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HARDNESS MODULUS AS AN ALTERNATE MEASURE OF HARDNESS TO THE STANDARD JANKA BALL FOR WOOD AND WOOD-BASE MATERIALS

Abstract

Comparisons of Janka-ball hardness values with hardness modulus (load versus depth of penetration of the hardness tool) on representative wood and wood-base materials indicate that a constant relationship exists between the two values. The hardness modulus procedure can be substituted for the standard Janka-ball procedure for thin materials, and equivalent values for Janka ball can be estimated by taking the hardness value in pounds per inch and dividing by 5.4. Such a procedure eliminates the need for laminating several thicknesses of material thinner than 1 inch.

HARDNESS MODULUS AS AN ALTERNATE MEASURE OF HARDNESS TO THE STANDARD JANKA BALL FOR WOOD AND WOOD-BASE MATERIALS

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Introduction

Standard test procedures for wood and wood-base materials are adopted by American Society for Testing and Materials. The procedure for determining hardness of wood has been the Janka-ball procedure, which uses as the hardness index the load in pounds required to embed a ball or hemipsherically ended cylinder with a diameter 0.444 inch (1 centimeter of projected area) to one-half its diameter. The procedure is detailed in Sections 83 to 87 of ASTM D 143.[2]

Hardness is determined in all the standard strength evaluations of commercially important wood species. Values are presented in such publications as the Wood Handbook[3] and Technical Bulletin No. 479.[4]

Hardness is not used directly in engineering design but it is an important strength index. Because the wood-base fiber and particle panel materials are used with wood and in the same places as wood, hardness becomes an index to

[1]Maintained at Madison, Wis., in Cooperation with the University of Wisconsin.

[2]American Society for Testing and Materials. Standard Methods of Testing Small Clear Specimens of Timber. ASTM D 143-52 (1965).

[3]U.S. Forest Products Laboratory, Wood Handbook. U.S. Department of Agriculture, Agriculture Handbook 72, 1955.

[4]Markwardt, L. J., and Wilson, T. R. C. Strength and Related Properties of Woods Grown In the United States. U.S. Department of Agriculture Technical Bulletin 479. 1935.

relate the materials. The index comelatea panel materials with many uses for wood where resistance to wear, indentation, and marring are important; it is also a way of determining resistance of the board materials to damage and how well they should serve in comparison to wood.

The Janka-ball test procedure was adopted for hardneess tests of board materials[5] to provide the needed comparison with values obtained for wood but this required the test specimen to have a thickness of at least 1 inch. As most board materials are less than that, enough thicknesses are laminated together to provide the required thickness. With low-density products a nonrigid adhesive like rubber cement is used to reduce the influence of the glueline on supporting the fibers as the ball is indented. With denser products, a rigid, higher strength adhesive is required to prevent delamination at the glueline as the hardness tool penetrates.

This extra step in fabrication, the lamimating of a specimen to a thickness of 1 inch or more, together with the uncertainty of effect of the glueline, suggested the possibility of using hardness modulus as an alternate procedure. If it was possible to obtain reliable results using a hardness-modulus index, and if a correlation could be established between hardness modulus and the regular Janka-ball value, then using the alternate method would be justified by savings in time and cost of specimen preparation.

Weatherwax and others[6] demonstreated that hardness modulus could be measured in wood and modified wood, but did not continue the experiment to the stage where it was determined if a correlation could be established.

This study was developed, then, to investigate the possibilities of a reasonable correlation between Janka-ball hardness value and hardness modulus. The particular emphasis was on the needs for insulation board, hardboard, particleboard, and other wood-base panel materials usually made in thicknesses of less than 1 inch. Hardness modulus as alternate procedure to the Janka ball could be useful in evaluating wood also if the available material was less than needed for a Janka-ball determination or, when because of some other factor, it was desirable not to indent the material as deeply as the 0.222-inch penetration.

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[5] American Society for Testing and Materials. Standard Methods of Evaluating the Properties of Wood-Base Fiber and Particle Panel Materials. ASTM D 1037-64, Sect. 53-58.

