



# **A MODERN OUTLOOK ON PALLET RESEARCH**

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PREFACE

The Information Report Series of the Forest Products Laboratory, Ottawa, is used primarily to report the results of limited research, or interim results of studies of long duration which are of current interest to segments of the forest products industry, committees of standards organizations and other special groups. Because some of the results reported are of an interim nature and others have a limited field of interest, not all reports are given general distribution.

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## A MODERN OUTLOOK ON PALLET RESEARCH

By

C.H. Nethercote and J.R. Reeves<sup>1</sup>

*Modern laboratory testing procedures more accurately determine a pallet's environmental performance characteristics.*

A sound and meaningful laboratory testing program is imperative for the efficient evaluation and determination of a pallet's performance characteristics. Reliable pallet field trials may require several months or even years of continuous planning, execution and inspection before any valuable information may be derived. A laboratory testing program can provide equivalent essential information, such as critical design criteria, strength and durability, after only a few hours of evaluation and observation; but the program must closely simulate the conditions found within an actual transportational and handling environment, as well as reproduce typical damage.

Pallets have been evaluated for many years in the laboratory by numerous traditional testing methods well-documented in many standards and publications. These tests include the 14-foot revolving drum test, the Conbur inclined impact test and the popular corner-drop test. The failures that will develop in stringer-type wooden pallets during these tests are very predictable in nature and are typically caused by corner splitting within a pallet's stringers (Figure 1). These splits run diagonally across the end of the stringers, through the staggered leadboard stringer nail lines, weakening the stringer leadboard contacts. The leadboard then simply falls away from the damaged stringers.

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It was apparent, from observations made in palletized warehouses, that these tests did not simulate actual transportational and handling conditions. It was clear that the laboratory research program neither faithfully reproduced the damage that would develop within a pallet during exposure to an actual handling environment, nor would recognized traditional laboratory practices indicate a pallet's true performance characteristics.

#### Field Tests Show the Way

In order to determine a pallet's actual environment, the Ottawa Forest Products Laboratory, of the Canadian Forestry Service, for nearly two years, studied a large sample population of nonreversible double-faced stringer- and block-type pallets within the transportational and handling environment of a major Canadian carrier. These pallets were handled principally by many makes and types of forklift trucks and occasionally by hand pallet trucks. This field study showed that although over 70 percent of all pallet damage was on the leading edge, it was not caused by diagonal splitting within a pallet's stringers; rather it was caused by a system of forces called simply, "the push-pry action of forces".

The repeated impacts of a forklift truck against the upper leading edge of a pallet will push the leadboard back from its initial flush position (Figure 2). This action, which may be referred to as incipient damage, twists and weakens the nailed joints bonding the leadboard to the stringers. The leadboard is finally pried from the pallet as the radius of curvature at the base of the forks repeatedly strikes the weakened upper leading edge during handling (Figure 3). This damage was in no way similar to that observed in the laboratory when traditional testing procedures were employed.

The laboratory's pallet testing program included free fall corner drop tests, the 14-foot revolving drum test and a Conbur inclined impact test. Each pallet tested in the laboratory

was subjected to all three tests and the number of drops to failure was considered to be an indication of the pallet's performance characteristics. A range of between 24 and 81 drops to failure occurred among the sample populations tested. Failure was considered to be that point where repairs were required to keep the pallet serviceable.

The field performance characteristics of eastern hemlock and jack pine pallets were very similar in nature, and yet in the laboratory jack pine withstood only 24 drops to failure while eastern hemlock withstood 62 drops. Aspen pallets withstood 65 drops in the laboratory, whereas a birch pallet and a composite maple and hemlock pallet, far superior in the field, withstood only 47 and 48 drops, respectively. Tamarack (eastern larch), comparable to birch in the field, withstood only 37 drops in the laboratory. The performance of stringer-type pallets, during the field trials was far superior to the performance of block-type pallets, and yet, in the laboratory, a stringer-type pallet withstood only 13 drops in the 14-foot revolving drum whereas a block-type pallet withstood 154 drops before failure occurred.

#### New Lab Tests Reflect Field Damage

From these field and laboratory observations, it was concluded that traditional laboratory practices lacked reliability. Therefore, to accurately represent field conditions, to faithfully reproduce pallet damage in the laboratory, and to develop design criteria for the development of improved wooden pallets, a totally new concept of criteria for pallet research is required. As a step in this direction, the Ottawa Forest Products Laboratory now uses two pallet component tests, a nondestructive stiffness test, and a newly developed destructive performance test.

