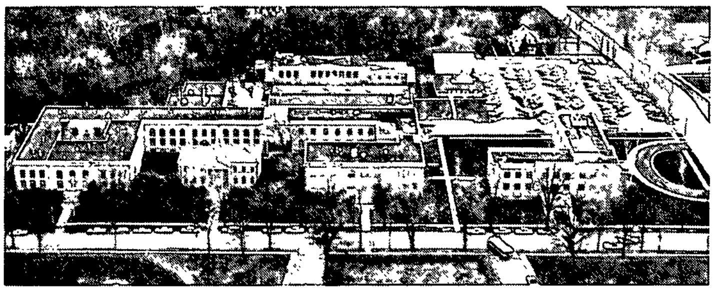

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FASTER, ALTERNATIVE ECT TEST PROCEDURE

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Faster, alternative ECT test procedure

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ABSTRACT This study was directed toward improving Edge Crush Test (ECT) measurement technology by developing a simpler, more efficient method of sample preparation and testing. The specific objective was to compare ECT results obtained with specimens prepared using newer ECT sample cutting and supporting procedures with results obtained using the current TAPPI Test Method (T 811). An alternative ECT test procedure using unwaxed 2 x 2-inch specimens has been developed which compares favorably with the TAPPI procedure specifying waxed-end specimens. The test averages are about equal to those obtained with the TAPPI procedure, and within sample test variability is much lower.

The 2 x 2-inch specimen is cut using a two-bladed automatic ECT cutter. The specimens are tested in a test fixture which supports the ends of the specimen with clamps at a controlled pressure. The fixture fits between the platens of flexible and rigid platen compression testers. No waxing of the ends is required.

Introduction

Edgewise compressive strength (ECT) is an important structural property of corrugated board because it is directly related to top-load box compressive strength. The TAPPI ECT Test Method (T 811)(1) requires specimens to be cut on a circular saw, with specimen height depending on flute type. The specimen's loaded edges are reinforced with wax to prevent edge failure. While this procedure is accurate, it is also time consuming and requires operator care. For these reasons a quicker and safer method of cutting and supporting test specimens was sought.

Several alternate cutting methods which use industrial knife blades were examined. These included a hand-operated Weyerhaeuser cutter, a hand-operated cutter marketed by the Sumitomo Corporation of Japan, and an automatic, dual-blade Billerud cutter sold by AB Lorentzen & Wettre, all used to make rectangular specimens. Other specimens' shapes, such as the necked-down shape (2-4), were not pursued because the cutting procedures are more involved. For simplicity, the feasibility of using a single specimen height was explored.

Several alternate methods of supporting specimens during testing were investigated to eliminate the need for waxing. These included the SCAN-P33:71 support blocks (5), the Morris holder (6), and a test fixture marketed by Sumitomo. ECT values obtained using these specimen cutting and supporting techniques were compared to those obtained using the TAPPI method.

ECT results obtained on new rigid-platen compression testing machines were also compared to those obtained on a conventional flexible-platen machine. The original TAPPI Test Method (T 811) mandates the use of a flexible-platen compression testing machine. Newer compression testers utilize rigid platens equipped with a load cell. TAPPI has revised method T 811 to permit use of these machines (See TAPPI Test Method T 823) (7).

ECT test equipment

The Weyerhaeuser cutter has a plastic block into which an industrial blade is clamped. The operator cuts the board by pushing the block along a guide on the base. Both machine- and cross-machine-direction cuts can be made, but only in two-inch widths. The blade is beveled on both sides and is 15.5 mils thick.

Similar to the Weyerhaeuser cutter, Sumitomo's cutter uses an industrial blade mounted on a hand-operated carriage. The board is held in place by two guides mounted at right angles. One of the guides is adjustable, allowing any specimen size to be cut. The blades are 24 mils thick and also beveled on both sides.

The Billerud cutter, made by AB Lorentzen & Wettre, is an automatic device which uses air pressure to drive the cutting blades (Fig. 1). Two 18-mil-thick blades are mounted on a moving carriage one or two inches apart, depending on the cutter. The cutting edge of each blade is beveled on one side only and mounted with the beveled edge facing outward. The specimen is cut cleanly by the inside, unbeveled edge of each blade. For our tests the specimens were cut to 2-inch heights, except where otherwise noted. The board was precut into two-inch cross-machine direction widths using a different method. Care must be taken to make sure the blades are mounted squarely to produce a cut edge perpendicular to the plane of the board; shims are sometimes necessary. The blades must be replaced after approximately 150 cuts because of dulling.

[Figure 1 here]

The Morris holder, developed by the Weyerhaeuser Co., uses two plates, each of which contains a 6-mm deep groove to support the specimen's loaded edges. Groove width is adjustable to accommodate normal board calipers. The grooves are beveled at a 5-degree angle, becoming narrower at the specimen's unwaxed edges.

Sumitomo's test fixture (Model D-105) provides direct support to the loaded edges of an unwaxed specimen (Fig. 2). Two clamps support the top and bottom 2 cm of the specimen. While the fixture is designed for specimens with a height of 60 mm, a specimen height of 2 inches works well. This results in an unsupported column height of approximately 10 mm. In the original design each clamp was operated by hand tightening a bolt. To eliminate this source of operator error, the fixture was redesigned using springs to achieve a constant clamping pressure as discussed in a later section.

[Figure 2 here]

Both flexible- and rigid-platen testers were used in this work.

Compression testing machines

Sixty-six combined board lots, made by members of the Fourdrinier Kraft Board Group (FKBG), were tested on a flexible-platen and a rigid-platen tester using the TAPPI ECT method. These lots ranged from 150-lb single-wall (SW) to 350-lb double-wall (DW). Figure 3 illustrates the good agreement between the average ECT value for each combined board series using each tester. The results confirmed that a rigid-platen compression testing machine is an acceptable alternative to the flexible-platen type.

[Figure 3 here]

Alternate ECT testing methods

A short series of tests was performed comparing three alternate cutting methods. The Weyerhaeuser and Billerud cutters both appeared to perform satisfactorily, while the Sumitomo cutter did not. The most probable explanation for this is the geometry of the cutting blade. The Sumitomo cutter uses a thick blade beveled on both sides. This will tend to deform the liner as it is being cut, causing premature edge failure during the ECT test. A thinner, single-beveled blade would be preferred, although this was not tried. The Weyerhaeuser cutter avoids this problem by using a thinner double-beveled blade, while the Billerud cutter uses two thin single-beveled blades mounted such that the specimen edges are cut with the straight, unbeveled edges of each blade. Any cutting method which follows these guidelines should be satisfactory.

