.25 to 1.25 inches in

**Table 1.** Average air drying time for various species.

<i>Hardwoods</i>	<i>Drying Time (Days)</i>	<i>Softwoods</i>	<i>Drying Time (Days)</i>
Red oak	70-200	Douglas fir	20-200
White oak	80-250	Eastern hemlock	90-200
Big leaf maple	60-180	White pine	60-200
Red maple	30-120	Redpine	40-200
Silver maple	30-120	White spruce	30-120
Sugar maple	50-200	Sitka spruce	40-150
Birch	50-200	Western larch	60-120
Beech	70-200	Loblolly pine	30-150
Aspen	50-150	Engelmann spruce	20-120
Ash	60-200	Sugar pine	15-90
Alder	20-180	Redwood	60-185
Yellow poplar	40-150	Ponderosa pine	15-150

**Table 2. Relative humidity and EMC Values. (Relative humidity values are bold and EMC values are in italic type.)**

Dry Bulb Temp. (°F)	Difference between wet-bulb and dry-bulb temperature (°F)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
35	<b>90</b>	<b>81</b>	<b>72</b>	<b>63</b>	<b>54</b>	<b>45</b>	<b>37</b>	<b>28</b>	<b>19</b>	<b>11</b>	<b>3</b>	-	-	-	-	-
	-	<i>16.8</i>	<i>13.9</i>	<i>11.9</i>	<i>10.3</i>	<i>8.8</i>	<i>7.4</i>	<i>6.0</i>	<i>4.5</i>	<i>2.9</i>	<i>0.8</i>	-	-	-	-	-
40	<b>92</b>	<b>83</b>	<b>75</b>	<b>68</b>	<b>60</b>	<b>52</b>	<b>45</b>	<b>37</b>	<b>29</b>	<b>22</b>	<b>15</b>	<b>8</b>	-	-	-	-
	-	<i>17.6</i>	<i>14.8</i>	<i>12.9</i>	<i>11.2</i>	<i>9.9</i>	<i>8.6</i>	<i>7.4</i>	<i>6.2</i>	<i>5.0</i>	<i>3.5</i>	<i>1.9</i>	-	-	-	-
45	<b>93</b>	<b>85</b>	<b>78</b>	<b>72</b>	<b>64</b>	<b>58</b>	<b>51</b>	<b>44</b>	<b>37</b>	<b>31</b>	<b>25</b>	<b>19</b>	<b>12</b>	<b>6</b>	-	-
	-	<i>18.3</i>	<i>15.6</i>	<i>13.7</i>	<i>12</i>	<i>10.7</i>	<i>9.5</i>	<i>8.5</i>	<i>7.5</i>	<i>6.5</i>	<i>5.3</i>	<i>4.2</i>	<i>2.9</i>	<i>1.5</i>	-	-
50	<b>93</b>	<b>86</b>	<b>80</b>	<b>74</b>	<b>68</b>	<b>62</b>	<b>56</b>	<b>50</b>	<b>44</b>	<b>38</b>	<b>32</b>	<b>27</b>	<b>21</b>	<b>16</b>	<b>10</b>	<b>5</b>
	-	<i>19.0</i>	<i>16.3</i>	<i>14.4</i>	<i>12.7</i>	<i>11.5</i>	<i>10.3</i>	<i>9.4</i>	<i>8.5</i>	<i>7.6</i>	<i>6.7</i>	<i>5.7</i>	<i>4.8</i>	<i>3.9</i>	<i>2.8</i>	<i>1.5</i>
55	<b>94</b>	<b>88</b>	<b>82</b>	<b>76</b>	<b>70</b>	<b>65</b>	<b>60</b>	<b>54</b>	<b>49</b>	<b>44</b>	<b>39</b>	<b>34</b>	<b>28</b>	<b>24</b>	<b>19</b>	<b>14</b>
	-	<i>19.5</i>	<i>16.9</i>	<i>15.1</i>	<i>13.4</i>	<i>12.2</i>	<i>11.0</i>	<i>10.1</i>	<i>9.3</i>	<i>8.4</i>	<i>7.6</i>	<i>6.8</i>	<i>6.0</i>	<i>5.3</i>	<i>4.5</i>	<i>3.6</i>
60	<b>94</b>	<b>89</b>	<b>83</b>	<b>78</b>	<b>73</b>	<b>68</b>	<b>63</b>	<b>58</b>	<b>53</b>	<b>48</b>	<b>43</b>	<b>39</b>	<b>34</b>	<b>30</b>	<b>26</b>	<b>21</b>