A shear test on a simulated leading edge determines a pallet's resistance to the push-pry action of forces. Two

appropriate lengths of stringer material and one twenty-inch length of leading edge deckboard material are nailed up to simulate a pallet's leading edge. A second deckboard butted against the leadboard may or may not be included. The test is conducted by placing a shear sample on the bed of a universal or compression testing machine with the stringers oriented in the vertical plane. The base of the sample is fixed, by means of support fixtures, to the bed of the testing machine, eliminating any lateral instability caused by the bending moment arm developed during loading. An upper bearing plate, rigidly fixed to the upper moving head of the testing machine bears upon the leading edge of the leadboard component along the span between the stringers (Figure 4). A vertical downward loading force is then applied to the member at some predetermined uniform rate of head movement. Preliminary studies suggest that maximum loading will occur within four to six minutes of initial loading with a loading head movement of 0.25 inches per minute. During loading, a shear force is developed along the leadboard and stringer interface which is resisted by the joint's resistance to the push-pry action of forces. The performance of the joints can be determined by measuring the maximum load to failure, the load v. displacement characteristics of the joints, or both. The performance of the joint can then be compared to some predetermined requirement. It is not the purpose of this test to determine the absolute strength characteristics of a pallet's leading edge; rather, it is a relative performance test.

A joint separation test evaluates a pallet joint's resistance to nail withdrawal and compares variables such as nails, nailing patterns, methods of nailing and the retention characteristics of wood species. The samples for this test are constructed by nailing a six-inch length of decking material to a ten-inch length of stringer material. The samples are nailed up in either the green or dry condition with or without predrilling. The prepared samples are placed on the bed of a universal testing

machine in a supporting fixture such that two arms, one on each side of the stringer, support the underside of the deckboard component. A vertical downward force is then applied to the upper edge of the stringer component through a two-point bearing fixture, resulting in direct nail withdrawal (Figure 5). The upper bearing fixture is rigidly fixed to the upper moving loading head of the testing machine ensuring that the nails are simultaneously withdrawn from each sample. The four bearing edges, bearing upon each sample are placed as close as possible to the nailing line within each sample, minimizing any error due to bending within the members of the samples. Maximum load will be attained within 4 to 6 minutes, using a uniform withdrawal rate of 0.05 inches per minute.

Stiffness is critical when loaded pallets are stored in warehouse racks. Although the stiffness of the material used to construct the pallet greatly affects its stiffness, so do other variables (such as nailing pattern and pallet configuration) all of which may influence the effective moment of inertia. A large-bed compression testing machine tests pallets in stiffness along two spans, one, 8 inches less than the length of the pallet, the other 8 inches less than its width. The pallet support points are two steel pipes 2-3/8 inch outside diameter placed crosswise to the span 4 inches from the ends. An increasing load is applied to the pallets through two identical pipes placed crosswise on the upper surfaces of the pallet at the quarter-points of the span (Figure 6). A pre-load of 3000 pounds is applied to the pallet when testing along the stringer span, and 2000 pounds, when bending across the deck. The load is then reduced by 1000 pounds and reapplied at a uniform rate of head movement of 0.10 inch per minute. Two micrometer dials mounted at each outside edge of the pallets are used to record the deflection of the pallet at each 100 pound increment of loading. The load v. deflection characteristics of the pallet are then calculated from the experimental data.

A destructive inclined impact performance test has been developed to more accurately simulate actual pallet damage. The test involves running a pallet onto two forks of the type used on a fork-lift truck. The two forks are rigidly attached to the backstop of a Conbur inclined impact tester and the test pallet with a 700-pound load securely fastened to it is placed on the dolly with end number one leading. The dolly is then drawn 1 foot up the track and released. This process is repeated at increasing increments of 1 foot until severe damage occurs. The pallet is then reversed and end number 2 is similarly tested to failure beginning at that height where the test is terminated on end number 1. The point of severe damage to end number 1 is considered to be a shattering of, or the partial loss or disengagement of a leadboard, and the point of failure is taken to be that point where severe shattering, or the total loss of a leadboard occurs (Figure 7).

This test closely reproduces actual pallet damage. The forks of a lift truck seldom enter a pallet parallel to its deck. The forks attached to the backstop of the Conbur are adjusted so that the pallet strikes and rides up on the forks during its last 8 inches of travel (Figure 8). This is accomplished by angling the forks vertically downward 4° from the direction of travel. Slow motion film shows that this test is truly representative of actual pallet damage (Figure 9).

It is hoped that the continuing development of these laboratory testing procedures will stimulate thought towards improving and redefining standard laboratory pallet testing procedures.

