SOME ASPECTS OF WOOD MOISTURE RELATIONS*

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Introduction

In discussing wood moisture relations the technical term which is most frequently encountered is equilibrium moisture content, usually referred to as E.M.C. Equilibrium moisture content is defined as the moisture content which wood will attain in equilibrium with a given temperature and relative humidity. This is an extremely useful concept and finds widespread use in dealing with wood. It is so well established, in fact, that a given set of temperature and relative humidity conditions is often referred to as an E.M.C. condition of so many percent--meaning that in this set of conditions wood will attain a predetermined moisture content.

From the foregoing it is clear that two of the factors which will influence E.M.C. are temperature and relative humidity. In practical application, these are usually assumed to be the only factors. Although this assumption is justified, there are nevertheless several other factors which can also influence equilibrium moisture content. One of these is that we are dealing with wood, a biological material, which has a great deal of inherent variation. We can never expect one individual piece of wood to behave exactly like any other piece. Another factor is the species of wood which we are dealing with. Although the influence of species is not very pronounced and may be overshadowed by the variation within one species, these differences nevertheless exist. And finally, a factor which cannot be entirely discounted is sorption hysteresis. The present discussion will be devoted to this factor.

The word hysteresis is derived from the Greek word hysterein, meaning to be behind; to lag. There are a number of different hysteresis effects. Perhaps the best known of these is the hysteresis encountered in electromagnetism. The

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*A more detailed discussion of the subject will be published in a forthcoming issue of the Forest Products Journal.

phenomena of sorption hysteresis manifests itself in sorption measurements on wood. Such measurements show that the equilibrium moisture content attained by a piece of wood exposed to a constant temperature and relative humidity will be higher when equilibrium is approached by desorption than when it is approached by adsorption. If we plot equilibrium moisture content as a function of relative humidity at constant temperature, we obtain two s-shaped curves, one of which is for desorption and the other for adsorption. The desorption curve thereby lies higher than the adsorption curve except at 0 and 100% relative humidity where they meet. These two curves form what is known as the hysteresis loop.

It has been shown that the hysteresis loop forms a boundary line for an infinite number of possible points of equilibrium. A specimen may come to equilibrium at any point within the hysteresis loop, depending on the constancy of conditions and the prehistory of the specimen. This means that the final equilibrium moisture content of a piece of wood will depend on the accuracy with which temperature and relative humidity are controlled and on the initial moisture content from which sorption was started. Relative humidity oscillations, especially, if sufficiently large, are known to eliminate the hysteresis effect. Desorption curves obtained with relatively large specimens under slightly oscillating conditions fall well within the hysteresis loop. It has been generally thought that the size of the specimen used in sorption measurements was a factor equivalent to oscillating relative humidity conditions, since it was believed that in a large piece of wood alternating adsorption and desorption would occur in various areas of the specimen and thus have the same effect as relative humidity oscillations.

In kiln drying practice, the phenomena of sorption hysteresis is taken into account in establishing the relative humidity and temperature conditions during the final conditioning cycle. There the E.M.C. conditions are set higher than those found on the well-known E.M.C. chart by a correction involving the hysteresis constant. The hysteresis constant, usually referred to as the hysteresis ratio, is the ratio of adsorption to desorption moisture content at a given relative humidity.

This ratio is practically a constant over most of the range of relative humidity conditions and becomes unity at 0 and 100% relative humidity, respectively.

The adsorption curve for large specimens has never been investigated. This and the general influence of thickness of wood on sorption hysteresis seemed worthy of study because any results obtained would have practical implications and would add to our fundamental knowledge about wood. Therefore, the following experiment was designed and conducted.

Experimental Work

Specimens of aspen (*Populus grandidentata* Michx.), 3" long, 2" wide, and ranging in thickness from 0.05 to 0.80 inches, were brought to equilibrium with six different relative humidity conditions by adsorption and by desorption. Different sets of specimens were used for the various relative humidity conditions and for adsorption and desorption measurements. The specimens were taken from logs specifically cut for the experiment, which insured a knowledge of the prehistory of the material. Constant relative humidity conditions were maintained over saturated salt solutions in a closed system with controlled temperature. A summary of the experimental variables is shown in Table 1.

