EVALUATION OF A NEEDLE PENETROMETER FOR DETECTING WEAK HIDES BEFORE PROCESSING*

A. L. EVERETT, W. E. PALM, E. H. BITCOVER, H. J. SCHERR, M. V. HANNIGAN, AND J. NAGHSKI

Eastern Regional Research Laboratory†
Philadelphia, Pennsylvania 19118

ABSTRACT

A practical, nondestructive sorting test is needed which can be applied to raw or cured hides for detecting abnormal weakness associated with defective fiber structure. The vertical fiber defect has been found to be responsible for such weakness in Hereford hides. Measurement of the resistance to needle penetration should reflect a significant difference between the defective, upright fibers and the normal, interwoven structure, and thereby predict which hides will make weak leather.

A bench-scale penetrometer device was developed to test the applicability of this principle. Preliminary testing justified further trials on a larger scale. Test results on 445 salt-cured Hereford hides, expressed on a thickness basis, showed definite correlation with ball burst values on resultant crust leather, but the accuracy of prediction was not considered good enough for practical use. However, suggested modifications look promising for future development.

INTRODUCTION

The problem of weakness in properly processed side leathers made from certain types of cattlehides continues to plague the industry in many parts of the world, and in this country in particular. The extreme weakness that has been commonly called "pulpy butt" is ascribed to the presence of the inherent vertical fiber defect, wherein the corium fibers are abnormally arranged perpendicular to the surface in a loose, poorly interwoven pattern. This defect is apparently limited to Hereford hides. It was first reported from Australia by Amos (1) in 1958, and later investigated more thoroughly in this country by Tancous *et al.* (2–4),

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†Agricultural Research Service, U. S. Department of Agriculture.

:verett *et al.* (5, 6), and Maeser (7). Properties of defective hides and leathers ave been well characterized by these studies.

On the assumption that the defect is probably hereditary, for which there was ecent presumptive evidence (6), the prospects for eliminating the defect by elective breeding were felt to be remote. Consequently a practical approach to etection of the defect in hides before processing was sought in order to provide or better utilization of rawstock in appropriate types of leather and thus greatly educe the number of costly performance failures. To be acceptable, such a orting test should be relatively accurate, rapid, and nondestructive. While there re obvious advantages to classifying the rawstock, sorting at the wet blue stage also highly desirable. Since it was known that Maeser (8) was working in is area, our leather testing was largely confined to the dry crust and finished ages.

Needle penetrometer devices of various types have been widely used for measring the firmness of food products, and especially the tenderness of meat (9). . "tenderometer" of this type is commercially available for estimating the tenderess of carcass meat (10). The idea of using a needle penetration test to differntiate between abnormally vertical fibers and normally interwoven fibers in ides occurred to one of the authors (W.E.P.) as a consequence of previous ork on deerskin leather (11). In that case the test was used to estimate the lative frictional forces required to stitch leathers of different tannages. In this se it was reasoned that the two types of fiber orientation would exert different egrees of lateral force against the tapered point of the needle as it spread the bers apart. Significantly lower values would thus be expected from defective ructure. A somewhat similar approach had been used by Tancous (3, 4) for e same purpose. She applied a modified puncture tester developed by Vickers 12), using a one-eighth inch rod with spherical tip, but without much success.

Other nondestructive tests that we have briefly explored for this purpose, me with partial success, include: a dynamic, forced-vibration resonance method eviously reported from this laboratory (13); a sonic resonance technique veloped to measure dynamic elastic properties of fruit (14); an ultrasonic nalyzer used for early detection of pregnancy in sheep (15); and a compression st using a T-bar to penetrate 0.1 inch. Additional techniques that were tried clude: diffraction of a helium-neon laser beam; beta-ray backscatter used for sting the composition of egg shells (16); radiography by neutrons (17); ito-radiography by X-rays from an isotope source; and also radiography from tube source. None of these was as promising as the needle penetration test.