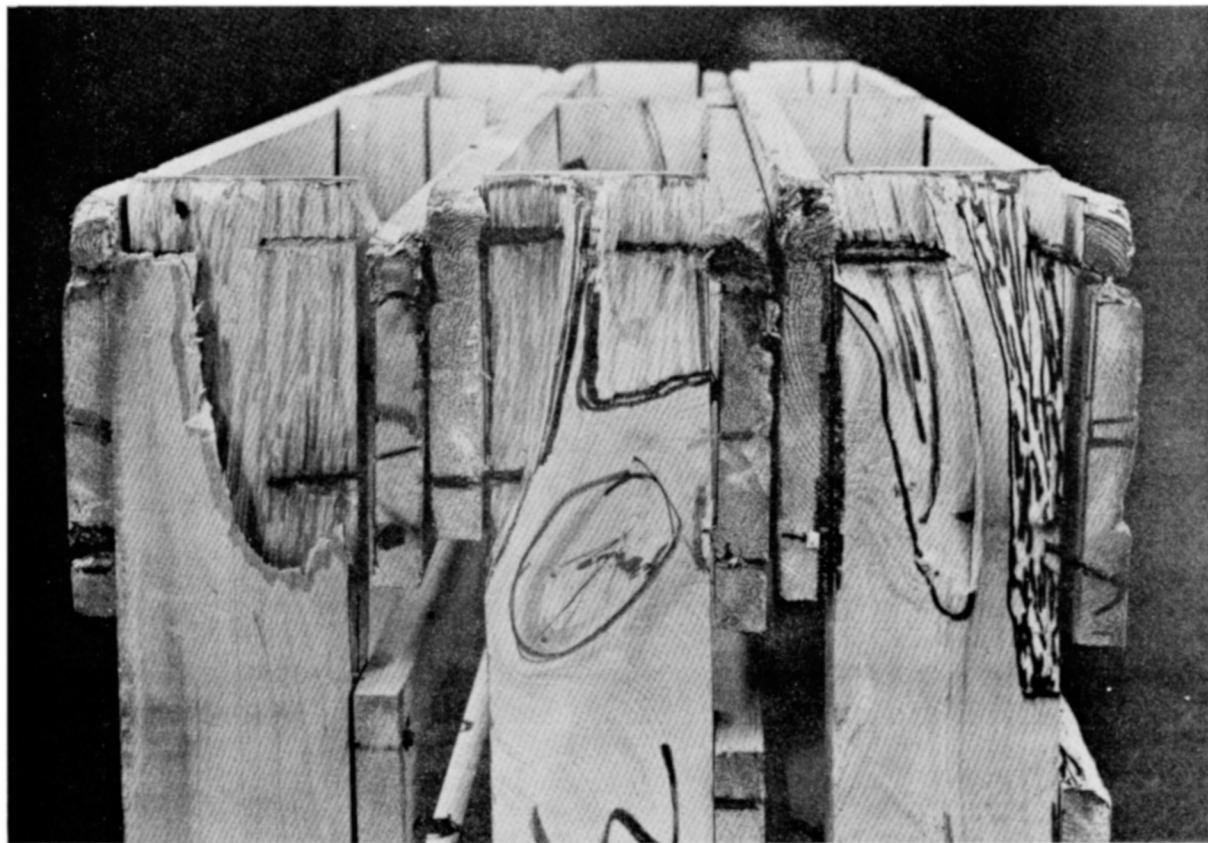


Figure 1. Diagonal corner splitting across a pallet's stringers (2-1995) caused by corner dropping in the 14-ft revolving drum.