Based on initial trials, the sixty-six combined board lots mentioned above were tested on a rigid-platen tester using the following test methods: (1) TAPPI Test Method T 811: grooved blocks, saw-cut, height depending on board type, waxed; (2) Clamped Specimen (CS): Sumitomo's test fixture, Billerud-cut, 2-inch height, unwaxed; (3) SCAN-P33:71, Billerud-cut, 1-inch height, unwaxed; (4) TAPPI Useful Method UM 814: Morris holder, Weyerhaeuser-cut, 2-inch height, unwaxed. Two-inch specimen widths were used in all cases.

As seen in Fig. 4-5, the CS ECT values are in very good agreement with TAPPI ECT values, averaging about one percent high. All correlations with the TAPPI method are good: within-grade correlations range from 0.67 to 0.80, while the correlation over all board grades is 0.955. The coefficient of variation for the CS method averages 4.0%, compared to 8.6% using the TAPPI method (Fig.

6). Excellent agreement with TAPPI ECT values, good correlations, and lower variability all suggest that the CS method is a successful ECT test method.

[Figures 4, 5, and 6 here]

Edge failures often occur when testing with the CS fixture; however, this did not result in low test values (see Fig. 4). ECT values from methods 3 and 4 averaged approximately fifteen percent lower than TAPPI ECT values, and were not pursued further.

These results indicated that the CS method showed the most promise as a faster, simpler alternative to the TAPPI method. To further verify the accuracy of this method, an additional 150 lots were tested after improving the support fixture. These lots, also provided by FKBG members, ranged from 150-lb SW to 500-lb DW.

Modified Sumitomo test fixture

The clamps on the original Sumitomo test fixture are hand-tightened until "snug". Because this is a possible source of operator error, a new clamping system which uses springs to exert a constant pressure was designed by Sumitomo. The clamps lock open for removal and insertion of the specimen, then slide closed when released to exert a stable, repeatable clamping pressure. The redesigned fixture came with springs which had a spring constant of K = 10.1 lb/in and produced a clamping pressure of 5.3 psi for all board calipers. This fixture was used to test the additional 150 lots mentioned above, the results of which are shown in Fig. 7-8. Within-grade correlations with the TAPPI ECT values were good, ranging from 0.81 to 0.93. The overall correlation coefficients is an excellent 0.991. Thus, controlling the clamping pressure improved the correlations between the CS and the TAPPI methods.

[Figures 7 & 8 here]

Within-lot variability of the CS method again averaged lower than that of the TAPPI method, measuring 3.9% as opposed to 5.5% (Fig. 9).

[Figure 9 here]

The overall average ECT is 2.7% lower than the corresponding TAPPI value, which is not as good as with the original fixture. Close examination of the average percent difference by series reveals that the values are about 0.5% low up to and including 200-lb SW series, about 3.0% low for the 275-lb SW to 350-lb DW series, and about 6.6% low for the 500-lb DW series. This is evident by the way the regression line drops away from the 1-1 line as board series increases (see Fig. 8). This indicated that a stronger clamping pressure was required.

To test this hypothesis, a group of 29 lots was retested using a series of stronger springs. It was found that the difference between the two methods decreased with increasing clamping pressure. Shown in Fig. 10 are the results using a higher, more optimal clamping pressure. Using springs with a spring constant of K = 20.4 lb/in. obtained from Sumitomo, the fixture exerts clamping pressures of approximately 7.1 and 11.6 psi on boards with calipers of 150 and 300 mils, respectively. The average CS ECT value is only 0.7% lower than the average TAPPI value. Within-lot variabilities are relatively constant with increasing clamping pressure, always remaining lower than TAPPI values.

[Figure 10 here]

While the agreement between the TAPPI and the CS ECT test methods using the K = 20.4 lb/in. springs is good, one problem was encountered with these strong springs: opening the clamps repeatedly was difficult for the operator. The clamp design was then modified to make them easy to operate, even with the stiffer springs. As a final test, the 29 lots were rechecked with this arrangement. The results were in good agreement over the entire range of combined boards tested. This arrangement has been recommended to Sumitomo as the final working design.

Box compression study

Because of the importance of ECT in the end-use performance of the box, box compression predictions were made using each ECT method and compared to actual box compression values. Predictions were made using the McKee box compression formulas (8):

Long Formula:

$$P = 2.028\ (ECT)^{0.746}\ [(D_x D_y)^{0.5}]^{0.254}\ Z^{0.492}$$

Short Formula:

$$P = 5.874\ (ECT)\ H^{0.508}\ Z^{0.492}$$

where $D_{x,y}$ = Flexural Stiffness

H = Combined Board Caliper

Z = Box Perimeter

These equations were used to predict the top-load box compression strength of the initial SW lots. Predictions made with the TAPPI and the CS ECT values were high (7.2-8.9%) using the long formula and slightly low (1.7-3.7%) using the short formula. Box predictions made with the other ECT methods were much lower because of the low ECT values. To better compare results from the various ECT methods, the constants in the McKee equations were rederived using the TAPPI single-wall ECT data.

Long Formula:

$$P = 2.180\ (ECT)^{0.727}\ [(D_xD_y)^{0.5}]^{0.273}\ Z^{0.454}$$

Short Formula:

$$P = 7.178\ (ECT)\ H^{0.546}\ Z^{0.454}$$

New box predictions, made with the TAPPI and the CS ECT values, averaged 0.7% and 2.2% high, respectively, using the long formula and 5.8% and 3.9% low, respectively, using the short formula. The average prediction accuracies achieved with the other ECT methods were again much lower. Thus the best prediction accuracy was obtained with the proposed new method using the clamped square specimen.

Conclusions

The Clamped-Specimen ECT test procedure developed here agrees very well with the TAPPI ECT procedure and is much faster and simpler to use. Specimens are cut quickly and safely using industrial knife-blades. Proper maintenance is required to ensure the blades are sharp and mounted squarely. The dual-blade Billerud cutter was found to work exceptionally well if the blades are replaced as they become dull. A single specimen size of 2 x 2 inches was shown to be satisfactory.

