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# COMPARATIVE TESTS OF WHITE OAK AND DOUGLAS FIR BARRELS

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Madison 5, Wisconsin  
In Cooperation with the University of Wisconsin

# COMPARATIVE TESTS OF WHITE OAK AND DOUGLAS-FIR BARRELS<sup>1</sup>

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This report is a comparative summary of two series of tests performed at the U. S. Forest Products Laboratory, Madison, Wis. -- one on Douglas-fir barrels, conducted during March, 1921, and the other on white oak barrels, conducted several years earlier and first reported in U. S. Department of Agriculture Bulletin No. 86.

The oak barrels, furnished by the St. Louis (Mo.) Cooperage Co., were 48 in number and were divided into six groups of eight, as follows: Group No. 1 of 5/8-inch stock, with 6 hoops; group No. 2, 5/8-inch stock, 8 hoops; group No. 3, 3/4-inch stock, 6 hoops; group No. 4, 3/4-inch stock, 8 hoops; group No. 5, 7/8-inch stock, 6 hoops; group No. 6, 7/8-inch stock, 8 hoops. The material was quarter-sawn white oak, practically straight grained, and free from defects. The barrels were of excellent workmanship and were well coated with paraffin inside. The staves varied in width from about 2-1/2 inches to about 7 inches. The heads were as a rule composed of four pieces joined together with 6-1/6-inch hickory dowels. Two heads were composed of three pieces each.

The Douglas-fir barrels, furnished by the Western Cooperage Co., of Portland, Ore., were 33 in number and were divided into three groups of eleven, which the company in their forwarding letter described in the following terms: "The stock in these packages is sawn from No. 1 Douglas-fir timber and represents our No. 1 grade 3/4-inch oil staves and our No. 1 grade 20-7/16-inch heading in 3/4 and 15/16-inch thickness. There are to be 33 barrels forwarded to Madison. Eleven of these are hooped with 6 hoops and headed with 3/4-inch head; 11 are hooped with 8 hoops and headed with 3/4-inch heads; and the balance are hooped with 8 hoops and headed with 15/16-inch heads. All headings used in these packages have glued joints, and the packages were set up from average stock the same as received from our mill, there being no special selecting."

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<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.  
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The barrels, of both species, after being completely filled with water, were subjected to the following tests: Side compression, diagonal compression, internal pressure, side drop, and diagonal drop. Some barrels of each group and each species were subjected to each kind of test. The results will be briefly discussed in the succeeding paragraphs and the general conclusions stated.

### Oak Barrels

In each kind of test the first water to appear on the outside of the barrel was usually from seepage lengthwise through the pores of the wood at the chime. The first leak usually occurred either between the staves and the head or between the staves at the chime. In all the tests except internal pressure the first leak was usually coincident with the slipping of the staves.

In the internal-pressure test there were two general classes of failures: (1) By springing and breaking of the head; and (2) by leaking between the staves at the bilge.

In the diagonal-compression test the failure was a general failure of the head combined with slipping of the staves. In the side-compression test the failure was a general leaking at the heads and slipping of the staves followed by the breaking of the staves at the bilge.

In the side-drop test the slipping of the staves caused loosening of hoops and leakage at heads, followed by breaking of the staves at the bilge. In three of the six barrels thus tested, failure was due to the heads being broken or forced out by the pressure produced by the impact.

The lower heads of all barrels tested by dropping on the chime were broken or forced out by the pressure due to the impact.

### Douglas-fir Barrels

First leakage in nearly all tests of Douglas-fir barrels developed in one of two ways: (1) By water passing completely around the edge of the head and appearing in the angle between the head and the chime, or (2) by water passing partially around the edge of the head and thence through the pores and appearing as small drops on the edge of the chime. Leakage of the first type is described as "leakage at croze," and the second as "seepage through chime." There were very few instances in which leakage between the staves occurred except after the barrel had been quite severely deformed as in the side and diagonal-compression tests. In the diagonal-compression tests leakage due to crushing at the edge of the head occurred

at a fairly early stage. As a special test, barrel No. 13 was so placed that the end grain of the head came at the point of pressure, and leakage did not occur until a considerably higher load was reached.