A preliminary penetrometer test performed on soaked hides showed only fair rrelation between hide measurements and ball burst values in the crust. Due the handling problems and the wide variations in moisture and firmness enuntered at this stage, subsequent testing results included in this report were nited to prefleshed, well-cured hides before processing, as a more practical approach. Although the objective of accurate prediction of leather strength was not quite achieved, it will be evident that the penetrometer still has much promise as a new sorting test. A subsequent report will describe its greater usefulness at present as a new method for testing leather strength directly.

EXPERIMENTAL

Test Hides

Bundled whole hides with typical Hereford-type hair color were selected from current shipments in the hide cellar of a co-operating tannery and were tested on the premises. All were prefleshed, well salted, and judged to be in good condition. In a preliminary one-day trial (Test #1), 99 heavy hides were used. For the main five-day test (Test #2), 389 light-mediums, ranging from 35 to 45 lbs., and 56 heavies, from 55 to 80 lbs., were tested. Hides of the two weight classes came from different sources.

Experimental Penetrometer

The test instrument was designed by one of the authors (H.J.S.) and constructed at this laboratory. Figure 1 shows a full view of the device with a piece

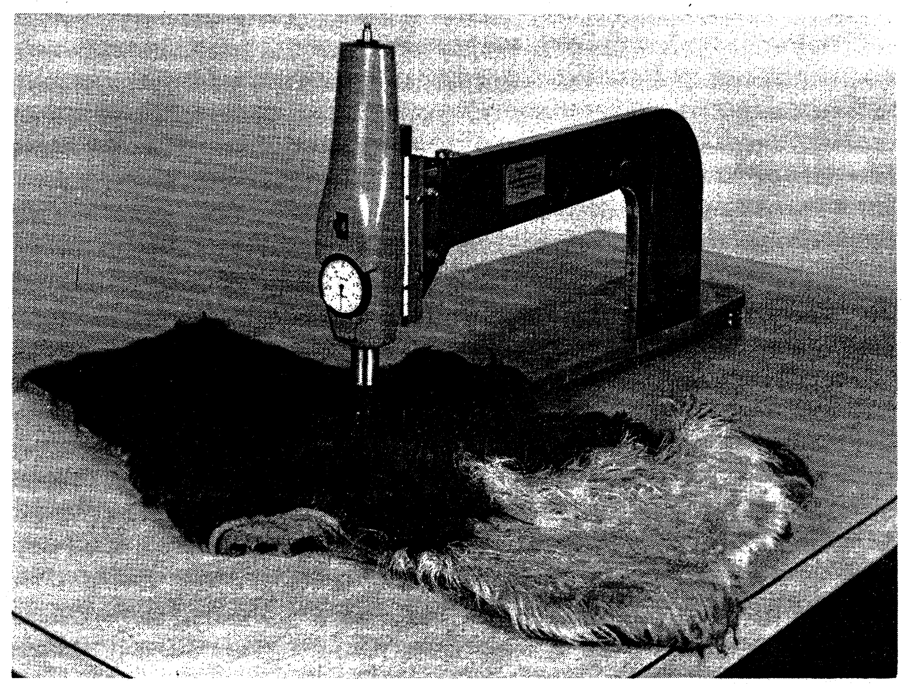
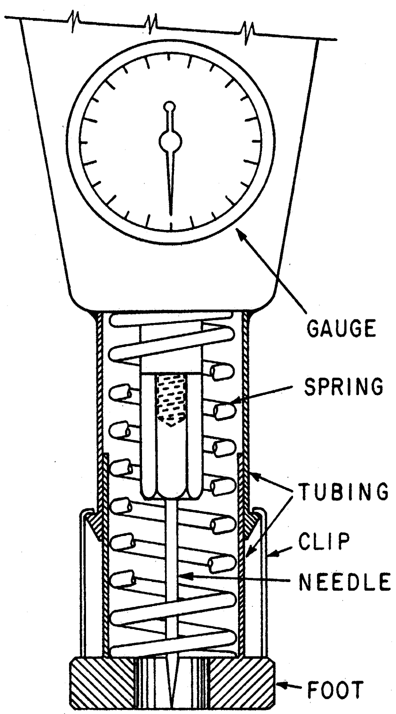


FIGURE 1.—Experimental penetrometer with piece of salted hide in position for testing. The force gauge in front records resistance to needle penetration; vernier and scale on the side measure hide thickness. Overall dimensions are about 21 x 5 x 8 in.