[6] Weatherwax, R.C., Erickson, E.C.O., and Stamm, A.J. A means of Determingin the Hardness of Wood and Modified Woods Over a Broad Specific Gravity Range. ASTM Bulletin 153. Aug. 1948.

A few preliminary determinations on fiberboards and particleboards indicated a straight–line relationship between Janka-ball hardness and hardness modulus. This report presents the results of the expanded study that was made to establish that relationship.

Material Included in Study

Eleven species of wood ranging in specific gravity from a low of 0.34 to a high of 0.73, were included. They were chosen not only for density, but were representative of both hardwoods and softwoods and included such prominent species as white pine, Douglas-fir, yellow-popular, red oak, and sugar maple. Two– by 2– by 6-inch specimens were prepared. Annular growth rings were oriented carefully so that radical and tangential faces were exposed for side-grain hardness determination.

The nine particleboards evaluated included typical commerical products and the "standard" Forest Products Laboratory research board. They are described in more detail as follows:

A - Standard Forest Products Laboratory Doughls -fir flake with phenolic binder
B - Typical Douglas-fir, medium-density, milled, gree planer shavings with urea–formaldehyde binder
C - Aspen, attrition–mill particle, low-density, urea-formaldehyde binder
D - Southern pine residue, hammermilled, high-density, with urea-formaldehyde binder
E - Flake–faced, sliver–core, urea-formaldehyde binder
F - Aspen, attrition–mill particle, medium-density, urea-formaldehyde binder
G - Pine residue, extruded board, urea-formaldehyde binder
H - Hardwood–sftwood blend flake, urea-formaldehyde binder
I - Fine hammermilled ponderosa pine, high-density, phenolic binder

The building fiberboard materials included the following:

K - Dry-porcess tempered hardboard
L–X - Wet–process medium–density hardboard
M - Wet–process standard hardboard
N-O - Wet–process service hardboard

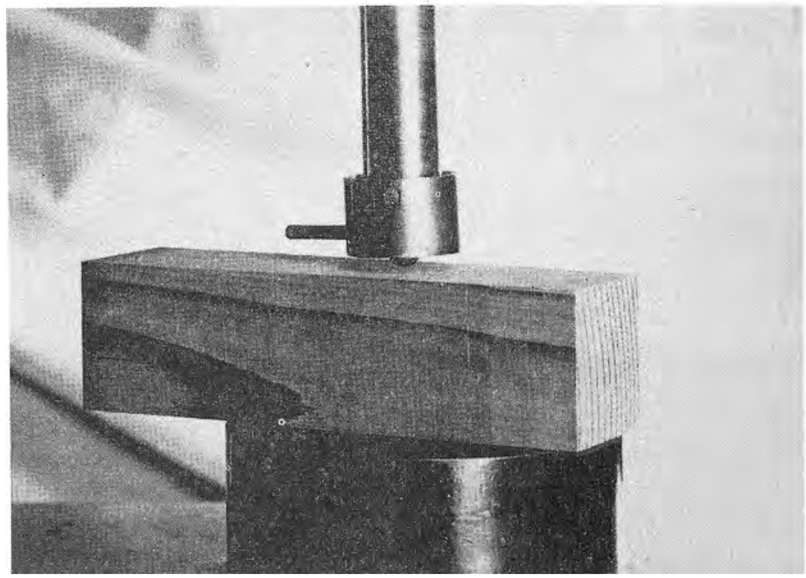

Figure I.--Standard Janka-ball hardness test, where the tightening of the collar around the hemispherically ended loading tool indicates that penetration has equaled one-half the prescribed ball diameter.