Aside from the first leakage, types of failures differed with the kind of test.

In side and diagonal-compression, later failures were by slipping in stave joints and shear or splitting of staves, combined with opening of the joint between staves and head and splitting of head. In this test there were numerous instances in which staves split or sheared for their entire length. In fact, it seemed to be almost as easy for such shearing to occur as for staves to slip on each other at the joints. This was true also in side and diagonal-drop tests.

Final failure in side and diagonal-drop tests was the driving out of the head by the shock of the contents.

Final failure in internal-pressure tests was by breaking or bursting out of the heads.

#### Comparison of White Oak and Douglas-fir Barrels

At first leak in side compression, the Douglas-fir barrels take only about two-thirds of the load carried by the white oak barrels. The white oak barrels, however, begin leaking at a much smaller deformation than do the Douglas-fir, and the product of load and deflection at first leak is in every case of comparison higher for Douglas-fir than for white oak. These facts indicate that when subjected to shocks against the bilge, the Douglas-fir barrels, although they develop less resistance before leakage, yield much more (or farther) and can absorb fully as great a shock as the white oak. It should be noted in this connection that a common practice is to store or stow barrels on their sides with the bottom row blocked at the quarters and upper rows laid in the "cantlines," or space between barrels of the row below, and with the bilges above the heads of the row below. It is to be expected that barrels so arranged will sustain considerably larger loads than were developed in the side compression test.

At first leak in diagonal compression, Douglas-fir barrels take less load than white oak barrels. Here again, however, white oak barrels stand much less deformation than the Douglas-fir, with the result that shock-resistance as indicated by product of load and deflection is practically equal for barrels of the two species.

The height of drop (both side and diagonal) for Douglas-fir barrels at first leak averages about three-fourths as much as for the white oak. Approximately



the same ratio applies to height of drop to produce leakage at the rate of one pound of water per minute.

When subjected to internal water pressure the Douglas-fir barrels develop two to three times as great pressure at first leak as do the white oak barrels. The pressure required to produce leakage at the rate of 1 pound of water per minute averages about 30 percent higher for Douglas-fir than for white oak.

### Discussion and Conclusions

The following conclusions apply only to white oak and Douglas-fir barrels having the combination of number, quality, and dimensions of hoops and thicknesses of staves and heads represented in the tests and described herein:

1. In the oak barrels, increase in thickness of stave is of much less value than increase in head thickness, and it is to be expected that oak barrels with 5/8-inch staves and 7/8-inch or 15/16-inch heads will prove fully as serviceable under ordinary conditions as barrels with 7/8-inch staves and 7/8-inch heads.
2. In Douglas-fir, barrels with 15/16-inch heads and 3/4-inch staves are somewhat superior in resistance to internal pressure to barrels with 3/4-inch heads and staves.
3. When there is little change in moisture content of the wood, as in these tests, the eight-hoop barrels show but little superiority over six-hoop. When barrels are subjected alternately to moist and dry conditions, with the consequent tendencies of the staves to swell and shrink, it is to be expected that the advantage of the eight-hoop barrels will be enhanced.
4. When barrels of both species are well and carefully made of properly selected stock, they compare as follows:

Douglas-fir barrels have about two-thirds as great resistance as have white oak barrels to leakage under steady loads, as in the bottom of storage piles. The Douglas-fir barrels, however, probably have sufficient resistance to carry safely such loads as are at all likely to come on them in storage or shipment. The Douglas-fir barrels, moreover, can be deformed to a greater extent without leakage than can the white oak. Resistance to shock is proportional to the product of load and deformation. Douglas-fir and white oak barrels are practically equal in this respect, a fact indicating that when loaded on end in railway cars they may be expected to withstand equal shocks without leaking. After leakage has begun, however, the steady force and the shock required to cause increased leakage are greater for white oak than for Douglas-fir barrels.