	-	<i>19.9</i>	<i>17.4</i>	<i>15.6</i>	<i>13.9</i>	<i>12.7</i>	<i>11.6</i>	<i>10.7</i>	<i>9.9</i>	<i>9.1</i>	<i>8.3</i>	<i>7.6</i>	<i>6.9</i>	<i>6.3</i>	<i>5.6</i>	<i>4.9</i>
65	<b>95</b>	<b>90</b>	<b>84</b>	<b>80</b>	<b>75</b>	<b>70</b>	<b>66</b>	<b>61</b>	<b>56</b>	<b>52</b>	<b>48</b>	<b>44</b>	<b>39</b>	<b>36</b>	<b>32</b>	<b>27</b>
	-	<i>20.3</i>	<i>17.8</i>	<i>16.1</i>	<i>14.4</i>	<i>13.3</i>	<i>12.1</i>	<i>11.2</i>	<i>10.4</i>	<i>9.7</i>	<i>8.9</i>	<i>8.3</i>	<i>7.7</i>	<i>7.1</i>	<i>6.5</i>	<i>5.8</i>
70	<b>95</b>	<b>90</b>	<b>86</b>	<b>81</b>	<b>77</b>	<b>72</b>	<b>68</b>	<b>64</b>	<b>59</b>	<b>55</b>	<b>51</b>	<b>48</b>	<b>44</b>	<b>40</b>	<b>36</b>	<b>33</b>
	-	<i>20.6</i>	<i>18.2</i>	<i>16.5</i>	<i>14.9</i>	<i>13.7</i>	<i>12.5</i>	<i>11.6</i>	<i>10.7</i>	<i>10.1</i>	<i>9.4</i>	<i>8.8</i>	<i>8.3</i>	<i>7.7</i>	<i>7.2</i>	<i>6.6</i>
75	<b>95</b>	<b>91</b>	<b>86</b>	<b>82</b>	<b>78</b>	<b>74</b>	<b>70</b>	<b>66</b>	<b>62</b>	<b>58</b>	<b>54</b>	<b>51</b>	<b>47</b>	<b>44</b>	<b>41</b>	<b>37</b>
	-	<i>20.9</i>	<i>18.5</i>	<i>16.8</i>	<i>15.2</i>	<i>14.0</i>	<i>12.9</i>	<i>12.0</i>	<i>11.2</i>	<i>10.5</i>	<i>9.8</i>	<i>9.3</i>	<i>8.7</i>	<i>8.2</i>	<i>7.7</i>	<i>7.2</i>
80	<b>96</b>	<b>91</b>	<b>87</b>	<b>83</b>	<b>79</b>	<b>75</b>	<b>72</b>	<b>68</b>	<b>64</b>	<b>61</b>	<b>57</b>	<b>54</b>	<b>50</b>	<b>47</b>	<b>44</b>	<b>41</b>
	-	<i>21.0</i>	<i>18.7</i>	<i>17.0</i>	<i>15.5</i>	<i>14.3</i>	<i>13.2</i>	<i>12.3</i>	<i>11.5</i>	<i>10.9</i>	<i>10.1</i>	<i>9.7</i>	<i>9.7</i>	<i>8.6</i>	<i>8.1</i>	<i>7.7</i>
85	<b>96</b>	<b>92</b>	<b>88</b>	<b>84</b>	<b>80</b>	<b>76</b>	<b>73</b>	<b>70</b>	<b>66</b>	<b>63</b>	<b>59</b>	<b>56</b>	<b>53</b>	<b>50</b>	<b>47</b>	<b>44</b>
	-	<i>21.2</i>	<i>18.8</i>	<i>17.2</i>	<i>15.7</i>	<i>14.5</i>	<i>13.5</i>	<i>12.5</i>	<i>11.8</i>	<i>11.2</i>	<i>10.5</i>	<i>10.0</i>	<i>9.5</i>	<i>9.0</i>	<i>8.5</i>	<i>8.1</i>
90	<b>96</b>	<b>92</b>	<b>89</b>	<b>85</b>	<b>81</b>	<b>78</b>	<b>74</b>	<b>71</b>	<b>68</b>	<b>65</b>	<b>61</b>	<b>58</b>	<b>55</b>	<b>51</b>	<b>49</b>	<b>47</b>
	-	<i>21.3</i>	<i>18.9</i>	<i>17.3</i>	<i>15.9</i>	<i>14.7</i>	<i>13.7</i>	<i>12.8</i>	<i>12.0</i>	<i>11.4</i>	<i>10.7</i>	<i>10.2</i>	<i>9.7</i>	<i>9.3</i>	<i>8.8</i>	<i>8.4</i>
95	<b>96</b>	<b>92</b>	<b>89</b>	<b>85</b>	<b>82</b>	<b>79</b>	<b>75</b>	<b>72</b>	<b>69</b>	<b>66</b>	<b>63</b>	<b>60</b>	<b>57</b>	<b>55</b>	<b>52</b>	<b>49</b>
	-	<i>21.3</i>	<i>19.0</i>	<i>17.4</i>	<i>16.1</i>	<i>14.9</i>	<i>13.9</i>	<i>12.9</i>	<i>12.2</i>	<i>11.6</i>	<i>11.0</i>	<i>10.5</i>	<i>10.0</i>	<i>9.5</i>	<i>9.1</i>	<i>8.7</i>

