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TESTS AND SUGGESTIONS FOR  
THE NAILING OF BOXES

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## TESTS AND SUGGESTIONS FOR THE NAILING OF BOXES

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The purpose of nailing a box is to hold it together and give it rigidity. To use more nails or larger nails than are necessary to accomplish this purpose is a waste of both material and labor. To use fewer nails than are necessary to hold properly under ordinary conditions results in breakage of the box and damage to the contents.

Tests at the Forest Products Laboratory of the United States Forest Service, at Madison, Wisconsin, and observation of packages in transit and at their destination have shown conclusively that where the nailing is insufficient, the package cannot be improved by putting in heavier lumber. Observation has shown also that the majority of failures in ordinary boxes are due, not to the lumber, but to the nailing. It is also evident that in many instances a better package could be obtained with much thinner material by the use of a few more nails.

In arriving at the proper nailing there are a number of factors that must be considered. These involve the nail, its length, diameter, and surface, and the species of wood, its thickness and condition.

It is desirable to know whether the nail should be smooth, barbed, or cement-coated. Our tests have shown that at least in the ordinary sizes, barbed nails are not so efficient in box construction as smooth ones. Apparently the ability of the barbs to increase the resistance of the nail to withdrawal is more than offset by their tendency to tear the wood. Cement-coated nails have given uniformly better results than smooth nails, although different lots of cement-coated nails have shown greater variation in efficiency than smooth nails. The holding power of the cement-coated nail is from 10 to 30 per cent greater than that of the same sized smooth nail. On an average, a box built up with the cement-coated nails will withstand about one and one-half times as much rough handling as a box made with the same number and gauge of smooth nails.

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## Length and Diameter of Nails

If the nail is short and is driven into soft wood the weaving of the box in transportation and shocks due to rough handling will cause the nail to work back and forth to its full length in the wood and come loose almost immediately, notwithstanding the fact that it may be of comparatively heavy gauge.

If the nail is very slender it will not drive well, and the longer it is the greater must be its diameter in order to insure that it will drive. If a very slender nail is driven to considerable depth in a piece of hard wood, the shocks of transportation and handling will bend the nail between the two planks of the box and it may fail by breaking off rather than by pulling out.

The diameter of a nail should be great enough so that it may be driven easily, which is usually the limiting factor, but should not be so small that it will break in use. It should be such that with the weaving of the package in transportation and the shocks of handling it will not be bent and will not work back and forth to its full depth in the wood. The proper balance is reached when there is an equal likelihood of the wood failing or of the nails breaking off or pulling from the end.

## Head of the Nail

As a rule, the head of the nail is too small, and failures of the box occurs because the head is pulled through the sides. With the larger heads made in accordance with the ordinary practice the material is too thin and the head breaks off. It is thought that a much better nail can be made than is being produced at the present time.

## The Wood

The species of wood is of importance, since each species has certain characteristics of weight and hardness which indicate its ability to hold nails, its strength and its likelihood of splitting, and thus determine the proper thickness of material and size and spacing of nails.



The most significant difference in the various species of wood is in their dry weight. A piece of lumber of very light weight has but little wood substance. It has been shown that all wood substance is of practically the same weight and that the weight of a piece of dry lumber, when free from resinous material, is an indication of the amount of wood substance it contains. It will be evident, therefore, that without sufficient wood substance it is impossible to have strength or nail-holding power, and that the more wood substance there is in a given species the greater its strength and nail-holding power are likely to be.

Figure 1 is a curve in which has been plotted the density or dry weight of the various species against their ability to retain nails driven into side grain. In this connection it may be noted that, with practically all species, the resistance to withdrawal is greater if the nail is driven into the side grain than if it is driven into the end grain. The curve shows conclusively that the heavier species hold nails much better. As a rule all the strength properties of wood increase with the weight. When a nail is driven into a dense piece of wood it produces a much greater splitting force than when the same nail is driven into a soft piece of wood. A dense piece of wood has greater resistance to splitting than a light piece of wood. These two factors tend to counter-balance each other but do not do so entirely. The dense species, as a rule, will split somewhat more than the lighter species with the same nailing.

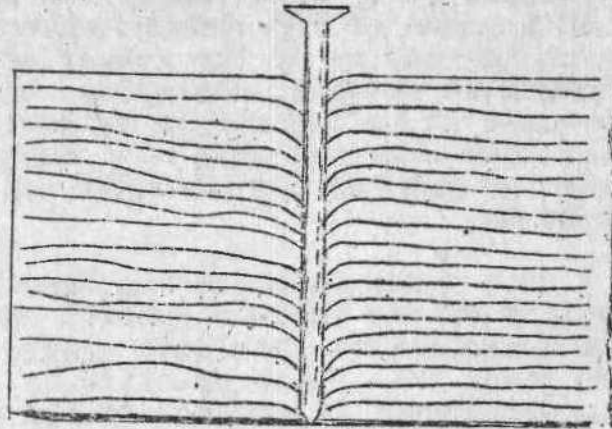
The lockiness of grain and other species characteristics are important factors in determining the resistance to splitting.