To further simplify the ECT method, a test fixture was used which eliminates the need for waxing. The fixture is made by the Sumitomo Corporation of Japan. Spring-operated clamps support the top and bottom 20 mm of the specimen during testing. The optimal clamping pressure was determined to be approximately 7.1 psi for 150-mil board and approximately 11.6 psi for 300-mil board. Springs with a spring constant of 20.4 lb/in. mounted in the Sumitomo test fixture produce the desired clamping pressures. The fixture fits between the platens of the compression testing machine. Flexible- and rigid-platen testers were shown to produce equivalent results.

Acknowledgments

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The support provided by the Sumitomo Corporation of America, AB Lorentzen and Wettre (through Scanpro Instruments) and Testing Machines, Inc., is gratefully acknowledged. The Sumitomo Corporation provided the Model D-105 fixture and made design changes to give a controlled clamping pressure. AB Lorentzen and Wettre modified their cutter to give a 2-inch wide cut. One rigid platen tester was obtained on loan from Testing Machines, Inc.; a second rigid platen tester was obtained under special arrangements from AB Lorentzen and Wettre.

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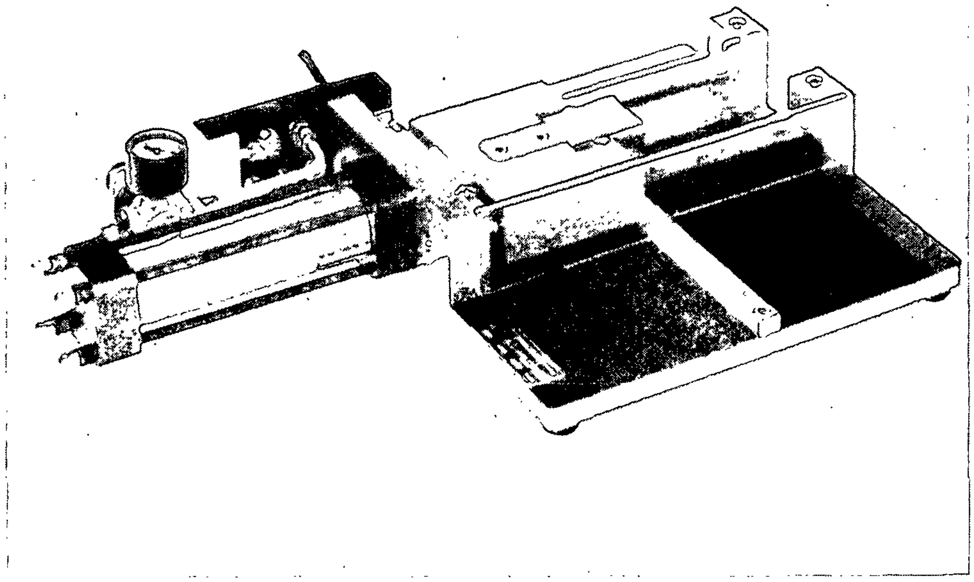
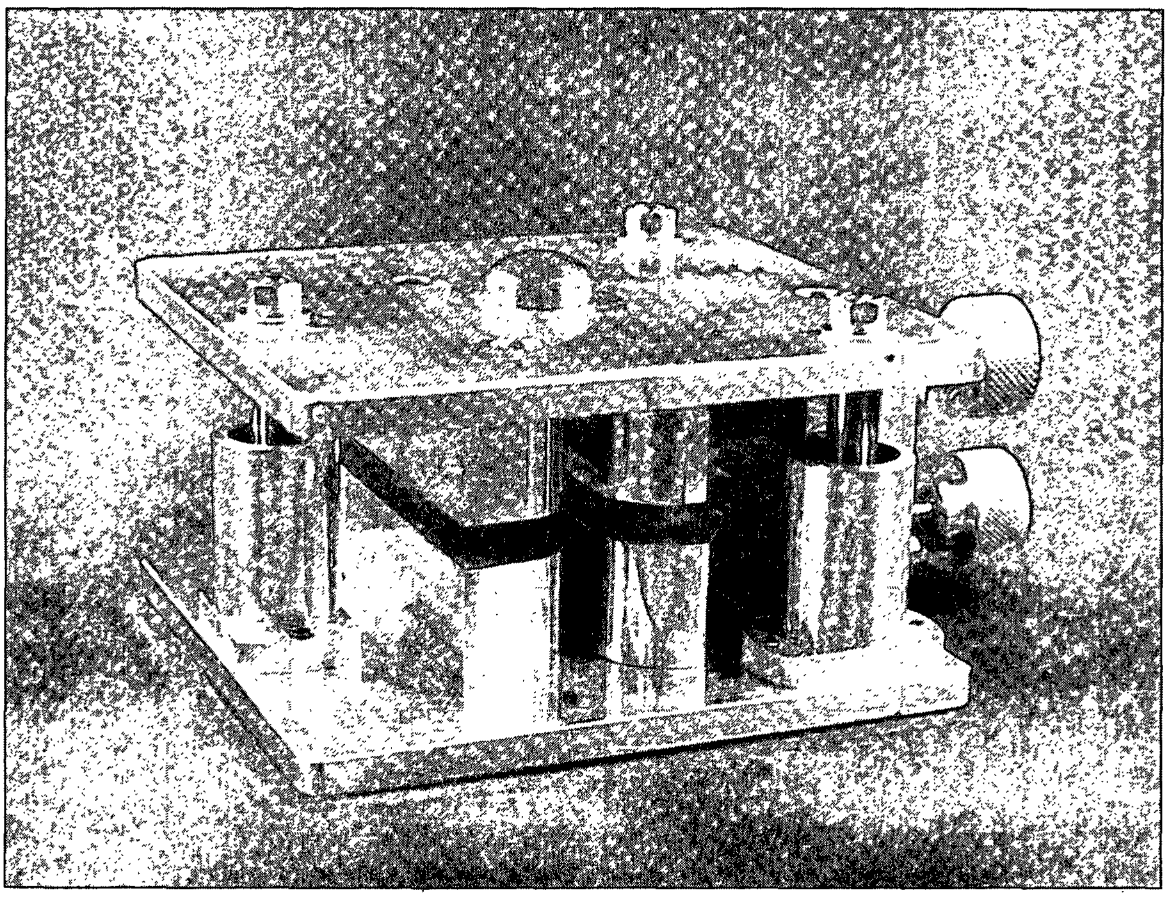
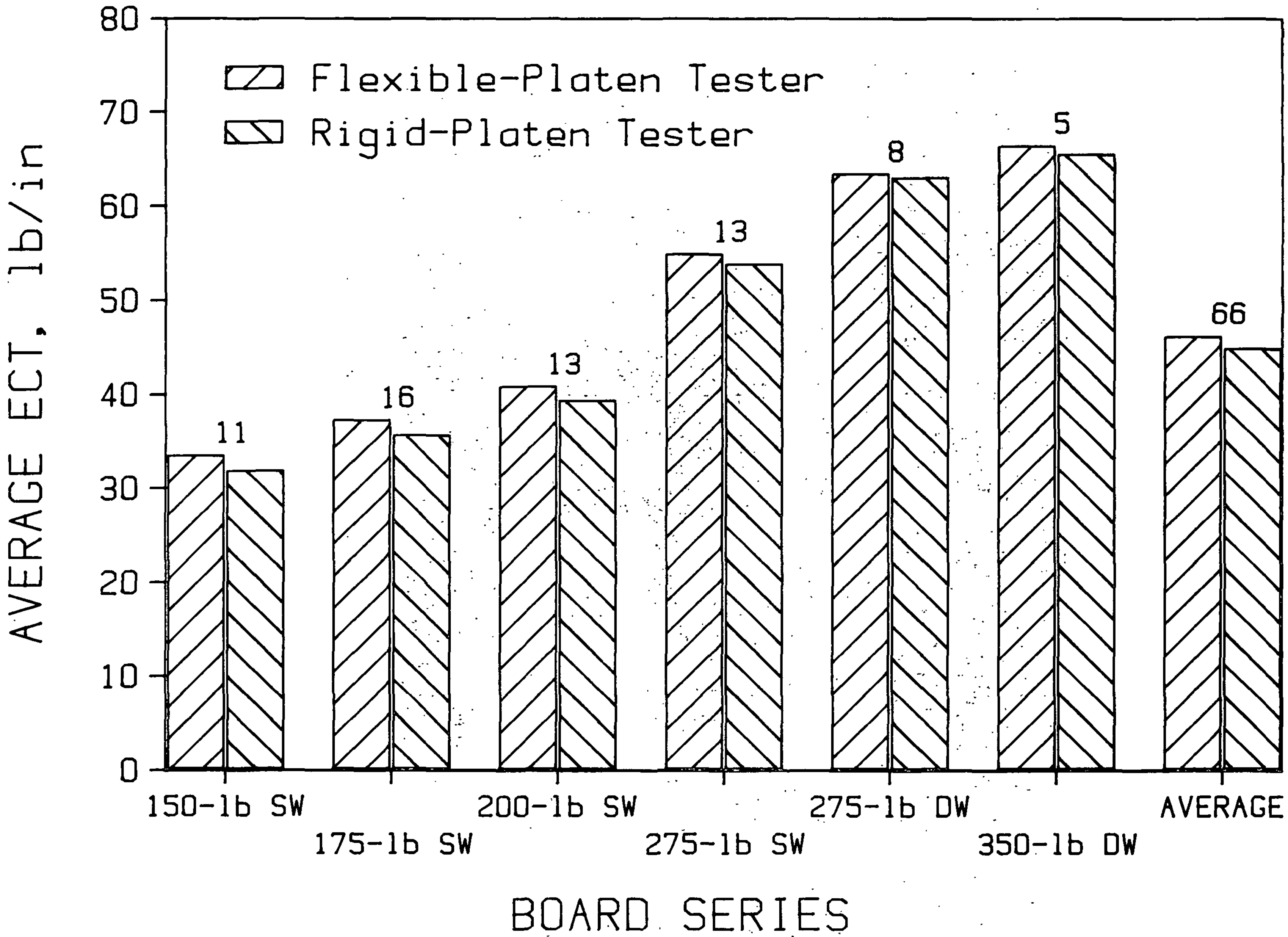