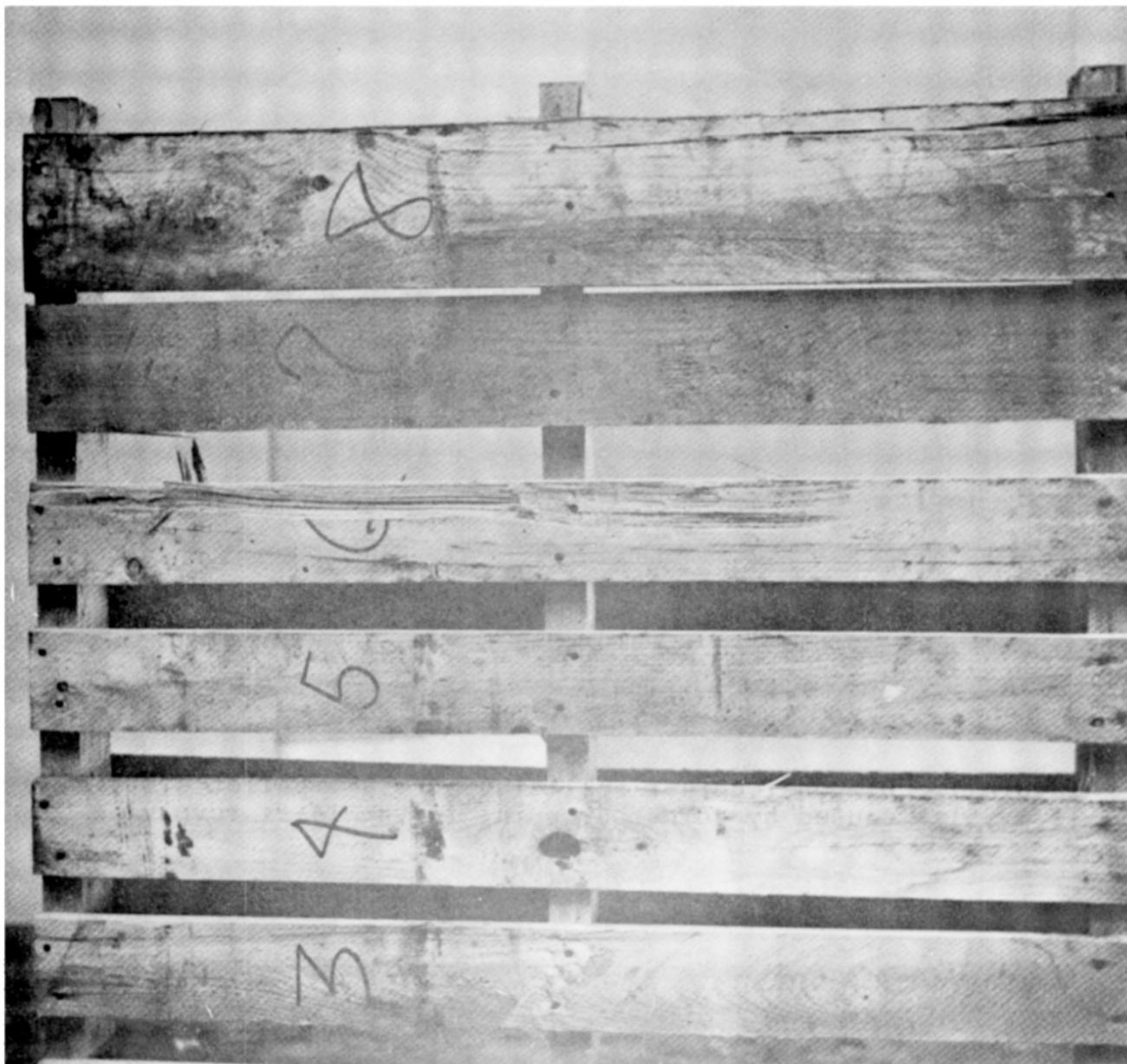


Figure 2. Incipient damage to a flush-stringer-type pallet (2-2072) tested in the field. Note how the leadboard has been pushed back from the leading edge.