Table 1.--Summary of variables and number of specimens used

Variable	Intervals	No. of classes in variable
Thickness (inch)	0.8, 0.4, 0.2, 0.1, 0.05	5
Relative humidity (percent)	24, 31, 57, 71, 83, 89	6
Type of sorption	desorption and adsorption	2
	No. of variable combinations:	60
	Replications:	3
	Total No. of specimens:	180

The results were expected to give six points each on the desorption and on the adsorption curve. By plotting moisture content at any given relative humidity separately for each thickness class, it was anticipated that a family of curves might be obtained, where the thinnest specimens would show maximum hysteresis, the thickest specimens minimum or no hysteresis, and the curves for specimens of intermediate thickness would fall between the two according to the influence of thickness.

Results and Discussion

The results are shown in Table 2. It is at once evident that there is a definite hysteresis effect for each relative-humidity condition, regardless of the thickness of the specimens. There are, however, certain trends for the moisture content to increase or decrease with an increase in thickness, but these trends are not uniform for all cases and cannot be explained on the basis of any one factor alone. Only the desorption specimens in equilibrium with 24 percent relative humidity show the expected trend of a reduction of the hysteresis effect accompanying an increase in thickness. The adsorption specimens in equilibrium with relative-humidity conditions of 31 and 57 percent, and the desorption specimens in equilibrium with those of 57 and 83 percent show a definite trend in moisture content such as might be expected if true equilibrium had not been attained. In all the remaining groups of specimens any trends accompanying an increase in thickness are either non-existent or not very clearly defined.

Drying curves showing the relationship between time and moisture content established beyond any reasonable doubt that the specimens were definitely in equilibrium, i.e., any differences due to lack of equilibrium would be well within the limits of experimental error.

The results of the experiment were analyzed statistically by analysis of variance techniques. This established that the thickness of the specimen had an influence on the moisture-content percentages obtained, but that this influence was very small compared with the influence of type of sorption. Since type of sorption in this case is an expression for hysteresis modified for statistical treatment, it means that hysteresis does occur regardless of the thickness of the specimen. Based on the results of the statistical analysis and the absence of a unidirectional trend in moisture-content percentages with an increase in thickness, it was assumed that the main influence of thickness was on experimental error. Therefore, Figure 1 was constructed from the mean values for each relative humidity and type of sorption combination.

Table 2.--Equilibrium-moisture content percentages for desorption and adsorption specimens of five different thicknesses at constant relative-humidity conditions and 75 degrees Fahrenheit.

Thickness (inch)	Relative humidity (percent)											
	24		31		57		71		83		89	
	1*	2**	1	2	1	2	1	2	1	2	1	2
0.05	3.9***	6.8	4.9	6.7	8.9	11.0	11.1	14.7	13.4	18.2	16.8	22.2
0.10	4.0	6.3	4.8	6.5	8.8	11.2	11.3	14.8	13.2	18.5	17.1	22.1
0.20	3.9	6.1	4.6	6.8	8.7	11.6	11.2	14.5	13.2	18.9	17.2	22.3
0.40	3.9	6.0	4.4	6.8	8.3	11.7	11.2	14.4	12.9	18.8	17.1	22.5
0.80	3.7	5.9	4.2	6.6	8.2	11.7	10.7	14.9	13.2	19.0	16.8	22.5
Average****	3.9	6.2	4.6	6.7	8.6	11.4	11.1	14.7	13.2	18.7	17.0	22.3
Hysteresis ratio*****	0.62		0.69		0.75		0.76		0.70		0.76	

*1 - Adsorption moisture content percentages.