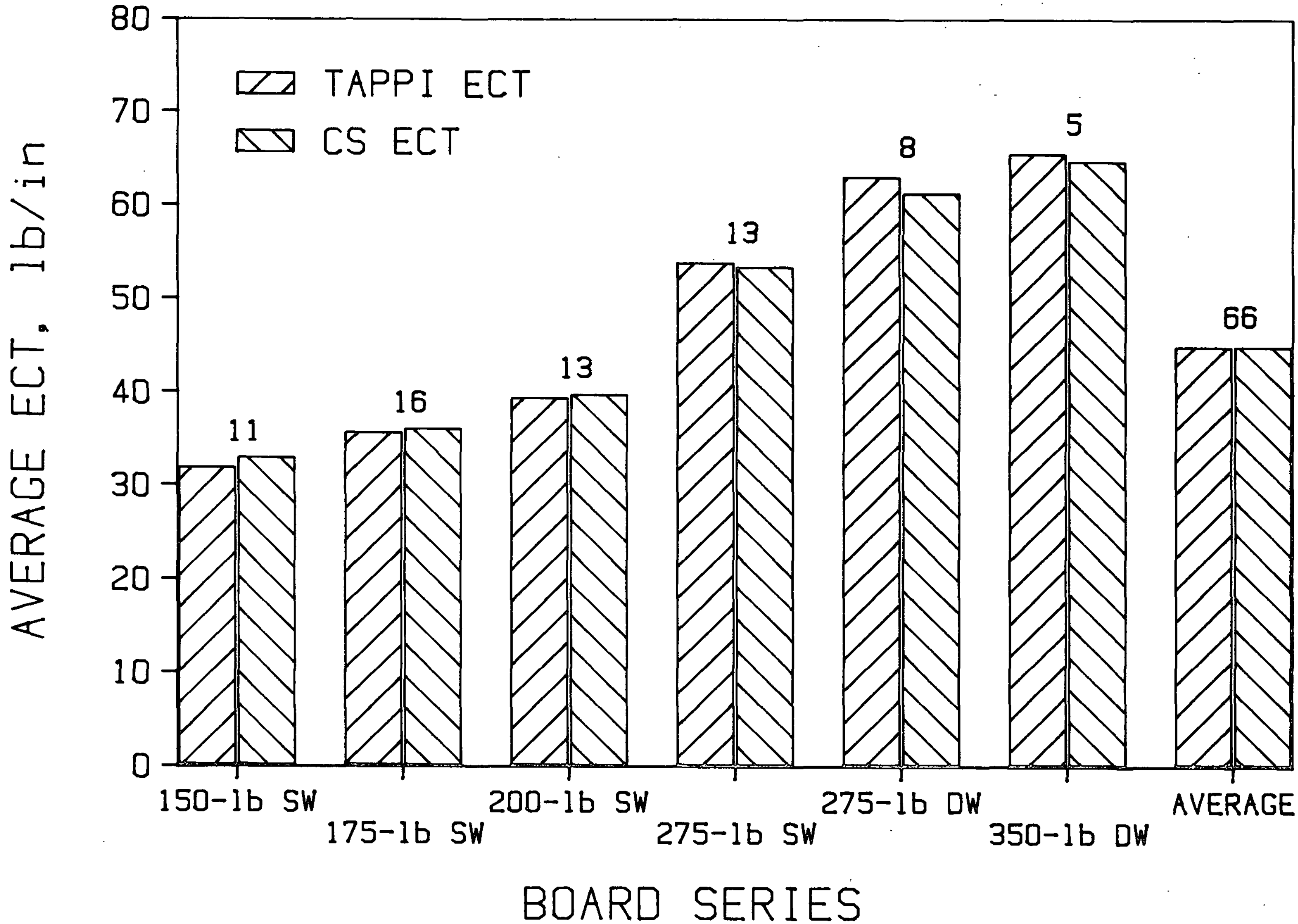
1. Billerud automatic cutter.