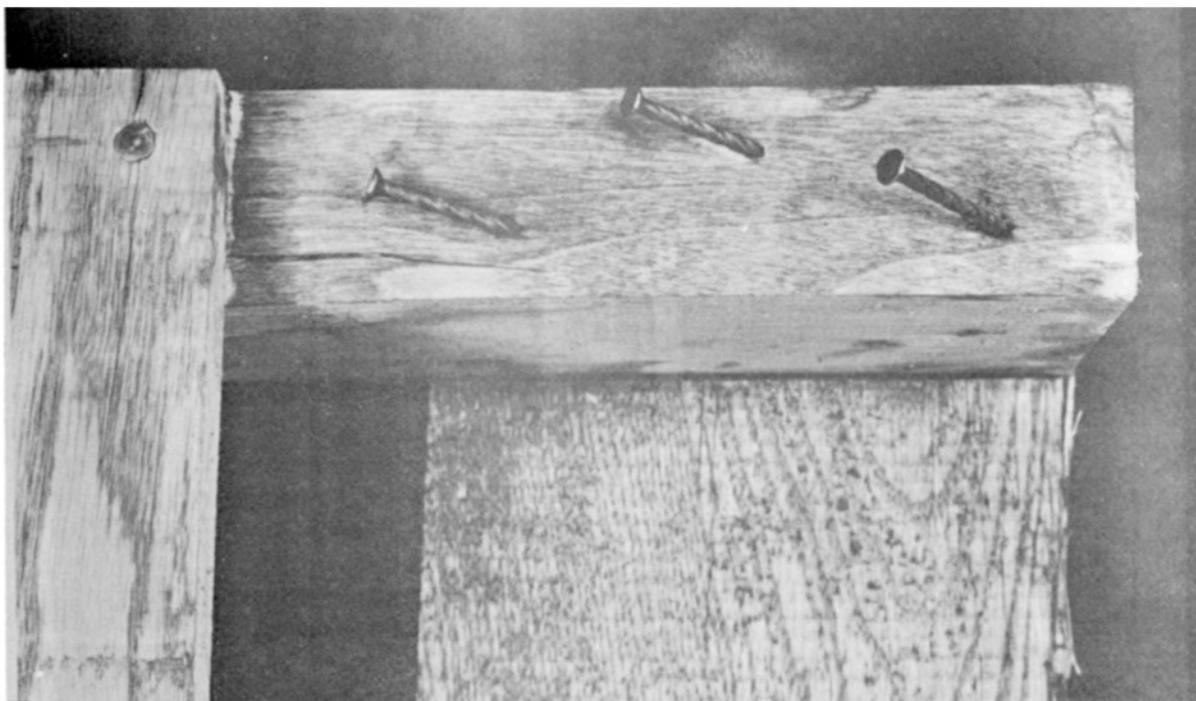


Figure 3. Twisted nails under the missing leadboard of a pallet (2-2098) tested in the field.

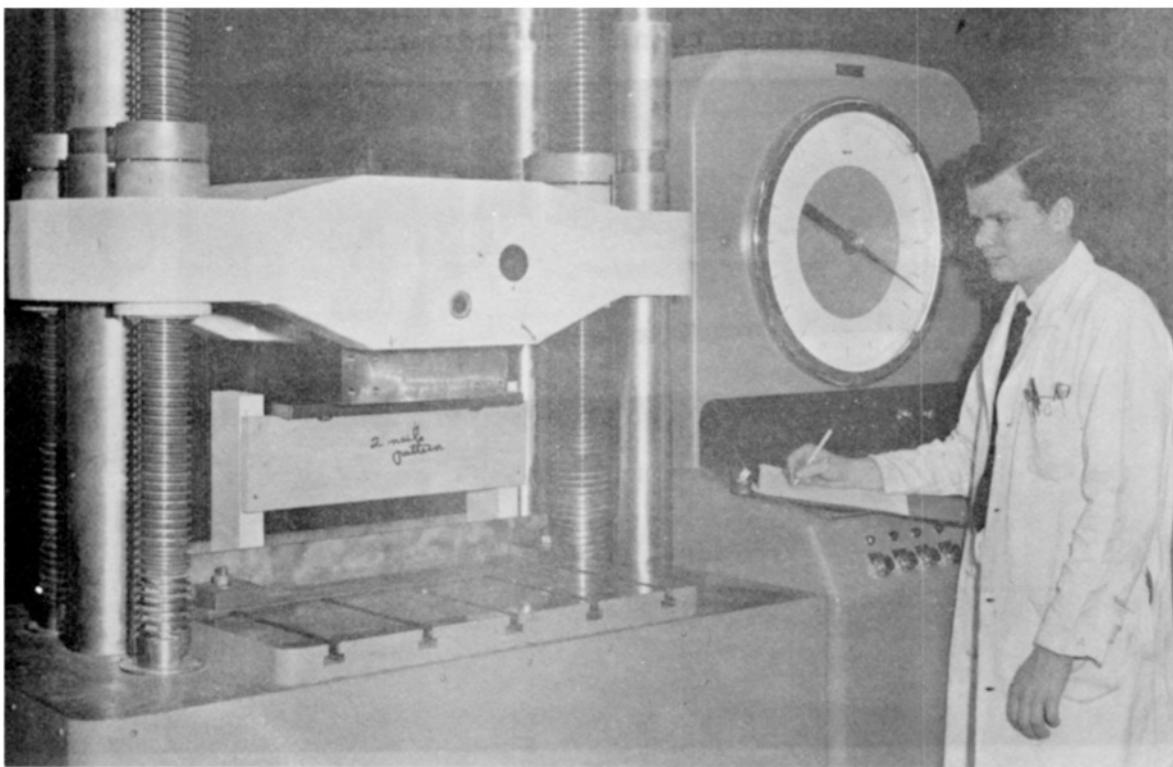


Figure 4. Shear test on a simulated leading edge. (2-2145)