**2 - Desorption moisture content percentages.

***All moisture content percentages in the major part of the table are averages of 3 samples.

****These are averages of 15 samples (five thicknesses x three replications).

*****Ratio of adsorption to desorption moisture content.

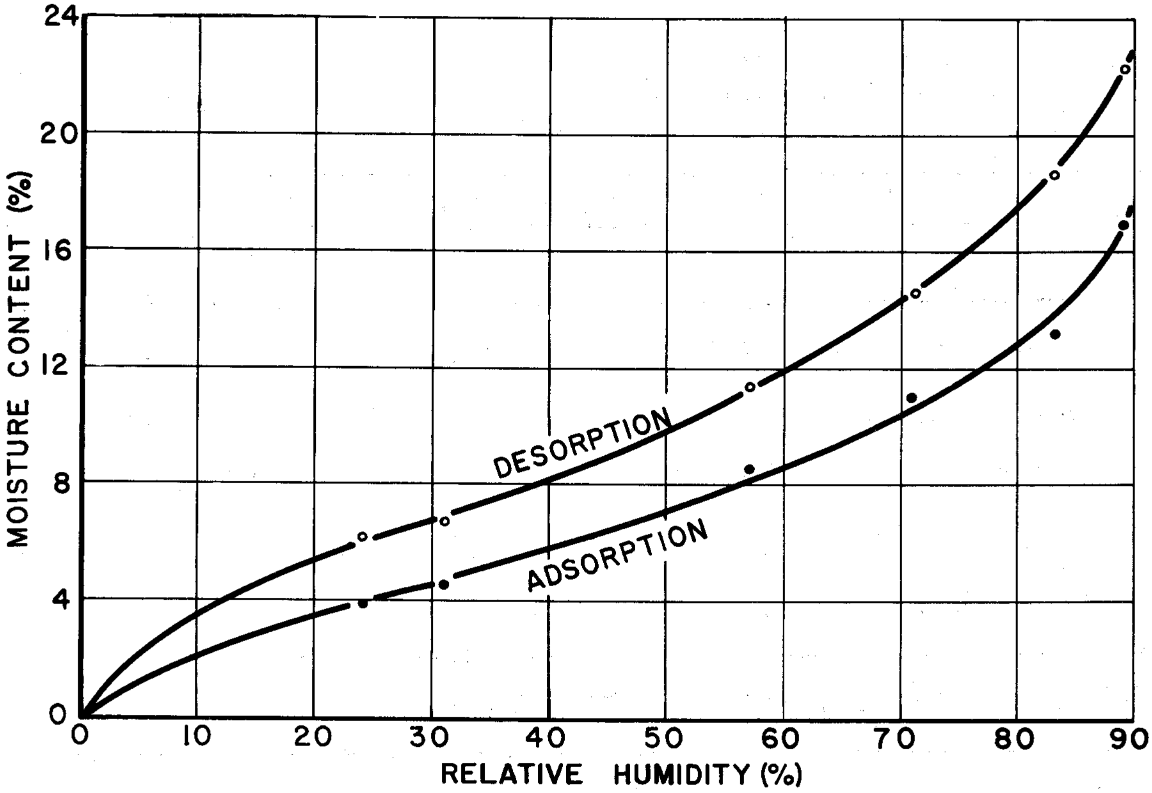

Figure 1.--Adsorption and desorption curve of the experiment, based on average values of all thickness classes.

Conclusion

The sensitivity of the present study was not sufficient to establish the exact influence of thickness of wood samples on sorption hysteresis. The results of this study show definitely that whatever influence thickness may have is very slight. The size of the largest specimens used in this study, 0.8 x 2 x 3 inches, was certainly sufficient to result in the establishment of a moisture gradient, which indicates that the adsorption and the desorption mechanism must proceed in a uniform and unidirectional manner and that the presence of such a gradient does not cause appreciable alternating adsorption and desorption within the specimen. Therefore, the size of a wood specimen would not be a major factor causing elimination of the hysteresis effect in sorption measurements. Under carefully controlled conditions, wood specimens of large sizes still exhibit sorption hysteresis.