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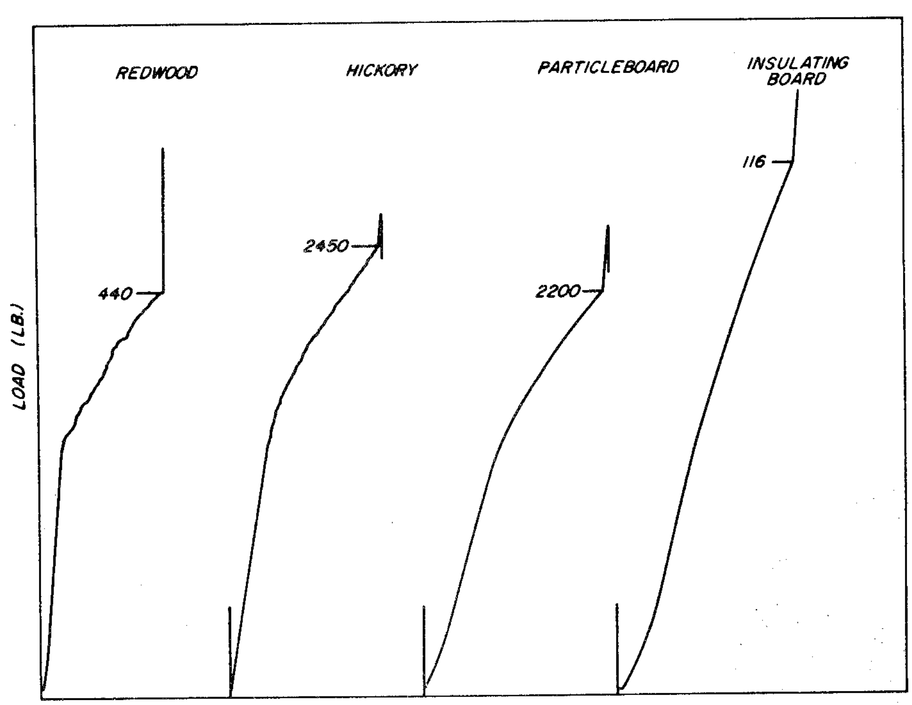

Figure 2.--Typical load-head travel curves for wood and wood-base panel materials as used in the Janka-ball hardness test as an indicator for ball penetration to one-half its diameter.

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P - Above-deck insulating board
Q - Waste paper-base, general-use insulation board
R-U - Regular-density sheathing insulating board
S - Laminated paperboard
T - Nail-base sheathing insulating board
V - Interior-finish insulating board
W - Super-hardboard, specially mad for use as diestock
Y - Wet-process tempered hardboard

These materials were also chosen to be representative of typical commercial producrts.

In each instance, with a building fiberboard or particleboard, enough thicknesses of 2- by 6-inch pieces were laminated to provide a thickness of 1 inch or more.

Methods of Testing

The standard Janka-ball test proeedure is detailed in Sections 83 to 87 of ASTM D 143.[2] Evaluations were made as shown in figure 1. Load was applied by a uniform rate of head travel of testing machine of 0.25 inch per minute. When the collar of the hardness tool tightened up, it was indicated that the "ball" had penetrated the specimen to one-half its diameter (0.222 inch). With dial, load-indicating testing machines, it is difficult for the operator to determine the load at which penetration is one-half the ball diameter. The only indication is a sudden increase in the rate of movement of the load-indicating hand.

Since many of the newer machines are equipped to autographically record load and movement, an investigation was made to determine the possiblilities or that equipment as an indicator of the load when the collar had tightened and the ball had penetrated one-half its diameter into the specimen. Figure 2 presents the load-head travel traces for four typical materials. The sharp break in the trace indicated by the horizontal line was the point picked for the hardness value.

The results of this phase of the study support the reccomdation that the technique of using "load-head travel" for indicating the end point be adopted for regular Janka-ball1 hardness determinations when autographic equpment is available on the testing equipment being used.

