

FIBER SATURATION POINT: A NEW DEFINITION

Harvey H. Smith
California Cedar Products Company
Stockton, California

When asked to present a paper, this subject "Fiber Saturation Point: A New Definition" came to mind. The technical program for this year's annual meeting includes a wide range of subject matter from the results of basic research to update reports on recent process developments. What I have to say fits very well into this general format. I am not reporting the results of new research, rather, I am presenting a reevaluation of some of the earliest research done in the field of wood science and wood utilization.

I believe the reevaluation of this basic concept of Fiber Saturation Point (or abbreviated to FSP) is necessary to clarify some of the misunderstanding and fuzzy thinking that seems to persist.

First, I plan to present some basic concepts. Second, review the development of the term FSP. Third, point out the inconsistencies between one and two. Fourth, propose a new definition.

My uneasiness about the definition for FSP began when I went to Madison, Wisconsin in 1941 to work at the U.S. Forest Products Laboratory.

During the ensuing several years, I was exposed to and studied under some notable scientists in the field of timber physics and lumber drying, the following names come to mind: Ray Ritz, Karl Loughborough, Oscar Torgeson, Al Stamm, and H.D. Tiemann. These were senior scientists for whom I had great respect--a respect and admiration that has grown through the years. Shortly after I arrived at the Forest Products Laboratory, these senior scientists and other heads of divisions gave seminars on various disciplines or areas of research at the lab, such as: Wood Preservation, Wood Chemistry, Timber Mechanics, Timber Physics, Pulp and Paper, and Derived Products.

The three seminars at which H.D. Tiemann shares some of the wisdom he had accumulated during the previous 40 years of research and study were exceedingly interesting to me. He talked at length on the fundamentals of lumber drying.

Let me review some of these basic concepts or "givens" in lumber drying.

- 1) If we don't use wood in its original green state, then we are obliged to dry it prior to use, or suffer the usually adverse effects of having the wood dry in use under uncontrolled conditions.
- 2) When wood dries, it shrinks. This is the norm. Anti-shrink treatments as with polyethylene glycol (PEG) have very limited applications.
- 3) When wood dries on the air yard or in conventional kilns, it dries from the outside in and a moisture gradient is established. Without a moisture gradient, and the associated vapor pressure differential, there would be no moisture

movement and drying would stop after the surface fibers became dry.

- 4) Shrinkage does not occur as free water is removed from the wood cell lumens, but is near to a straight line function as water is removed from the wood substance, i.e., the molecularly adsorbed or surface bound water and the subcapillary condensed water held in the submicroscopic structure of the cell walls.
- 5) As this bound, or adsorbed water is removed, wood substance becomes harder and stronger.
- 6) Because shrinkage is restrained as wood dries and becomes harder and stronger, full shrinkage potential is not attained, and all wood fibers from the surface to the core of the piece become set while under tension.

These, then are the three basic inescapable facts concerning the drying of the wood:

- 1) It shrinks as it dries from the green state to some suitable final use moisture content.
- 2) In all usual drying processes, such as air drying or kiln drying, a moisture gradient develops.
- 3) Wood does not remain plastic, but becomes harder and stronger and develops a more or less permanent tension set during the drying process.

Thiemann pointed out that:

- 1) If wood didn't shrink as it dries from green to some final use moisture content, or
- 2) If it could be dried without a moisture gradient, or
- 3) If wood remained plastic instead of becoming harder and stronger and develop a "set"----

If any one of these three could be changed, then it would be no more difficult to dry than the Monday wash. Lumber drying would be simply a problem of supplying heat to provide for the needed evaporation. It would be a heat transfer problem. Because wood does shrink as it dries from the green to some final moisture content, and because wood does not remain plastic, but develops a set during drying, the only option left to us is to control the extent, or steepness of the moisture gradient. This we do by controlling the temperature and equilibrium moisture content during the drying cycle by applying suitable kiln schedules. This is what kiln schedules are all about.