thickness and from 0.75 to 2 inches in width. Stickers should be placed at the ends and above each foundation block for every layer. They should be flushed at the ends to eliminate possible end checking and splitting. Spacing between stickers should be from 16 to 24 inches for 1 inch hardwoods. However, wider spacing can be used for softwoods and thicker lumber. Stickers should be carefully aligned as each new layer is laid down to prevent warping within the layers of lumber. Stickers should also be uniform and dry to prevent the transfer of mold and fungi to the stacked wood. Sticker material selection can be very important to prevent sticker stain in some species.

Lumber should be stacked to a height that is easily managed with the equipment available. Individual stacks of lumber may be stacked atop one another provided the bolsters between stacks are properly aligned with the stickers in the individual stacks. Figure 1 illustrates a properly stacked lumber pile. Placement of lumber stacks within the wood yard will effect the efficiency of any air drying operation. The stacks must be arranged to facilitate adequate air flow as well as future access to stacks as they dry. Generally, stacks are oriented parallel to the prevailing winds to prevent the upwind stack from blocking air flow to other stacks.

### Modifications of the air drying process

Although air drying ultimately depends on climate conditions, drying times can be reduced and quality may be increased by

making basic modifications to the standard air drying method. Modified air drying techniques can be broadly grouped into four categories. These are shed fan, heated shed fan, unheated shed, and outdoor under roof. The main objective of these modifications is to reduce drying time and improve lumber quality by protecting the lumber pile from rain, excessive sun exposure, and by increasing air circulation and uniform distribution of temperature of the surrounding air. Table 3

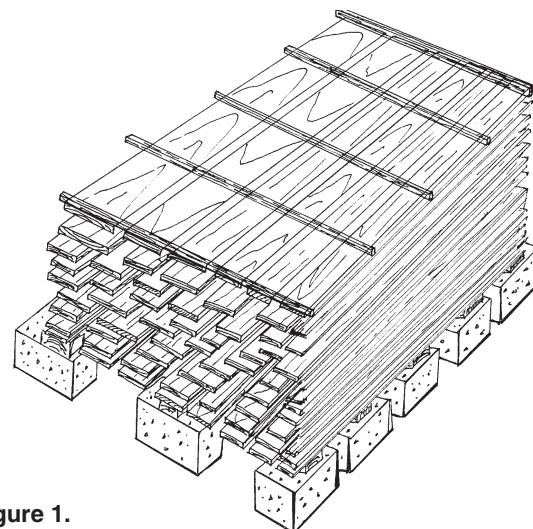


Figure 1.