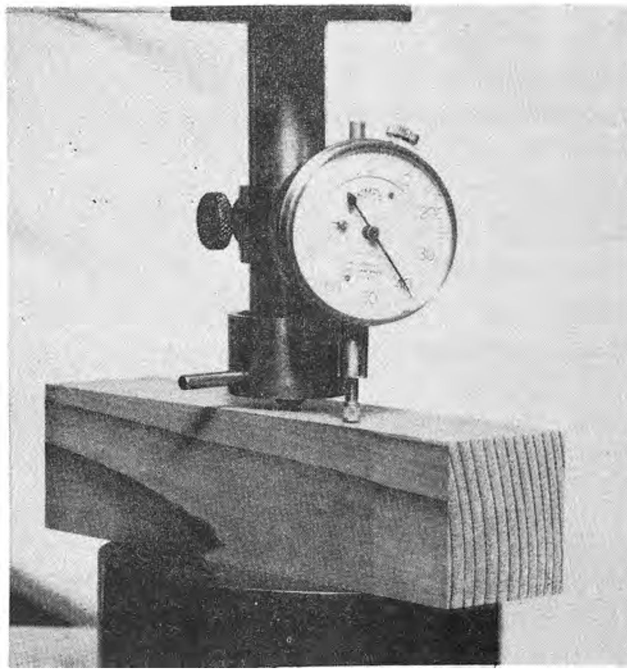

Figure 3.--Janka-ball hardness tool equipped with a micrometer dial for measuring penetration.

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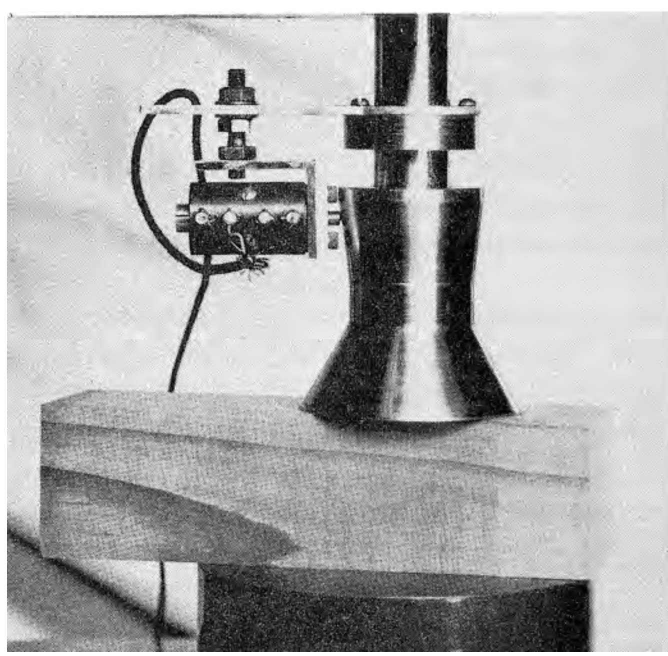

Figure 4.--Janka-ball hardness tool adapted with cone and microformer unit for direct autographic recording of load-penetration data.

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In order to measure the depth of penetration(indentation) of the hardness tool, the test assembly shown in figure 3 was used. This unit was further modified as shown in figure 4, to permit simultaneous recording of load and penetration, thus eliminating the need for a second technician during test to record and plot penetration values at measured loads.

The results of a preliminary evaluation of a few board products indicated that the typical plot of load versus indentation of the Janka-ball tool yielded a straight-line portion; the slope of which could be computed by dividing load by the amount of penetration for apoint on the straight-line portion. The preliminary results also indicated that penetrations in the order of 0.1 inch were sufficient to provide the data necessary to establish this slope.

Figure 5 shows typical load-indentation curves as obtained with the autographic equipment shown in figure 4. When the dial-indicator equipment shown in figure 3 is used, a series of points was obtained which determined the slope of the "straight-line" portion of the curve. As will be noted in figure 5, the typical curve was straight during the major part, after generally a concave upward part at very low loading. It is this straight-line portion that was used to compute hardness modulus.

Initially, four side-grain hardness modulus determinations were each made on the tangential and radial faces of these wood specimens. Rates of head travel were maintained at 8.05 inch per minute. Penetration was stopped at 0.1 inch and the loading repeated at identical points using the standard tool with the collar, and the Janka-ball value determined for the full penetration of 0.222 inch.

A similar plan was followed in loading the 24 building fiberboard and particleboard specimens, which were 2 by 6 inches in area and laminated to a thickness of 1 inch or more. Four determinations were made on the wide faces of each specimen. All wood and board material in this study was conditioned to equilibrium at 75° F. and 50 percent relative humidity before test, and testing of all except the most dense specimens was done in a room at that condition. The dense specimens, were tested at the prevailing laboratory condition but were not removed from the controlled condition until just prior to test.