When dropped upon the chime or upon the bilge, the Douglas-fir barrels withstand without leakage about 25 percent lower drops than white oak, indicating somewhat greater susceptibility to damage from rough handling in rolling or sliding down skids.

The Douglas-fir barrels withstand from two to three times as much internal pressure before leaking as do the white oak barrels.

5. The Douglas-fir barrels tested were made with 17-gauge by 1-3/4-inch and 18-gauge by 1-1/2-inch hoops in order to have them uniform in this respect with the oak barrels tested, and also to comply with I. C. C. specification No. 10. As Douglas-fir is softer and exerts less force in swelling than oak, it is not certain that these sizes are necessary. Further tests would be required to determine the safe and most economical size of hoops for Douglas-fir barrels.

In connection with these comparisons of white oak and Douglas-fir barrels it is to be remembered that all the barrels tested were of selected stock and well manufactured. The oak staves and heading were white oak, which is much more resistant than red oak to penetration by liquids. Because of this quality and other properties, such as great stability of form and shape under changing moisture conditions and greater resistance to decay, white oak clear of sapwood is recognized as much superior to red oak for barrel making. The Douglas-fir barrels were from timber selected for its special suitability for barrel manufacture. These points are mentioned to bring out the fact that the barrels tested were such as can be made only through careful attention to selection of timber and to manufacturing details, and that the barrels were of comparable quality in their respective species.

The results of the tests lead to the conclusion that with carefully selected timber and carefully manufactured barrels, white oak will excel Douglas-fir barrels in serviceability under ordinary shipping conditions. If, however, the white oak barrels are of indifferently selected stock containing sapwood or defects, or are carelessly manufactured, they may be expected to render much poorer service than Douglas-fir barrels well made of properly selected material.

#### Selection and Handling of Material

Timber is selected and stock handled with great care by the larger manufacturers of Douglas-fir barrels, and it is well to consider here a number of points bearing on the making of barrels of the best quality from the species. These points have been developed from the experience of manufacturers, observation of the barrel tests described herein, mechanical tests of Douglas-fir, and field observations of the properties and peculiarities of the species.

1. It is believed by barrel manufacturers that material of suitable character can be secured only from trees grown in the low-lying regions or so-called fog belts.
2. Staves of the Douglas-fir barrels tested had an average of about 23 annual growth rings per inch. The minimum number was 7 and the maximum 44. It would be well to require that staves show not less than 8 growth rings per inch.
3. It is recommended that Douglas-fir bolts be converted into staves and kiln-dried promptly after cutting from the logs, in order to avoid the rather rapid deterioration that may occur through the checking of short bolts in drying.
4. It is of prime importance that the staves be as nearly as possible perfectly quarter-sawn or edge-grained. Incipient ring shake or weakness of bond between the annual rings is rather frequently encountered in Douglas-fir. Where this occurs in a stave having the plane of the annual rings striking through its axis at angle of less than about 60 degrees with its surface, slippage along the rings having such weakness is very likely to happen. It is recommended that in specifications for tight barrels of Douglas-fir a limit be set to the deviation from perfect edge grain. The following is suggested as a simple and practical statement of the allowable deviation:  
  
"Staves shall be so manufactured that the annual rings at any point do not deviate from a line perpendicular to the face of the stave by more than one-half of the thickness of the stave."
5. Cutting of staves in the manner recommended has a further advantage, since the shrinkage in width of quarter-sawn stock averages only from one-half to two-thirds that of slash-grain material. Barrels made of quarter-sawn staves therefore shrink and swell less with change in atmospheric and moisture conditions and give less trouble with leakage, regardless of species. Not only strength properties but also the tendency to shrink and swell are factors that should be considered in estimating the suitability of a given species for tight cooperage. The shrinkage or swelling of quarter-sawn stock with change of moisture content is practically the same for oak and Douglas-fir. Consequently, it is to be expected that troubles from this source will be least for the barrels whose staves are most perfectly quarter-sawn.