An improved method for measuring the volume of large wooden objects

Technical Note

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Abstract

A water displacement specific gravity procedure, previously developed at the Forest Products Laboratory, was modified and used to measure the volume of solid wood in pallets. The procedure is inexpensive, efficient, and accurate. It can be adapted readily to measure the wood content of any large, irregularly shaped wooden object and, as such, is useful for researchers and wood products manufacturers.

Measuring the solid wood content of large, irregularly shaped wooden objects can be tedious, costly, and inaccurate, A measurement procedure developed by the U.S. Forest Service at the Forest Products Laboratory (FPL) was designed to overcome these problems. It is a modification of a water displacement procedure originally developed at FPL to measure specific gravity and volumetric shrinkage of small, wooden blocks (1,2). The new measurement procedure is versatile, accurate, and inexpensive, and can improve volumetric estimates for a wide range of large or complex wooden objects.

The new method has since been used to statistically estimate wood products used in pallets manufactured in the United States, as part of a cooperative research project between the Forest Products Laboratory, Southern Illinois University at Carbondale, and Tuskegee Institute. This report will describe two measurement procedures initially considered and rejected for the pallet study, and describe the development and use of the new procedure.

Initial measurement procedures

Two procedures were initially considered for measuring the volume of solid wood in individual pallets, and subsequently rejected. The first procedure involved measuring each piece of lumber in the pallet with a tape measure, calculating the cubic foot volume of each piece, and summing over all pieces in the pallet. This method is simple to perform, requires no sophisticated, expensive equipment, and can be applied to any type of pallet.

Unfortunately, results from this method were not reliable. Pallet lumber is frequently not straight, square, or of uniform thickness. Large knots, checks, and other defects are common. Variously shaped stringer notches also present measurement problems. Repeated measurements of the same pallet yielded variations in cubic foot volume of up to 20 percent.

A water displacement measurement procedure was also tried. A pallet was submerged in a large metal tank which had been filled with water to a predetermined level. A rigidly fixed siphon was used to establish precisely the water level before and after submersion. Displaced water was siphoned into a collection vessel and weighed. The volume of the submerged pallet was then calculated by using the weight of a cubic foot of water (62.4 pounds) because the submerged object displaces a volume of water equal to its own volume. Because pallets absorb water during submersion, the difference in pallet weight before and after submersion was added to the weight of the displaced water. Weighing the water to the nearest 0.25 pound allowed pallet volume to be measured very accurately.

This procedure appeared, in theory, to be well suited for measuring the volume of solid wood in a pallet. Variations in lumber thickness, the presence of

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Forest Products Research Society 1985.
Forest Prod. J. 35(1):33-35.

checks, knots, and other defects, and irregularly shaped stringer notches have no effect on the results. It can also be used on any type pallet and can be easily applied by technicians. Considerably more equipment was required than in the tape measure method, but the equipment was neither complicated nor expensive.

Several problems arose, however, which made this procedure impractical to apply. Maintaining precise water levels in the tank was very time consuming, requiring additions of water to replace that absorbed by previously measured pallets. The water had to be perfectly calm prior to and during pallet submersion to permit the siphon system to function properly. These problems did not affect the accuracy of the measurements, but they did make the time required to measure each pallet prohibitively long.

Previous FPL water displacement measurement procedure

A water displacement technique was developed at FPL in 1954 and modified in 1969 to measure specific gravity and volumetric shrinkage of small, solid wooden blocks (1, 2). The method involved weighing the wooden object twice, rather than weighing the displaced water. The object was first soaked in water for up to a week to insure complete saturation, thus eliminating water absorption during submersion. The object was then weighed once in air and once submerged in water. Its volume (in cm^3) is equal to the difference (in g) of the two weights. The submerged weight will be negative if the object has a tendency to float, and will be, in effect, the sum of the two weights. If weights are measured in pounds, the volume (in $ft.^3$) equals the weight divided by the density of water (62.4 $lb./ft.^3$). The water does not have to be perfectly still, nor does the total volume of water in the tank have to be constant.

This water displacement technique seemed ideally suited for measuring the volume of solid wood in pallets because it has the precision of the water displacement procedure previously described and takes a reasonable length of time. However, the method has only been used for objects weighing 5,000 grams or less.