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[7] Special acknowledgment is made to Curtis L. Johnson, Engineering Aid at She Forest Products Laboratory, who designed the modification to permit autographic recording of the data and performed the calibrations necessary to prove its accuracy.

Presentation and Discussion of Results

The results for the hardness determinations on the wood specimens are presented in table 1, and those for the panel materials are presented in table 2. Examination of the individual values for hardness modulus and those for the Janka–ball hardness indicates a comparable consistency of results for both tests.

Mean values from each of these tests of the wood materials are plotted in figure 6 with the values for Janka–ball hardness as ordinates and hardness modulus as abscissas. Figure 7 is a similar presenentation of the mean values for the building fiberboards and particleboards. These figures indicate a linear relationship of 5.4 between the proposed hardness-modulus procedure and the standard Janka–ball test. Further, because of the importance of this hardness comparison for the lower density species of wood, particleboard, and building fiberboards, figure 8 presents all values from tables 1 and 2 with Janka-ball values of less than 500 pounds on an expanded scale. The line representing the ratio of 5.4 between hardness modulus and Janka-ball hardness fits the data on this expanded plot as well as in figures 6 and 7 for the denser products.

From this it appears entirely feasible to use the hardness-modulus technique as a procedure for measuring hardness in panel products and then obtaining the equivalent Janka–ball value by dividing the value obtained from the modulus procedure by a factor of 5.4.

Such a procedure offers the advantage, insofar as panel products are concerned, of eliminating the necessity of gluing together several thicknesses of material to obtain a total thickness of at least 1 inch. Further, becuase of the tendency for delamination in hardboards when full penetration (0.222 inch) is required, more valid results should be obtained. Hardboard specimens K, M, N, O, and Y (table 2) are examples of delamination during full penetration of the Janka–ball tool.

With materials that are very dense, for example material W was a specially densified hardboard product (specific gravity 1.32), material is displaced upward adjacent to the ball when it is densfied further under the Janka-ball loading. This causes premature tightening of the collar device on the loading tool and a lower indicated load than should be obtained.

Table 2.--Hardness and hardness-modulus values for typical building fiberboards and particleboards[1]

Material identation	Moisture content	Specific gravity[2]	Hardness modulus					Janka-ball hardness				
			No. 1	No. 2	No. 3	No. 4	Av.	No. 1	No. 2	No. 3	No. 4	Av.
	Percent		Lb./in.	Lb./in.	Lb./in.	Lb./in.	Lb./in.	Lb.	Lb.	Lb.	Lb.	Lb.
A	8.5	0.63	6,560	6,450	7,140	5,480	6,410	1,000	1,020	1,140	1,040	1,050
B	8.7	.76	4,350	3,880	4,120	5,130	4,370	860	810	880	960	880
C	8.5	.45	2,120	2,230	2,320	2,250	2,230	410	405	415	420	410
D	8.2	.88	11,200	11,200	12,300	12,500	11,800	2,200	2,200	2,220	2,180	2,200
E	8.0	.63	5,210	5,440	4,430	5,210	5,070	800	840	815	855	830
F	7.6	.76	6,670	7,060	7,320	7,700	7,190	1,460	1,460	1,540	1,650	1,530
G	7.4	.57	2,890	3,900	4,000	4,060	3,710	610	660	685	735	670
H	7.1	.66	4,900	5,440	5,160	6,410	5,480	1,180	1,230	1,270	1,250	1,230
I	5.7	.99	20,300	19,400	18,200	17,400	18,800	3,830	3,830	3,770	3,840	3,820
K	5.7	1.08	22,700	27,800	26,000	27,300	26,000	3,670	3,250	3,620	....	[3]3,510
L	5.5	.73	5,320	4,830	4,900	4,170	4,800	1,240	1,240	1,160	1,220	1,220
M	4.2	.95	15,200	14,800	15,200	15,200	15,100	2,120	1,990	1,990	1,680	[3]1,940
N	5.4	.97	17,400	17,100	14,300	18,200	16,800	2,180	2,050	2,180	1,900	[3]2,080
O	5.7	.97	15,200	16,200	15,600	16,400	15,800	....	2,630	2,500	2,570	[3]2,570
P	7.3	.24	245	255	165	250	230	57	60	58	59	58
Q	8.0	.43	1,200	1,230	1,310	1,300	1,260	255	255	265	255	260
R	6.6	.45	540	560	570	520	550	112	116	108	112	110
S	7.4	.48	1,180	1,180	1,230	1,330	1,230	300	290	295	295	295
T	5.1	.37	780	750	880	770	800	170	150	175	165	165
U	6.5	.43	520	510	500	490	500	110	106	112	116	110
V	6.8	.27	420	390	390	360	390	80	77	74	75	76
W	5.3	1.32	64,500	63,200	68,200	....	65,300	(4)	(4)	(4)	(4)	(4)
X	5.7	.72	5,040	4,510	5,460	4,720	4,930	1,280	1,240	1,310	1,200	1,260
Y	5.5	.97	....	15,900	16,700	17,300	16,600	2,500	2,570	2,570	2,170	[3]2,450