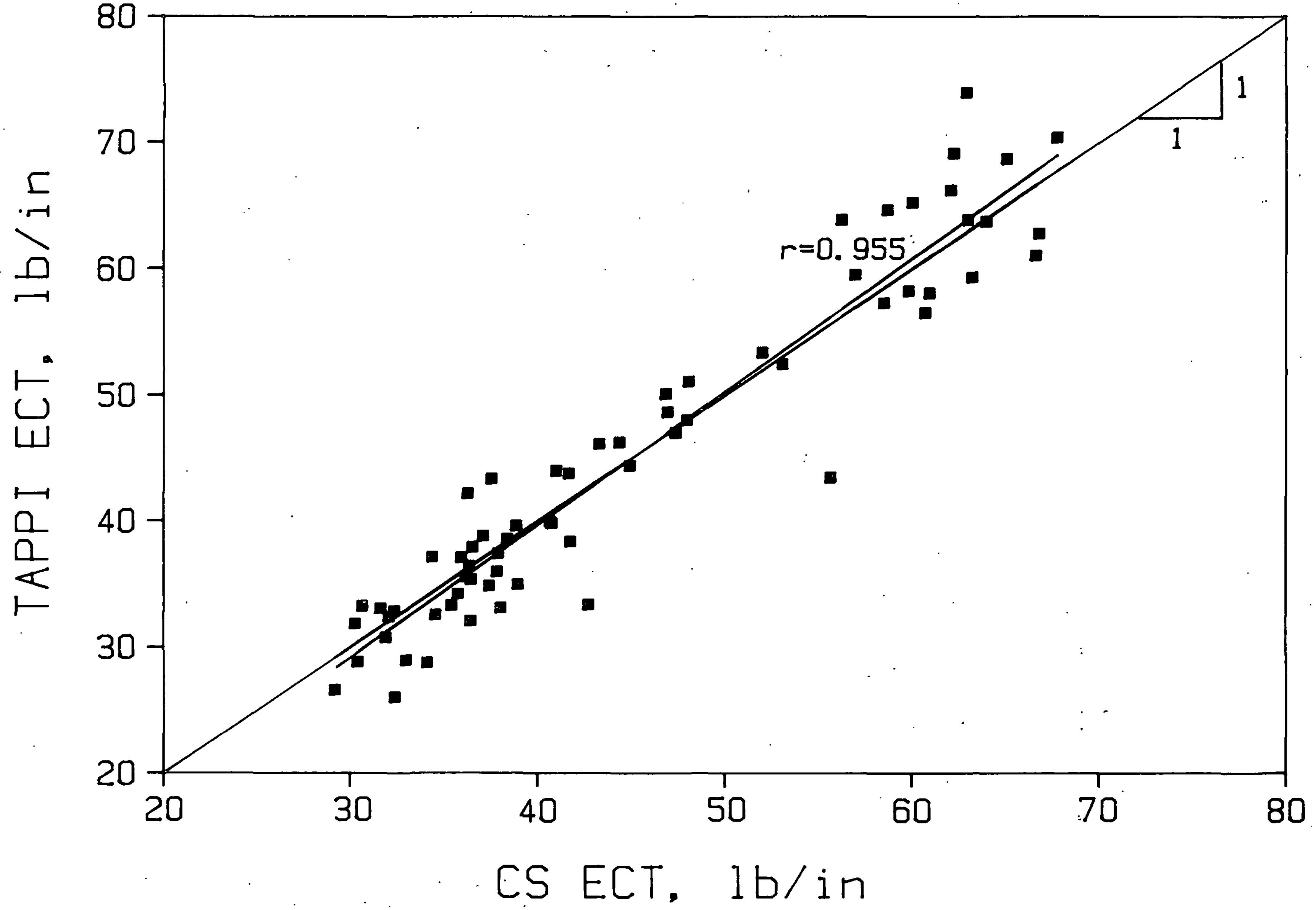
2. Sumitomo's test fixture, Model D-105.