ɩE 2.—Sectional view of gauge and needle assembly. Spring tension clamps the presser foot against the hide as gauge is pushed downward. Telescoping tubes join the foot and gauge and also guard the needle and spring.

e in position for testing, while Figure 2 shows a sectional drawing of the assembly. The principal component is a mechanical force gauge (John lon & Sons‡) with a capacity of 50 lbs., an accuracy of ± 0.5 percent full and a main shaft travel of 0.1 in. Attached to the main shaft of the gauge test needle, made of cold rolled steel 1/16 in. in diameter and 1-1/16 in. with a gradually tapering point. A spring-loaded presser foot mechanism 2) is attached to the instrument case, and serves to exert a clamping action sample during penetration, as well as to provide a protective guard for edle.

force gauge assembly is joined to a C-shaped supporting frame by means iding mechanism; this consists of a grooved steel block fastened to the back gauge and two brass guide rails fastened to the C-frame. This arrange- insures that the needle will move in a straight line normal to the sample penetration. A latching device holds the force gauge assembly up and from the bottom leg of the C-frame, which is a necessary condition for the hide sample into the throat of the frame. The throat of the supporting

eference to brand or firm name does not constitute endorsement by the U. S. De- nent of Agriculture over others of a similar nature not mentioned.

frame is 14 in. deep, with a clearance of four in., to allow room for manipulating a hide at some distance from its edge. A metric scale and vernier are attached to the C-frame and gauge assembly, respectively, to measure hide thickness with a resolution of 0.5 mm.

To perform a penetration test with the hide in position, the latch is released and the gauge assembly is gently lowered, bringing the foot in contact with the hide as shown in Fig. 1. Hide thickness is then recorded in mm. from the metric scale. By exerting firm, gradual pressure on the top of the gauge assembly, the needle is then forced completely through the hide and into an open well in the base of the frame. At this point, the hand on the gauge registers and holds the maximum force exerted against the needle. Finally, the needle is pulled up out of the hide and the assembly is latched in the open throat position, ready for reuse after the gauge hand is returned to zero.

Testing Scheme

Five needle penetrations were performed on the right side of each test hide, according to the scheme shown in Fig. 3. Starting at a point ten in. forward

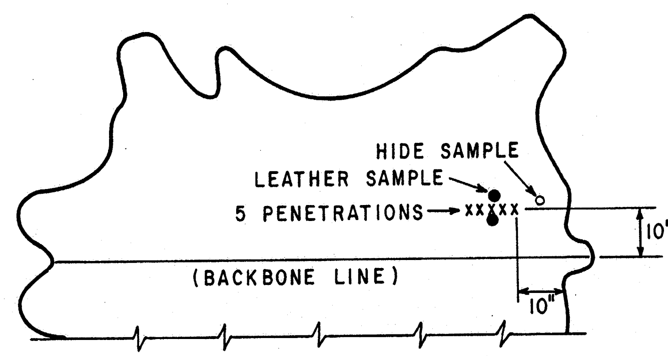


FIGURE 3.—Diagram of testing and sampling scheme used in penetrometer tests. Needle penetrations were performed, at intervals of about two in., at the points marked "X." Defective structure is typically found in this area.

from the tail root and ten in. from the backbone line, where defective structure is most likely to be found (7), successive tests were performed at intervals of about two in., as indicated by the row of X's in the diagram. Test results were expressed as lbs./in. by means of a locally prepared conversion table and the average was calculated. Sides selected for testing in leather were identified by stamped numerals near the tail, and were marked as experimental by cutting out a ¾ in. disk from the butt flap, at the point labeled "hide sample." These hide disks were saved for histological evaluation** of fiber structure and fat by means of frozen sections.

**Sections were conventionally stained with hematoxylin and eosin (18, p. 230) for fiber structure or with Oil Red O (19, p. 118) for fat.

The hides were processed into 4-5 oz. shoe upper leather. Experimental sides were set aside at the crust stage, and two sample disks, each two in. in diameter, were cut out at the points labeled "leather sample" in the diagram. In Test #2 only a representative portion of the experimental lot was tested in leather. The scheme was to retest all those that fell below a predetermined cutoff of 105 lbs./in. in the hide test, but to recover only every fifth one above this cutoff, since these are presumably normal. A total of 101 hides was selected in this manner.