#### Condition of Wood

Green wood is much softer than dry wood, and the nails can be driven in and withdrawn from green much more readily than from dry wood.

The moisture content of wood, when green, may vary from 30 to 200 per cent of the dry weight, depending on the species and on conditions of growth. As the wood dries it first loses the free water in the cells and afterwards that from the cell walls. When the water begins to leave the cell walls the wood begins to shrink in both width and thickness but not materially in length. This causes the fibers which

are bent down along the nail, as illustrated to shrink away



from the nail in the direction of the end grain, in which direction the nail was being most firmly held in the first place. Thus we have the nail which has been driven into green material, afterwards dried, held only by two sides. The weaving action during transportation will readily cause such nails to come loose and work out of the box without any rough handling, and the boxes will not stand more than 10 per cent as much rough handling as those nailed up at 15 per cent moisture and kept in practically that condition.

A nail driven into a dry piece of wood which afterwards is allowed to become soaked and then dried will act as does a nail driven into green lumber.

Boxes made of lumber in the proper moisture condition will stand ordinary storage without any appreciable loss in the ability of the nail to hold.

The effect of over-driving nails is to reduce their resistance to withdrawal, the proportionate reduction probably being greater in the case of dry wood than in green.

#### Thickness of Material and Spacing of Nails

After the above fundamentals as to nails and wood, consideration should be given to the thickness of material and the spacing of nails.



The ends of the boxes must be of such thickness that the nails will not run out under ordinary conditions. The nails must be small enough in diameter so that they will not cause splitting of the material. The inclination to split is increased with decreased spacing. The spacing, then, must not be so close as to cause splitting.

Experiments have been made and a great many observations taken on the splitting of material by nails. The following conclusions have been drawn and appear to be substantiated by two years of observation:

In using the cooler or sinker in species of medium hardness, the "penny" of the nail cannot be greater than the thickness, in eighths of an inch, of the wood which holds the point of the nail.

For the softer woods nails may be one "penny" larger and sometimes even two "pennies." For the hard wood nails one "penny" smaller should be used.

The ordinary box machine, when nailing boxes of the sizes usually used for canned foods, cannot space the nails close enough to cause splitting of the ends or to develop the strength of the lumber.

The following rule has been suggested for guidance in the spacing of nails for domestic shipment.

For six "penny" or smaller nails held in the side grain, there should be a spacing of 2 inches, and for the same nail in the end grain a spacing of 1-3/4 inches. For larger nails, the spacing should increase 1/4-inch for each "penny!" To a great many people, this spacing will appear to be too close, since it gives many more nails than have formerly been used. As a matter of fact, however, it is only about two-thirds of the number that can be put in before excessive splitting of the ends is encountered, and is only about two-thirds of the number required to balance fully the strength of the box in other respects. Therefore, even with this spacing, which is shown on the attached schedule, the nailing is still the weakest point of the ordinary box.

#### Proposed Schedule for Nailing Boxes

The gauge of nails to be used is determined by the thickness and species of the wood in which the POINTS of the nails are held after driving. The following schedule is based upon standard cement-coated box nails. If the designated penny of the nail is not available, use the next lower penny and space nails proportionately closer.

### Spacing of Nails

When nails are 6d or less space those holding boards to end grain of end 1-3/4-inch apart, and holding boards to side grain of end 2 inches apart. Increase spacing of nails 1/4-inch for each penny over 6. No board should have less than 2 nails at each nailing end. When nails holding top and bottom to sides are specified they should be spaced 6 inches or more apart when nails are 6d or less, increasing the spacing 1 inch for each penny over 6.