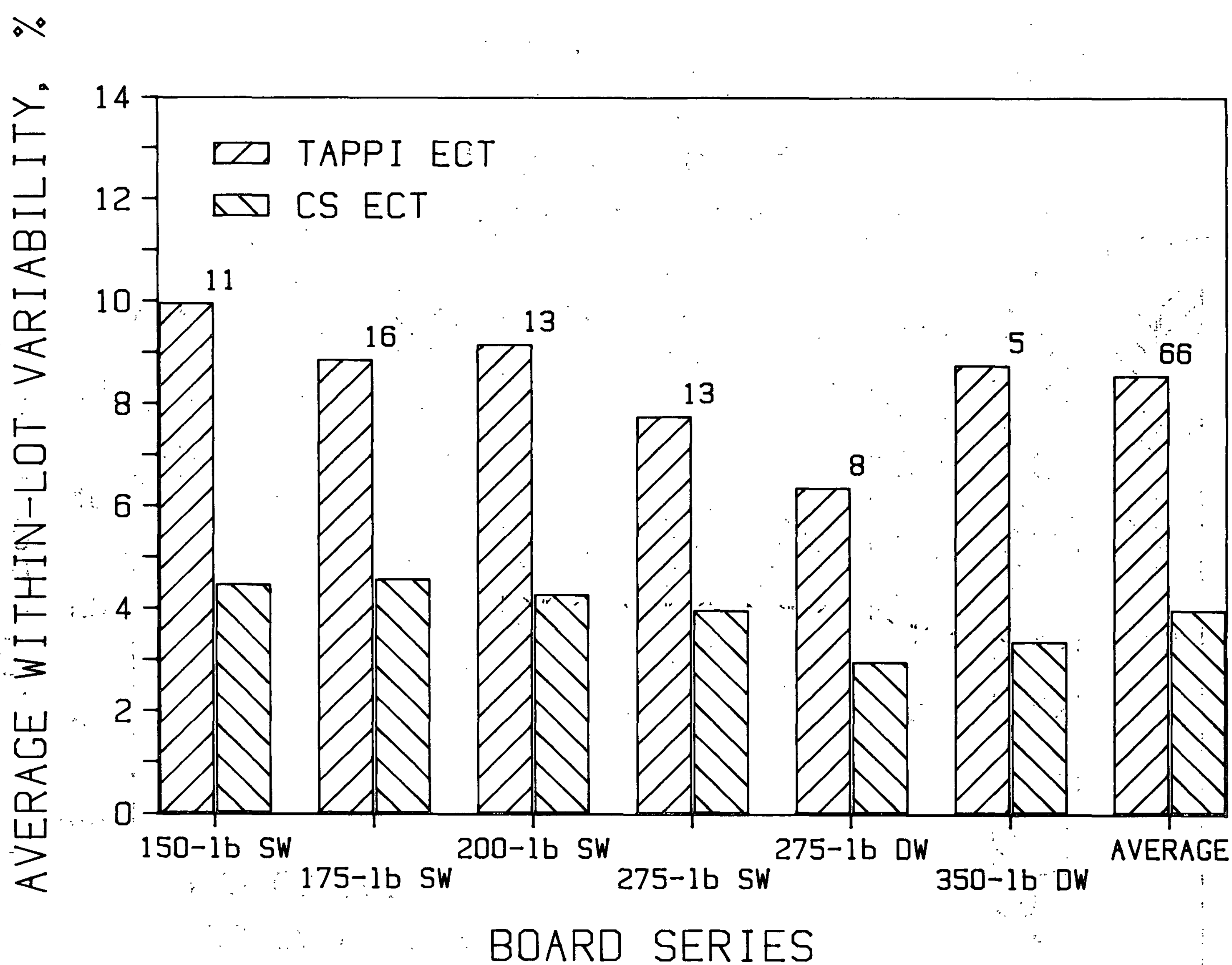
3. Flexible- and rigid-platen compression testing machines give equivalent ECT test results.



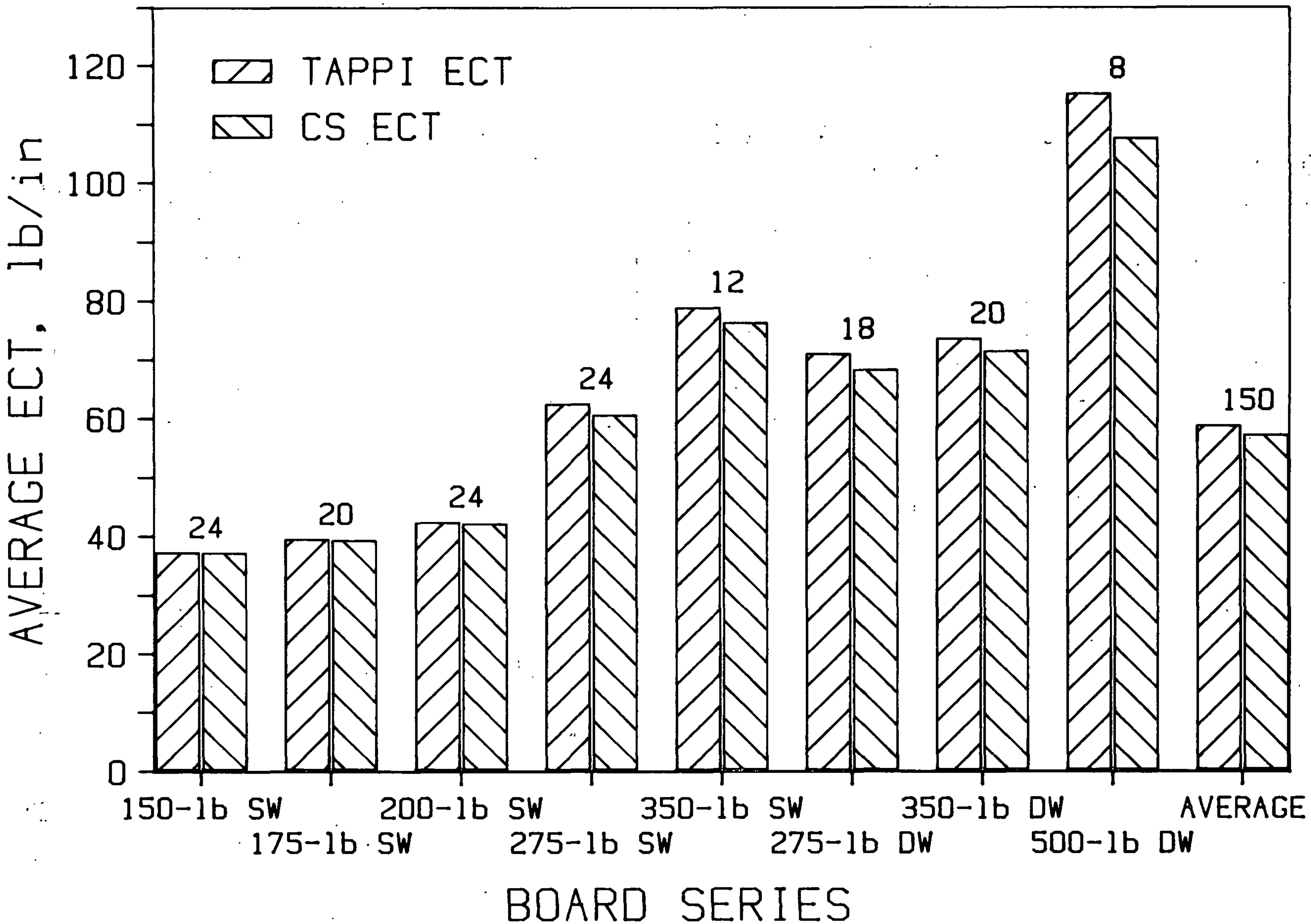
4. Clamped Specimen ECT test results, unwaxed, are in close agreement with TAPPI unwaxed ECT results (66 combined board lots).



