MECHANISMS OF MOISTURE MOVEMENT IN WOODS[1]

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The main purpose in seasoning wood is to remove the water in order to reduce weight of the wood and to improve its properties and dimensional stability in use. The manner in which moisture moves through wood has a great influence on how well and how easy these objectives can be accomplished. The structure of wood has a direct effect on the seasoning problems. Differences in drying properties within a species are sometimes as great as from one species to another.

Ways in Which Water Moves Through Wood

1. Capillary flow - commonly stated as a wick effect. This occurs in wood that has water in the cell cavities (above the fiber-saturation point).

2. Diffusion as hygroscopic water (bound water) which is the water that is in the cell walls and is responsible for the shrinkage of the wood when it is removed from the cell walls. This water is below the fiber-saturation point. In terms of percent this will be about 28-30% moisture content. If the cells of wood are wetter than this, there will be free water in the cell cavities. Free water just adds weight to the wood and, with very few exceptions, as in collapse, its removal does not cause shrinkage or a change in strength properties of the wood.

3. Diffusion as water vapor through the air in the cells and through the openings in the cell walls. This method would take place in the part of the wood that has no free water (below fiber-saturation point).

4. Combinations of two or all three methods. During drying, a board may be green (above fiber-saturation point) in the center and decrease in moisture content toward the surface. All three methods will cause drying at the same time in that board.

Characteristics of Mechanisms of Movement

In the first method - capillarity - the ability of the water to form a definite meniscus in a small tube whose sides it can wet is the main reason why free water can move by this method. As water is evaporated from the very small openings in the cell wall and in the pit membranes, if they are not closed, each meniscus tends to stay at the entrance to the small opening; but to stay there, water must be pulled toward the opening or toward the wet-line in the wood. At the very start of drying the wet-line will be at the surface of the board and as drying continues this boundary between the free-water zone and the zone that has no free water will move farther toward the center.

Because of the openings that connect one cell to another, the evaporation at the wet-line can cause a pull on the water in cells which are several or even many rows to the inside. Because of this pull, water can flow toward the wet-line and thus decrease the amount of water at some distance inside the wet-line. In other words, there is neither a sharp nor a great difference in moisture content in the zone of the wet-line, either toward the outside or toward the inside. Because of this, the wet-line may not be distinct or sharp to the eye when a board is cross cut.

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The condition just described is common in pervious woods and with sapwoods generally. If a tiny bit of air is in the cell and if it is larger than the largest opening in the cell wall, the air will expand and allow the water to be drawn out toward the dry wood. The pull due to capillarity is greater than the vacuum force created by the withdrawal of the water from the cell. This is the case in sapwoods and pervious heartwood. In some heartwoods the openings between cells are either nearly closed or are clogged and if the cell cavities are full of water, there is no air to expand as the water is drawn out. The capillary force of the meniscuses in the small openings in the cell walls next to cavities that have an air supply is so great that the air does not flow in to relieve the tension in the water. This is similar to the fact that it is much more difficult to blow out the film of water in a fine-mesh screen than in a coarse mesh screen. As water is withdrawn by evaporation at the wet-line, a strong pull is exerted through the water which, in turn, is adhering firmly to the cell walls. The pull may be so strong that, if no relief is given by the breaking of a meniscus and letting in air, the cell walls may be pulled together. This is one cause of the seasoning defect that is called collapse. Slides will be shown to illustrate capillary flow.

Diffusion of water in cell walls takes place below fiber saturation point and the direction of movement is toward the drier cell walls. The diffusion pressure or driving force is caused by the difference in the amount of water in the cell walls. This is related to the intensity with which this hygroscopic water is held in the wood. Wood at 25% moisture content will lose moisture more easily than at 10%; this is proved by the difference in relative humidity required to cause drying in the two cases. The lower the moisture content the more strongly the remaining moisture is held in the cell walls. At lower drying temperatures, diffusion within cell walls is thought to be the most important means of water movement in wood below fiber-saturation point. This is because the attractive force of water to wood is greater at low temperature than at high, whereas the vapor pressure of water (the tendency of water to exist in the vapor form and which is measured as a gas pressure) is low at low temperature but increases greatly as the temperature is increased to 160° F and above.

In vapor movement, water moves as separate molecules (in gaseous form) across cell cavities, through openings in the cell wall such as in the pit membranes, also through cell walls as bound water followed by evaporation at the surface on the other side, then across another cell cavity, and so on toward the surface. The amount of water that moves in this way will depend upon several factors. A moisture difference in a board that is nearly wet in one zone and very dry in another will tend to give the greatest moving force at a given temperature. This is because the vapor pressure will be higher at the wet zone and least at the dry zone. If the drying temperature is increased, the number of water molecules that evaporate into a cell cavity will increase (the vapor pressure will be greater). Therefore, the vapor pressure in the moist zone will now be much greater than at the dry zone and the drying rate will be increased because a greater amount of water vapor moves to the surface zone where the amount of water vapor in the cell cavities is kept low by low relative humidity of the outside air. Vapor movement in wood is very important below the fiber-saturation point - - more important than movement of water within the cell wall - - and it becomes more important as the moisture content decreases (below f.s.pt.) and as the specific gravity of the dry wood decreases.

There is more cell-cavity space, thinner walls, and often more openings in the cell walls in light wood as compared to heavy woods. This gives more diffusion space and more passage-way area between cells.

Drying Rate and Moisture Gradient

The moisture gradient (change in moisture content from surface to center) is not the same below the fiber-saturation point as it is above. Also above f.s.pt. the gradient is different for sapwood and pervious heartwood than it is for impervious wood that is saturated. This was referred to briefly in the section on free-water movement. Lantern slides will be shown to present these relationships. In general the moisture content curve rises rather fast near the surface and flattens out toward the center of the board. The longer the board has dried, the less difference there will be in the rate of change and the actual amount of moisture content from outside to center. The rate of movement of water (free and bound) is related to the thickness of the wood, temperature, etc., the drying time will increase approximately as the square of the thickness of the board. The initial and the final weight of water in the wood also affect the drying time.

Shrinkage and Case Hardening Effects

In most cases, shrinkage takes place only when the water below fiber-saturation point is lost. There are exceptions, usually associated with collapse, such as certain oaks, redwood and red cedar sinker stock, which show shrinkage while the wood is still quite wet. Since the movement of water is mainly a limitation of diffusion rate, a moisture gradient cannot be avoided and it must also result in a shrinkage gradient when it is below fiber-saturation point. Case hardening effects are due to the stress from shrinkage in one zone acting on another zone at a different moisture content. Ordinary shrinkage itself causes complicated stresses in the wood. Tangential shrinkage is greater than radial in softwoods and summerwood shrinks more than springwood. Some slides based upon recent research on shrinkage will be shown to demonstrate some of these points.