Use cement-coated nails of gauge indicated when species of wood holding nails is

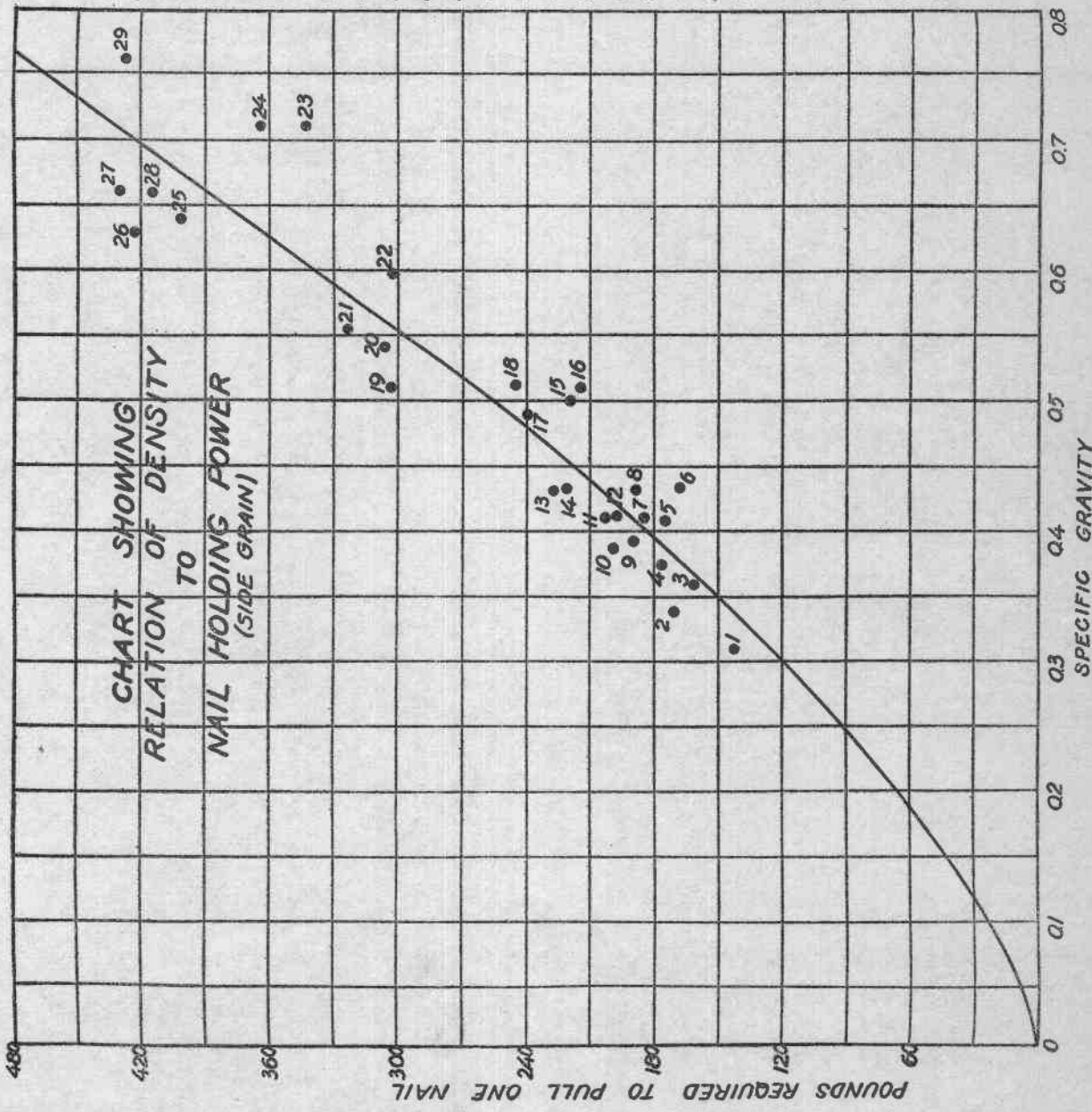
Thickness of ends or cleats to which sides, tops and bottoms are nailed.

	3/8"		11/16"	
	Less	or	or	or
Group I. Woods .....	4d	5d	6d	7d
Group II. Woods .....	4d	5d	5d	6d
Group III. Woods .....	3d	4d	5d	6d
Group IV. Woods .....	3d	4d	4d	5d
				8d
				7d
				7d
				6d
				9d
				8d
				7d
				7d
				6d

Woods Commonly Used in Manufacture of Boxes, Grouped According to Nail-Holding Qualities

	Group I	Group II	Group III	Group IV
Alpine fir	Cottonwood	Douglas fir	Black ash	Beech
Aspen	Cucumber	Hemlock	Black gum	Birch
Balsam fir	Cypress	Larch (Tamarack)	Maple, soft or silver	Hackberry
Basswood	Jack pine	Southern yellow pine	Pumpkin ash	Hickory
Buckeye	Lodgepole pine	Va. and Car. pine	Red gum	Maple, hard
Butternut	Magnolia	White pine	Sycamore	Oak
Cedar	Noble fir	Willow	Tupelo	Rock elm
Chestnut	Norway pine	Yellow poplar	White elm	White ash





1. White Cedar.
2. Cottonwood
3. Engleman Spruce
4. Black Cottonwood
5. Basswood
6. White Fir
7. Aspen
8. Western Yellow Pine.
9. White Spruce
10. White Pine
11. Red Spruce
12. Yellow Poplar
13. Sap Gum.
14. Jack Pine
15. Hemlock
16. Norway Pine
17. Heart Gum
18. Loblolly Pine
19. Soft Maple
20. Elm.
21. Sycamore
22. Longleaf Pine
23. Oak
24. Locust
25. Ash
26. Maple
27. Beech
28. Birch
29. Honey Locust