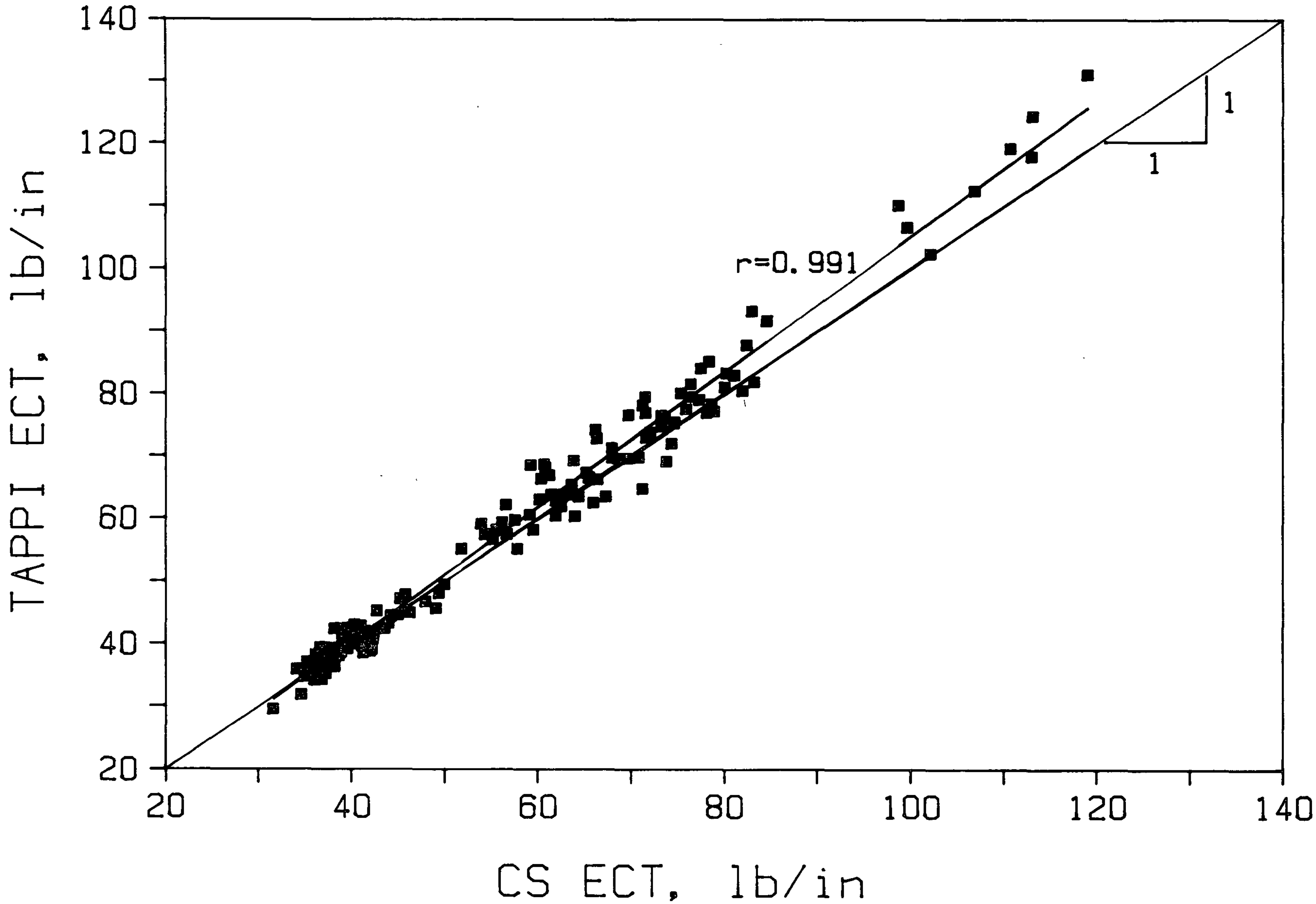
5. Clamped Specimen ECT tests are also well correlated with TAPPI ECT test results (66 combined board lots).



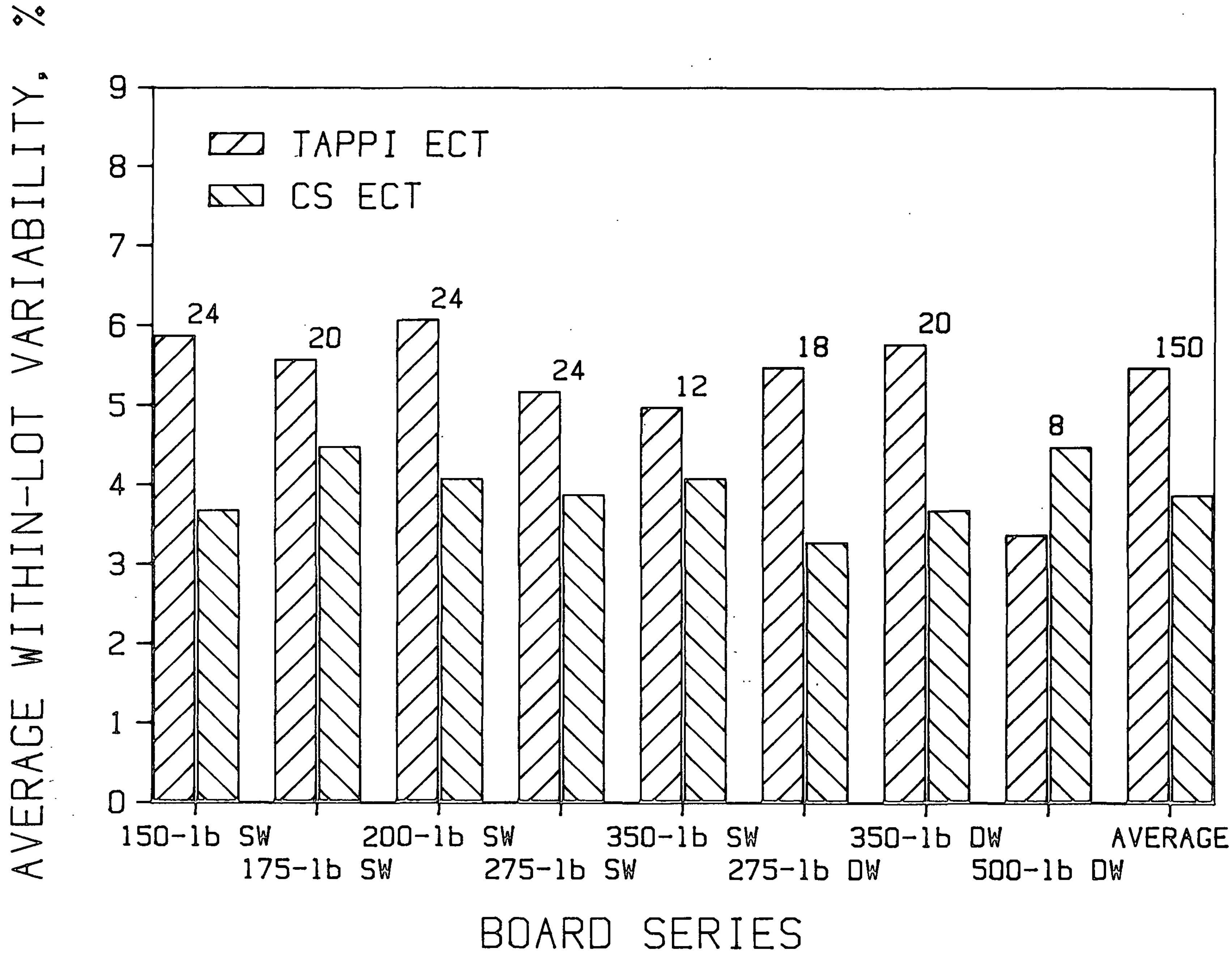
6. Clamped Specimen ECT test results exhibit much less variability than TAPPI ECT test results (66 combined board lots.)