**Table 3. Drying time in days of three species for different air drying techniques.**

Technique	Maple	Cherry	Oak
Shed-fan	80	90	100
Heated shed	30	70	60
Unheated shed	100	110	120
Outdoor roof	130	150	200

displays drying time of 1 inch thick specimens under different drying techniques.

Shed fan air drying is the most commonly used of the four modified air drying techniques. Adding fans on the wall in this method improves the uniformity of air circulation throughout the load. The heated shed method has the advantage of improved air flow as well as rudimentary humidity control, which helps to reduce drying time and offer some control of quality. Unheated sheds simply protect lumber piled under an outdoor roof against rain and direct exposure of sunlight. Figures 2 and 3 show outdoor under roof and shed fan drying methods.

### Estimated cost of air drying

The cost of air drying can be estimated by the following equation :

$$\text{Cost} = T/C [(P + L + V) r + P (x + y) + V (Z)]$$

T: Average drying time per year

C: Yard capacity (bdft)

P: Cost of yard, preparation, and road ways (\$)

L: Value of land (\$)

V: Value of lumber (\$/bdft)

r: Interest rate

x: Depreciation

y: Maintenance cost

Z: Insurance cost

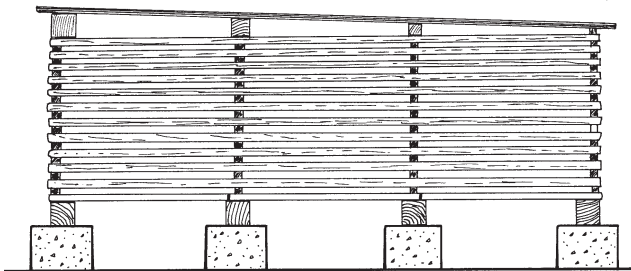
For example, if 5 million board feet of lumber with a dried value of \$500,000 dries for 10 months and cost of the yard, value of the land, and interest rate are \$60,000; \$10,000; and 5 percent, respectively. The depreciation, maintenance, and insurance cost are 20, 15, and 2 percent, and the yard capacity is 1 million board foot; the total drying cost per 1,000 board foot can be found as follows.

Total drying cost per bdft will be

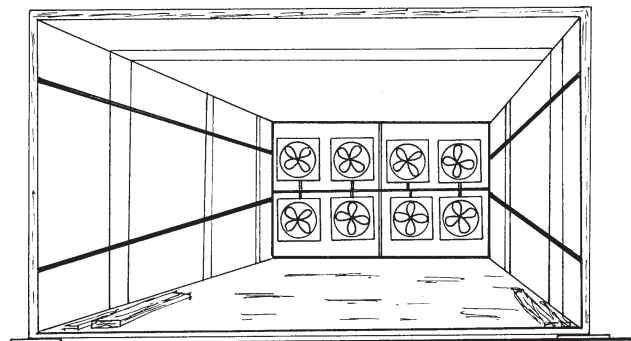
$$0.83 \div 1,000,000 [(60,000 + 10,000 + 500,000) 0.05 + 60,000 (0.20 + 0.15) + 500,000 \times 0.02] = \$0.0496 \text{ per bdft or } \$49.60 \text{ per } 1,000 \text{ bdft.}$$

Detailed information about air drying of lumber can also be found in the following literature:

1. Dry Kiln Operator's Manual. 1991. Edited by William T. Simpson. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin.
2. Air drying of Lumber. 1972. Raymond C. Rietz and Rufus H. Page. U.S. Department of Agriculture. Agriculture Handbook No. 402.
3. Drying Wood with the Sun. 1983. The National Center for Appropriate Technology. P.O. Box 3838 Butte, Montana.



**Figure 2.**



**Figure 3.**

## The Oklahoma Cooperative Extension Service

### *Bringing the University to You!*

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

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  - It is administered by the land-grant university as designated by the state legislature through an Extension director.
  - Extension programs are nonpolitical, objective, and research-based information.
  - It provides practical, problem-oriented education
- for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
  - It utilizes research from university, government, and other sources to help people make their own decisions.
  - More than a million volunteers help multiply the impact of the Extension professional staff.
  - It dispenses no funds to the public.
  - It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
  - Local programs are developed and carried out in full recognition of national problems and goals.
  - The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
  - Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

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