Leather Strength

The standard ASTM ball burst test procedure (D 2207-64) was chosen as the reference method to determine leather strength for correlation with hide measurements. It is not only a reliable test but it is also nondirectional and therefore requires only one set of samples. The average was recorded for the two determinations made on each pair of sample disks. Cut edges of the disks were also examined under a stereoscopic microscope to evaluate fiber structure (6).

RESULTS

Penetrometer Cutoff

Careful examination of the test results indicated that the average of the first three hide penetrations was preferable, instead of using all five, for representing the weak area of each side. Also it was found that the penetration loads must be expressed on a thickness basis (lbs./in.) to show any correlation with the ball burst. A frequency distribution plot of test values was prepared to give a logical indication of the separation between normal and abnormal hides in the composite plot. This is shown in Fig. 4. Shaded portions in the bars represent the smaller Test #1 with 99 heavy hides. Unshaded portions represent Test #2 with 389 light-medium and 56 heavy hides. Numbers of hides on the vertical axis are plotted against increments of penetrometer values. The distinct break between the third and fourth bars from the left, shown by the arrow, indicates that the logical cutoff point between weak and strong is about 100 lbs./in. for both tests.

Ball Burst Cutoff

A similar plot of the ball burst values from the sides tested in crust leather is shown in Fig. 5. Owing to some losses, there were 96 sides from Test #1 and 90 from Test #2. In this graph the cutoff is somewhat less distinct but appears to be at 1600 lbs./in. The extremely defective leathers fell below 1200 lbs./in.

Penetrometer Predictability

Test #2 was designed to answer the crucial question of how well the hide penetrometer values would predict leather strength. These results are shown in histographic form in Table I. Each "X" represents a test side and they are listed

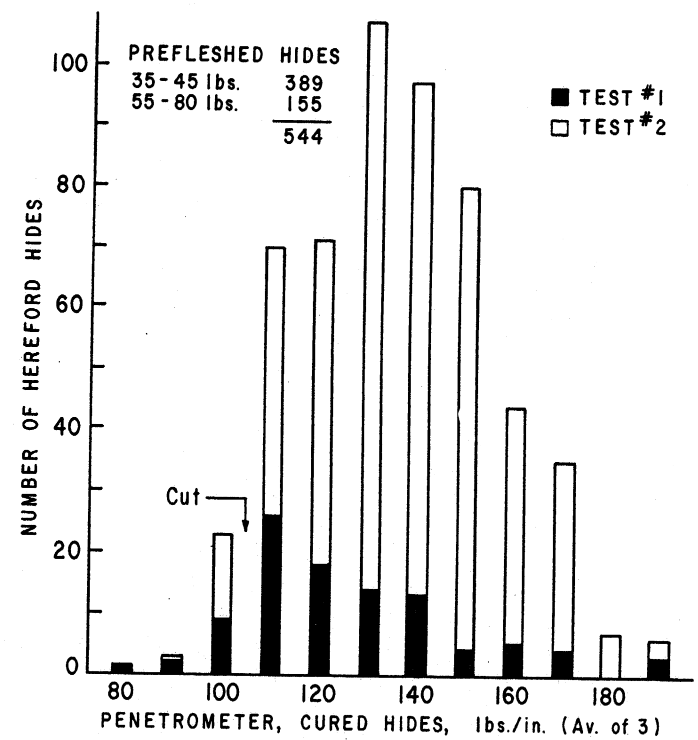


FIGURE 4.—Frequency distribution plot of penetrometer values for the cured hides tested. Abrupt change shown by arrow indicates a cutoff at 100 lbs./in. for selecting the weak hides.

by increments of penetrometer values *vs.* corresponding ball burst value. The penetrometer cutoff is shown by the horizontal broken line while the ball burst cutoff is shown by the vertical broken line. The upper left quadrant formed by these lines should therefore include all of the weak sides if the predictability were perfect. As can be seen, there were six weak sides to the left of the vertical line but only three of these were correctly predicted. Furthermore, the ten strong sides in the upper right quadrant were all incorrectly picked. Regression calculations gave a correlation coefficient (R) of only 0.31, which is conclusive evidence of insufficient accuracy as a sorting procedure.