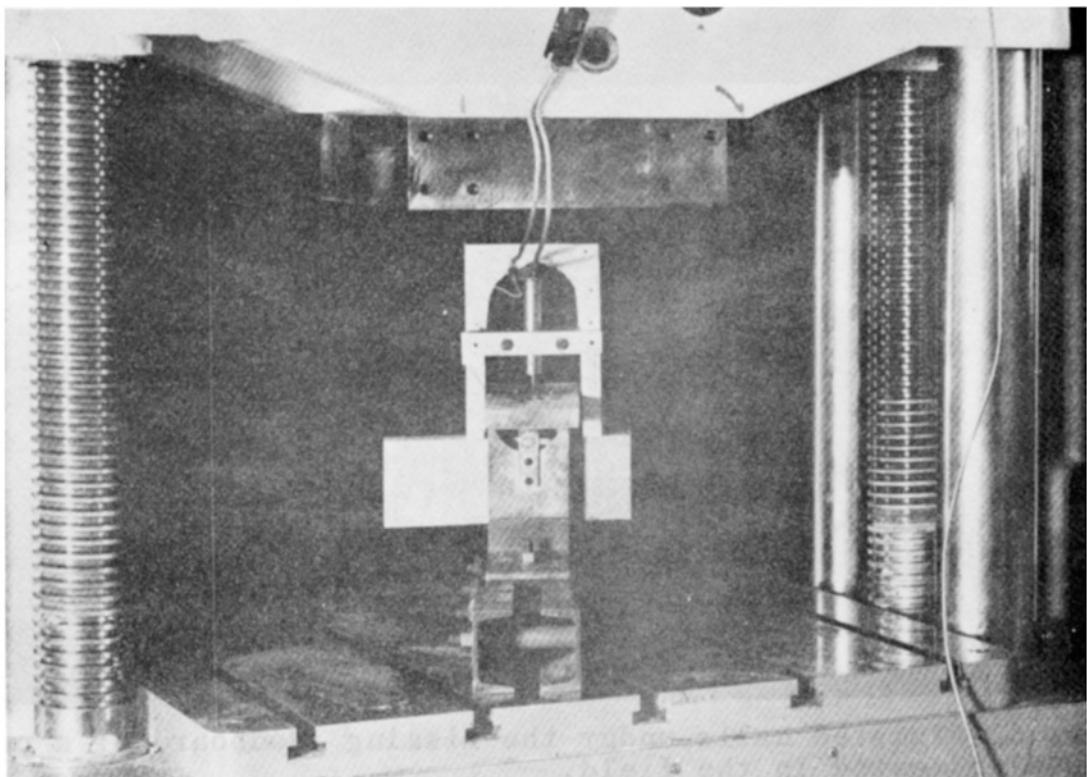


Figure 5. Joint separation. Evaluating a pallet joint's  
(2-1938) resistance to nail withdrawal.

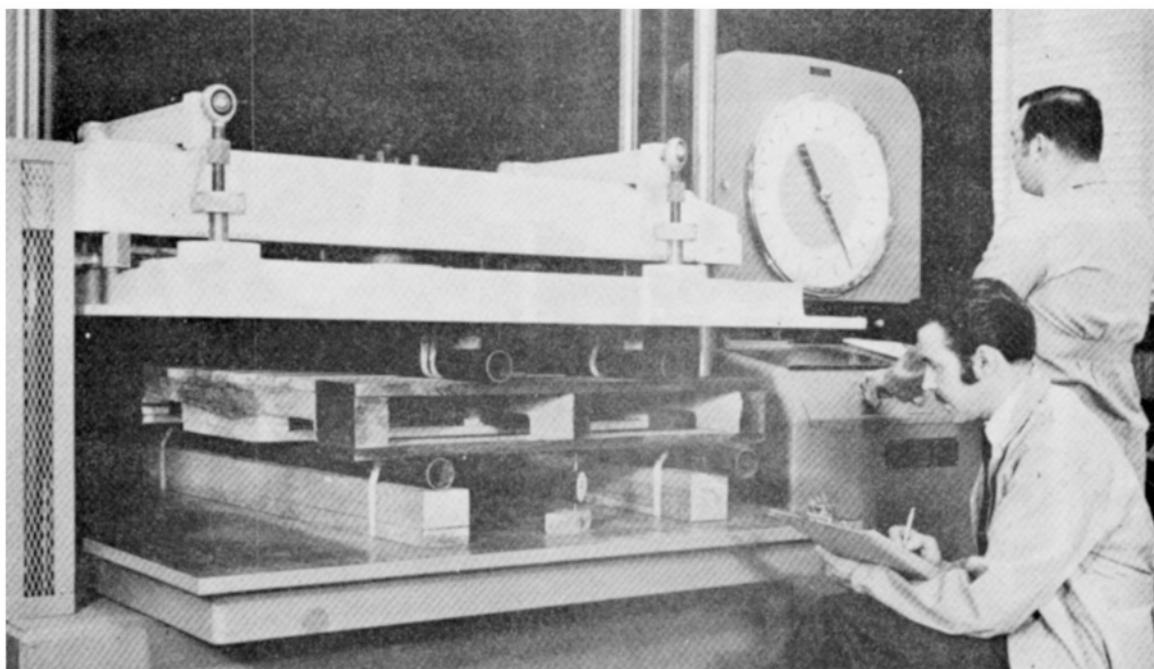


Figure 6. Determining a pallet's stiffness characteristics.  
(2-2119)