By now, many of you may be wondering why waste our time going over what every wood technologist already knows--when are we going to hear about some wonderful new definition of FSP?

I am coming to that, but first let me present some of the definitions of FSP as found in just about every publication on lumber drying.

I start with Thiemann's original statement based on studies at Yale Forest School and reported in F.S. Bulletin #70, "Effects of Moisture on the Strength and Stiffness of Wood." This was published in 1906, so the work was done more than 80 years ago.

Test specimens $3/4 \times 3/4$ " square and $1 \ 1/2$ " long were tested to ultimate crushing strength, parallel to the grain, at different moisture contents. Moisture content was determined from discs taken at the point of failure. Until a certain dryness was reached, the points held to a straight line, beyond which a steep curve developed.

The intersection of this curve with the straight line was taken as the "Fiber Saturation Point. Please note that this establishes where--at what moisture content the change takes place--not what the FSP really is.

In another study reported in his book, Wood Technology, Constitution, Properties and Uses, second edition published in 1944, he has a somewhat different definition:

The hygroscopic attraction of wood for water is so great that much heat is liberated by the union of dry wood and water. When water molecules are condensed from vapor in the air, the heat generated is called heat of adsorption and when taken on from liquid water heat of wetting. The affinity is very great when the wood is completely dry and falls to zero when the wood substance becomes saturated. This point, when the substance becomes saturated and heat of adsorption becomes zero, I have designated as the FSP.

I like what he has said, but, unfortunately, he confuses the concept by adding:

It is probably unnecessary to remind the student that removal of 'free water' does not cause shrinkage. In other words, shrinkage begins when the block in drying reaches its FSP.

The FSP has subsequently been determined by other methods, including studies in the electrical properties (Myer & Rees, 1926), centrifuge (Pirem, 1954), and by measuring shrinkage.

Out of all this have come more simplified definitions of FSP.

The fiber saturation point is the critical condition reached in the process of seasoning at which (by definition) the wood contains just enough moisture to saturate the cell walls without the presence of any additional moisture in the cell cavities. Reduction of moisture content below the FSP is accompanied by dimensional changes and changes in the mechanical properties of wood.

The moisture content at which cell walls are completely saturated (all 'bound water') but no water exists in cell cavities, is called the 'fiber saturation point.' The fiber saturation point of wood averages about 30 percent moisture content. The fiber saturation point also is considered as that moisture content below which the physical and mechanical properties of wood begin to change as a function of lowering the moisture content.

Fiber saturation point--the stage in the drying or wetting of wood at which the cell walls are saturated with water (bound water) and the cell cavities are free of water. It is usually taken as approximately 30 percent moisture content, based on the weight when oven dry.

Now we get down to the nitty gritty of this whole dissertation.

How do you reconcile these definitions that consider the FSP to be a specific point in the process of drying of solid wood in the form of sawn products such as squares, lumber, dimension, etc., with the fundamental, inescapable fact that in all

conventional drying methods, such as yard drying and kiln drying, a moisture gradient develops very early in the process?

Fibers close to the surface dry below the FSP almost immediately, and then additional fibers, layers of fibers, reach the FSP successively as drying proceeds.

I submit that any definition of the FSP that is associated in any way with the drying of a "piece of wood" is not correct, and leads to considerable misunderstanding and confusion.

In fact, I say there is no such a thing as the FSP of a piece of wood during drying from the green state to some final use moisture content.

Because of the misunderstanding and confusion caused by these quite generally accepted definitions, I'd like to suggest a more accurate definition:

FSP is a cell by cell phenomenon, and is the stage of drying of each cell at which all the free or absorbed water has moved out by liquid flow or vapor diffusion, leaving the wood substance of the cell completely saturated with bound or adsorbed water. The term FSP cannot be applied to a piece or block of wood as in drying lumber in a dry kiln.