New FPL water displacement measurement procedure

To measure objects as large as pallets, we suspended a steel rack of known volume from a scale having a maximum capacity of 600 pounds and accurate to .25 pound. A pallet with no special preparation was then placed in the rack and lowered into a water tank (Fig. 1). The weight of the rack was sufficient to insure complete submersion of the pallet. Trapped air beneath the pallet was allowed to escape by gently rocking the submerged pallet. The combined weight of the submerged pallet and rack was recorded to the nearest .25 pound after approximately 2 minutes in the water, allowing for water absorption weight gain by the pallet. Pallet and rack were then raised from the water and allowed 2 minutes drip time, after which they were again weighed. Weighing the pallet in air after weighing it in water eliminates the need for the long soaking period used in the original FPL method. The volume of wood in the pallet was calculated using the equation:

$$V = \frac{W_a - W_s}{D} - V_r$$

where

V = cubic foot volume of wood in the pallet
W_a = combined weight (lb.) of the wet pallet and rack in air after 2 minutes drip time
W_s = combined weight (lb.) of the pallet and rack submerged in water for 2 minutes

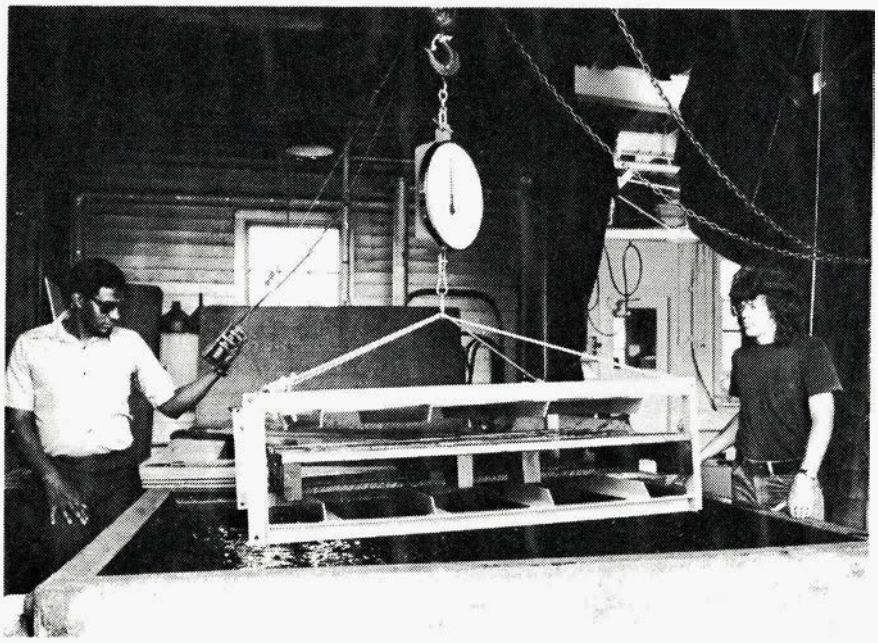

Figure 1. — Measuring the solid wood volume of a pallet using the FPL water displacement measurement procedure.

D = density of water = 62.4 pounds per cubic foot

V_r = volume of steel rack.

Pallets too large to fit into the rack or water tank were cut into several pieces and measured separately. The length of time required to measure an individual pallet averaged 10 minutes. Cubic foot values were accurate to within less than 1/2 of 1 percent for an average sized pallet.

Results and conclusions

The modified FPL water displacement procedure was tested for accuracy by measuring several pallets constructed at FPL from clear, straight lumber and plywood. Stringers were not notched. Volume differences of less than 1/2 of 1 percent were obtained between the tape measure and the water displacement procedures. Thus, if pallets were made from high-quality lumber, volumes could be reliably estimated from taped dimensions. However, pallets currently being produced in the United States are not made with high-quality lumber.

Results of this procedure were also compared with results from the tape measurement procedure using standard industry produced pallets. Differences in individual pallet volumes were as high as 18 percent, averaging 8.5 percent (Table 1). These differences were due in part to the low quality of lumber used in pallets, and to irregular, difficult-to-measure stringer notches.

TABLE 1. — *Comparison of industrial pallet volumes using tape measure and water displacement measurement procedures.*

Pallet	Volume (cubic feet)		Percent difference
	Tape measure	Water displacement	
1	1.30	1.48	13.8
2	.85	.86	1.2
3	1.00	1.15	15.0
4	1.46	1.53	4.8
5	1.09	1.29	18.3
6	1.04	1.17	12.5
7	1.36	1.44	5.9
8	1.34	1.36	1.5
9	1.33	1.38	3.8
10	1.37	1.48	8.0
Avg. difference	—	—	8.3

Perhaps the most useful aspect of this measurement procedure is its versatility. Not only do pallet size, style, grade, and species of lumber, and wood products used have no effect on accuracy, but with simple modifications to the submersion rack, the procedure can be readily adapted to measure the volume of any large, irregularly shaped wooden object.

Literature cited

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