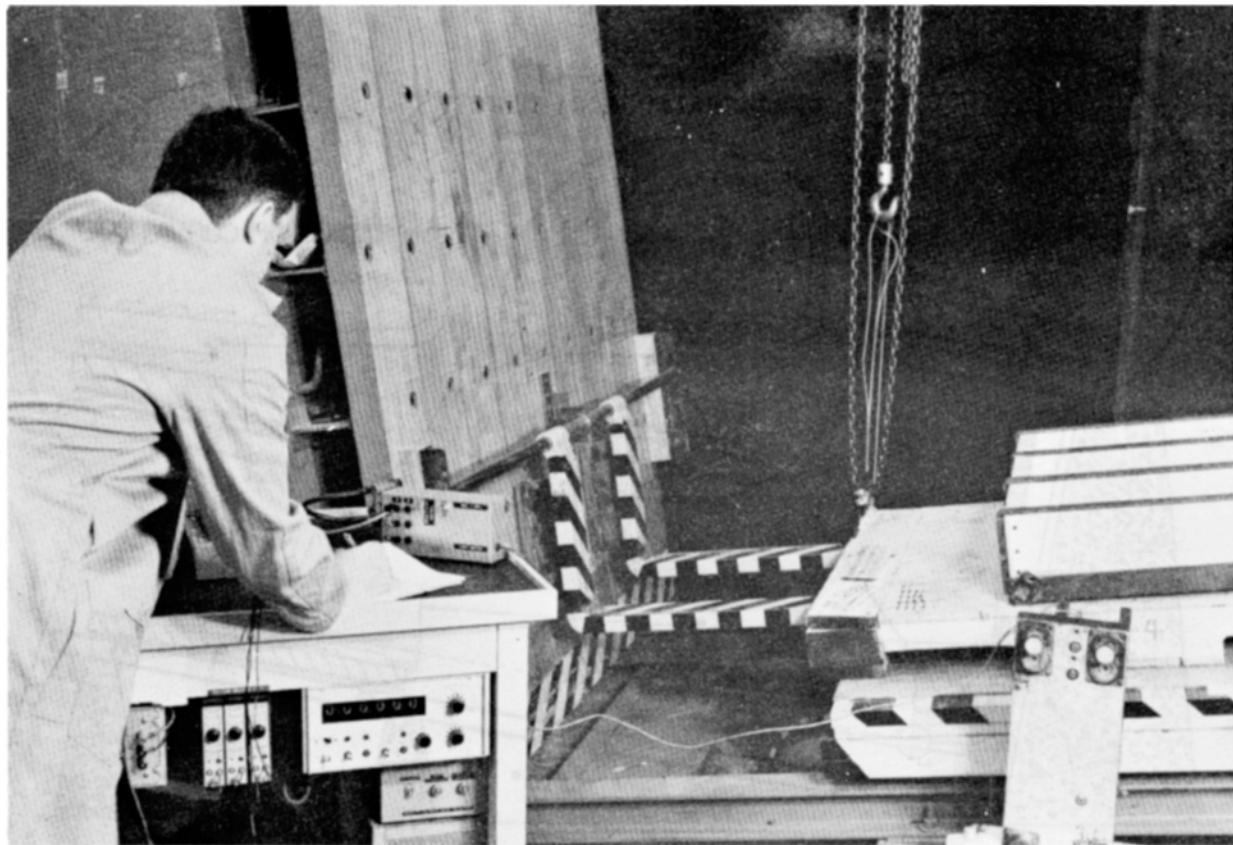


Figure 7. Inclined impact destructive evaluation test.  
(2-2120)