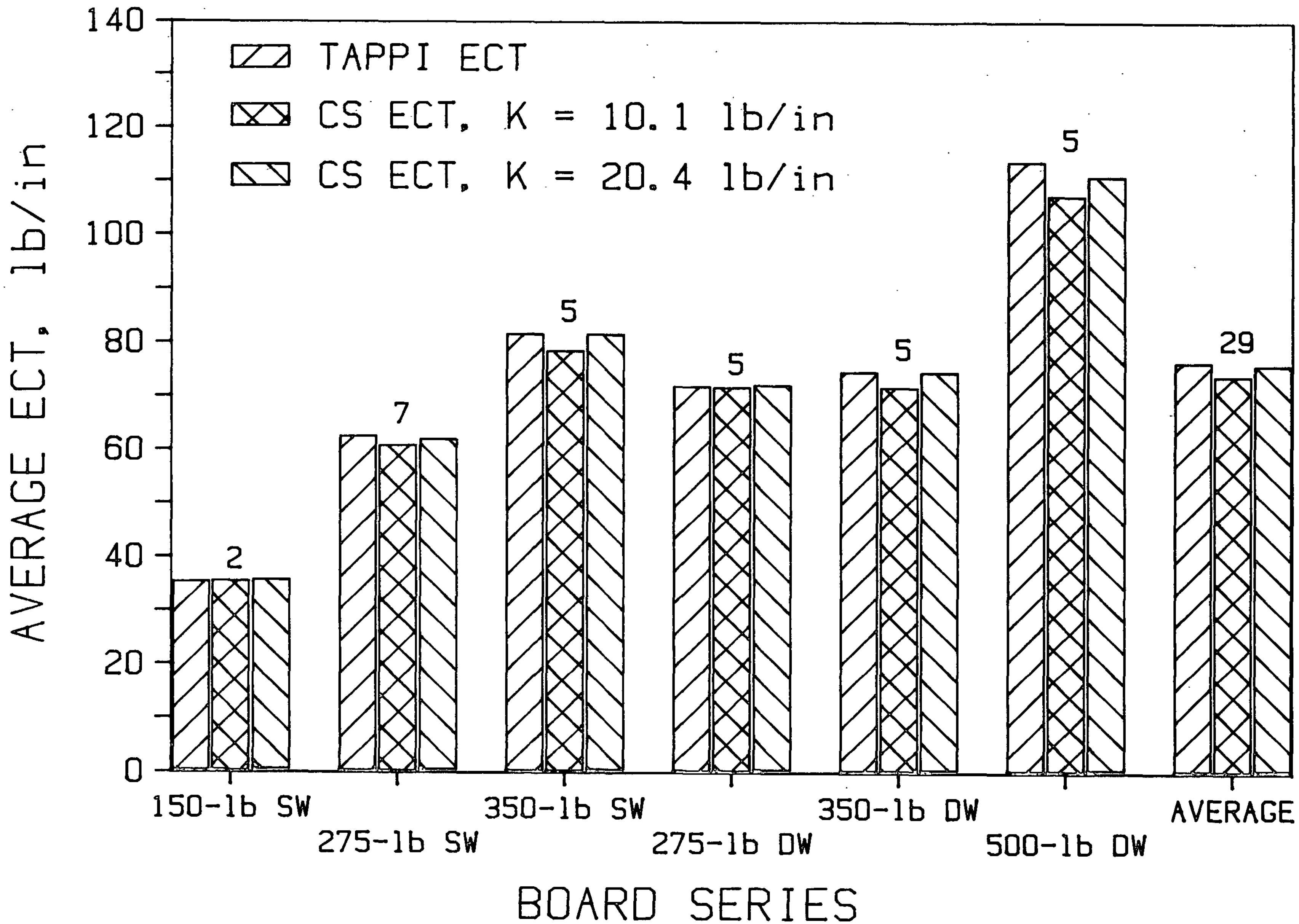
7. With insufficient clamping pressure, Clamped Specimen ECT results tend to be slightly lower than TAPPI results for high-series combined boards (150 combined board lots).



8. Even with insufficient clamping pressure, Clamped Specimen ECT results still correlate well with TAPPI results (150 combined board lots).



9. Clamped Specimen ECT variability is still lower than that of TAPPI, in spite of low clamping pressure (150 combined board lots).



10. With the K = 20.4-lb/in springs, the Clamped Specimen ECT test results are again in close agreement with the TAPPI test results for SW and DW boards (150 combined board lots).