[1]Specimens A to I, inclusive, were particleboards; remaining were insulating boards or hardboards.

[2]Based on volume at test and ovendry weight.

[3]Specimen delaminated under Janka ball; value less than true Janka-ball hardness.

[4]Material pushed up adjacent to indentation point during Janka-ball determination; satisfactory value could not be obtained.

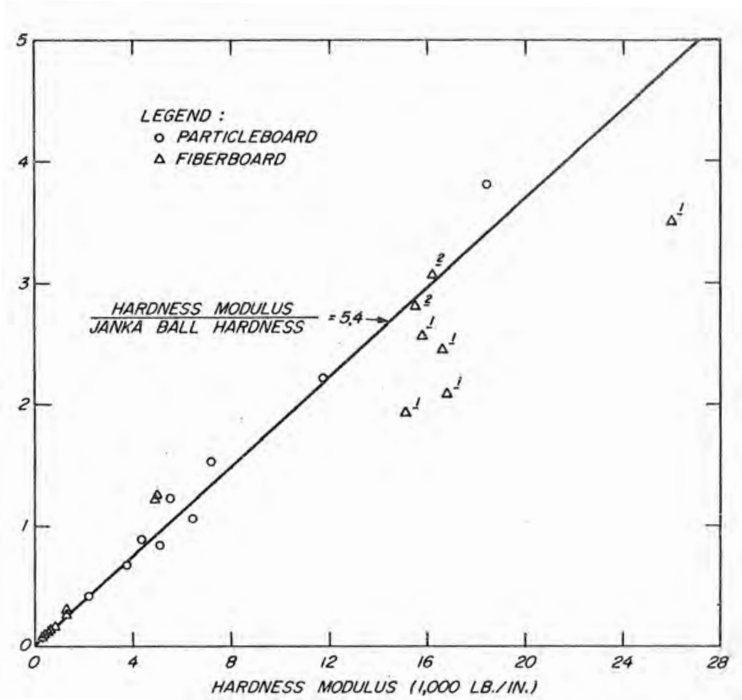

Figure 7.--Hardness modulus, Janka-ball hardness relationship for particle-boards, hardboards, and insulating boards. Points marked with 1 were for hardboards that delaminated under penetration of the tool to one-half its diameter, hence the Janka-ball value is low. Because of this delamination in the hardboard specimens, the two additional values marked 2 from the exploratory series are included.