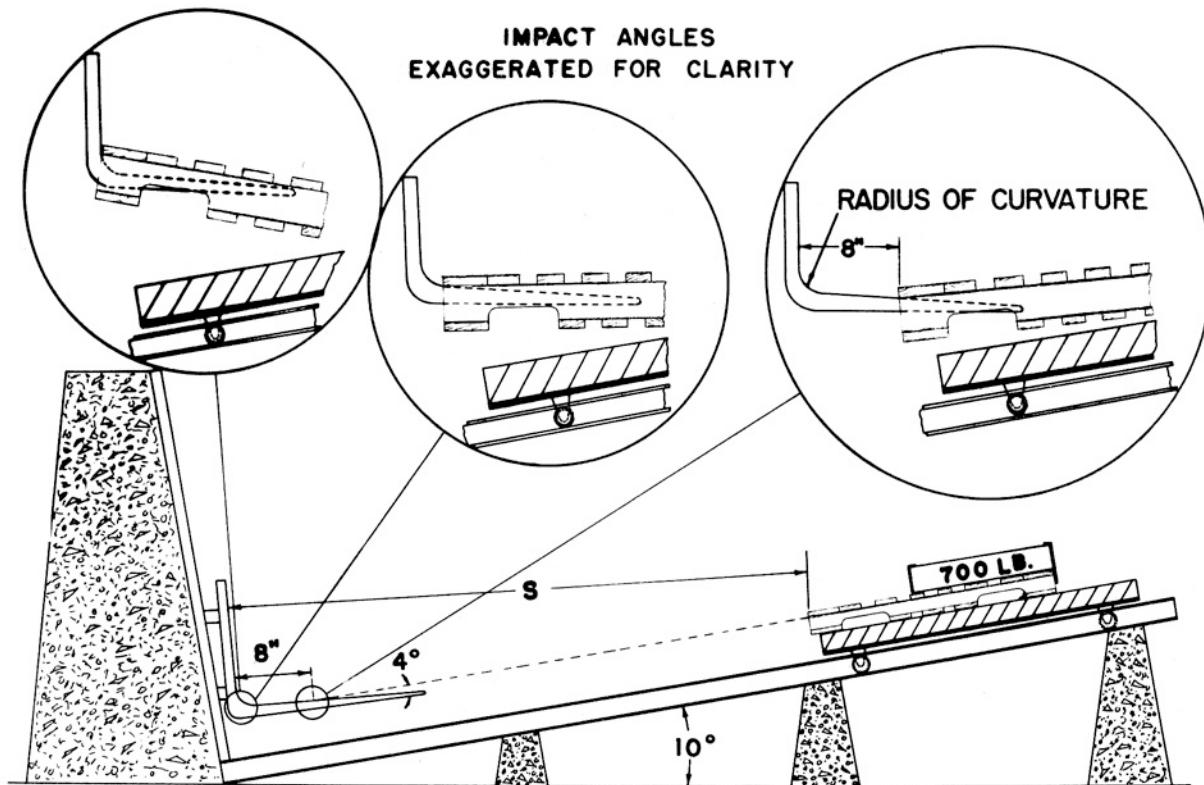


Figure 8. Schematic diagram of inclined impact test. Note how the pallet rides up the forks prior to impact, followed by a pronounced lifting of the leading edge as it strikes the radius of curvature at the base of the forks.

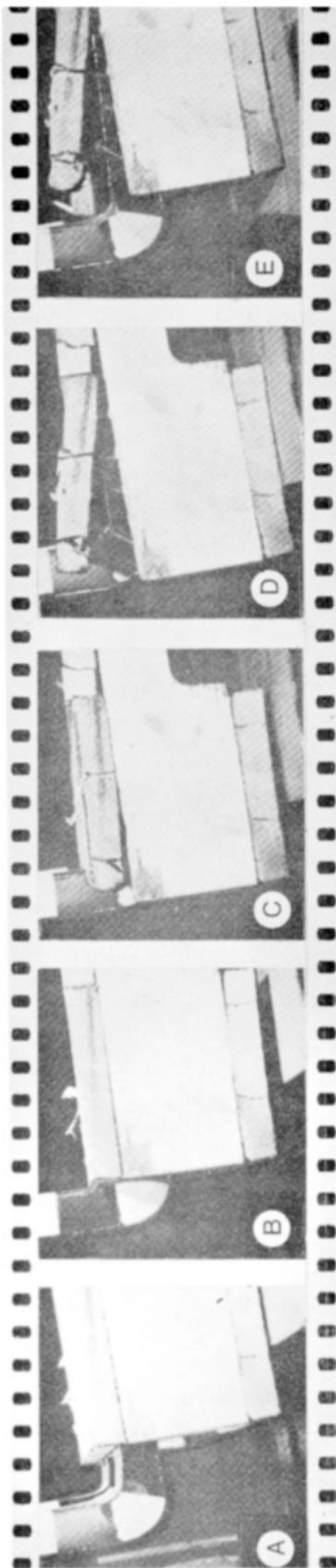


Figure 9. Damage sequence on the inclined impact tester. A: The test pallet is shown riding up the forks attached to the Conbur just prior to impact. B: During impact the pallet rides up the radius of curvature at the base of the forks lifting the pallet from the deck of the dolly. C: The severe shearing forces developed during impact splits and pushes the leadboard back from the leading edge. D: The leadboard is being pried from the stringers during impact. Note the twisting of the leadboard nails. E: Failure of the pallet after impact.