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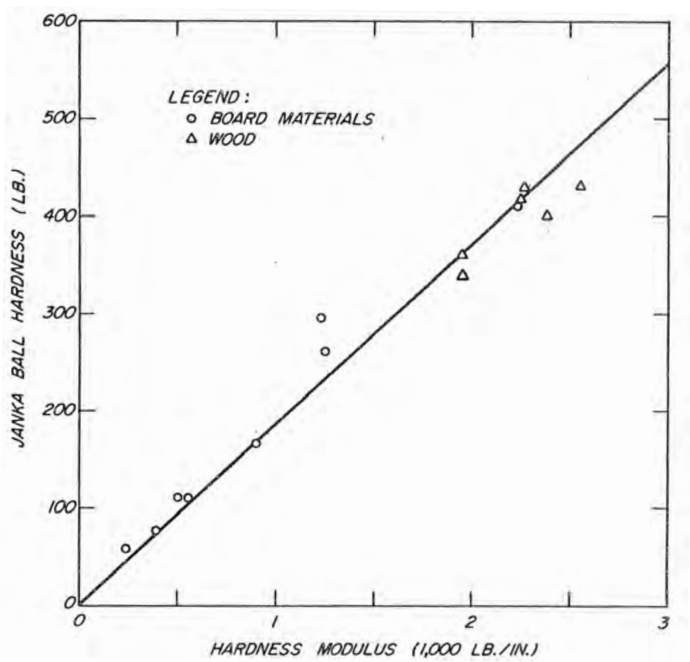

Figure 8.--Hardness modulus, Janka-ball hardness relationship for lower density wood species, insulating boards, and low-density particleboard.

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Summary and Conclusions

A series of evaluations of hardness of side-grain wood and typical wood-base panel materials (insulation boards, hardboards, and particleboards) of representative densities, using the standard Janka-ball hardness procedure and a proposed new procedure using a load depth of penetration modulus with a modified tool, supports the following:

1. The technique of determining the load-indentation relationship using the standard hemispherically ended Janka-ball tool (0.444 inch diameter) yields a straight-line relationship of load versus depth of penetration after an initial curved portion.

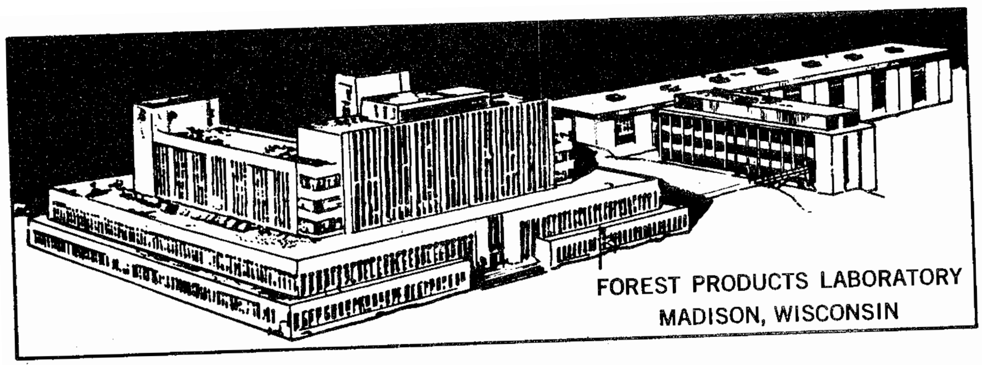
2. Penetrations of 0.10 inch are sufficient to determine the slope of this straight-line portion of the curve.

3. The hardness modulus determined from the slope of the line, load divided by penetration, is reproducible from test to test and can be used as an alternate test procedure to the standard Janka-ball test for wood.

4. When evaluating insulation board, hardboard, particleboard, and other wood or wood-base panel materials less than 1 inch thick, the hardness-modulus technique is preferred because it eliminates the need for laminating sufficient thicknesses of material together to form a minimum thickness of 1 inch. Further, with some dense, hardboard-like materials, delaminations during the full penetration of 0.222 inch in the standard Janka-ball produce erroneously low values.

5. When testing very dense materials using the full-penetration procedure, the "pushing up" of material around the indented part of the specimen causes premature indication of full penetration and lower than true indications of hardness.

6. The comparison between Janka-ball values and the proposed hardness-moddus values was linear for both wood and wood-base panel materials. Hardness modulus (load in pounds per inch of penetration) divided by Janka-ball hardness (pound) was consistently 5.4. Thus, it will be possible to determine hardness modulus for a material using the proposed procedure and then present the equivalent Janka-ball value by dividing that value by 5.4.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