Structural Effects

Examinations of cross sections from recovered hide and leather samples explained many of the discrepancies in this test. Basically the problem is that penetration measurements on full-thickness hides include the lower portion of corium, which is later split off before strength measurements are made on the leather. Whenever the upper and lower corium are extremely nonuniform, a discrepancy results. Variations in fiber structure and fat deposits were usually found to be

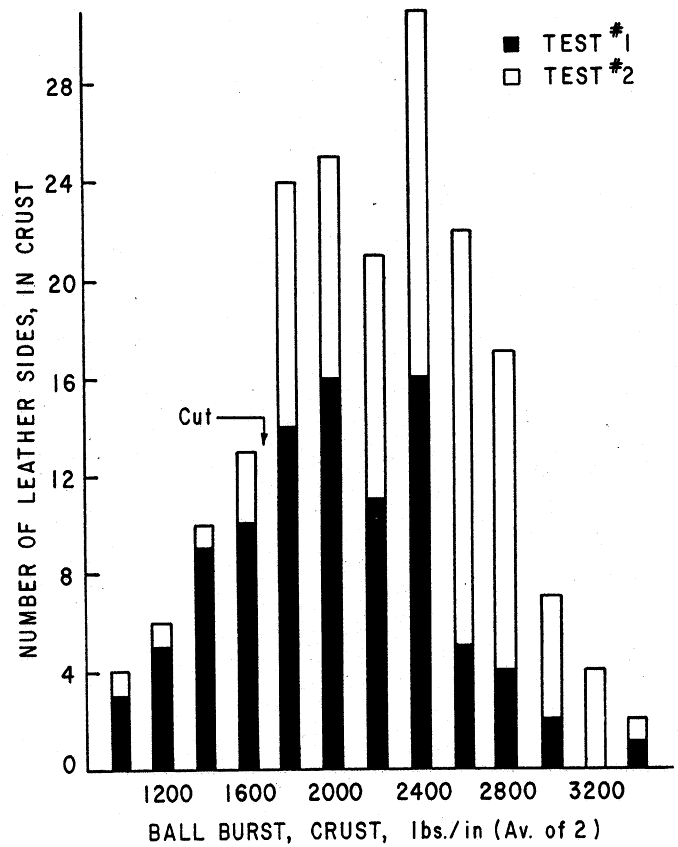


FIGURE 5.—Frequency distribution plot of ball burst values for the 186 test sides in the crust. Abrupt change shown by arrow indicates a cutoff at 1600 lbs./in. for selecting the weak sides.

responsible, as amply illustrated by the micrographs published by Tancous (4), who first recognized this problem. In our case the influence of fat was especially troublesome in reducing the resistance to needle penetration. Many of the strong sides in the upper right quadrant of Table I fell in this category.

In a previous paper (6) it was pointed out that two degrees of fiber abnormality are responsible for two corresponding degrees of weakness in leather. The vertical fiber defect is found in very weak or "pulpy" leathers while an intermediate type of structure is usually present in "weak" leathers. Strong leathers almost invariably show normal structure. The data shown in Table II indicate the correlations between structural features and strength test values for the 90 test sides. It is evident that the fiber structure was closely related to ball burst strength in leather, but for the reasons mentioned above, the penetrometer was less sensitive in detecting it. With respect to the corium fat, which was mostly

TABLE I

PENETROMETER ON CURED HIDE *VS.* CRUST LEATHER STRENGTH

Penetrometer† (lbs./in.)	Ball Burst Strength (lbs./in.)*					
	1200	1600	2000	2400	2800	3200
81–90				X		
100	XX	X	XXX	XXX	XXX	
110		X	XXX	X	XXXX	
120			XX	XX	XXX	
130			XX	XXXX XXXX	XXX	XXXX
140			XXXX	XXXX	XXXX XX	XXX
150		X	XXX	XXX	XXXX X	X
160		X	X	XX	X	X
170			X	X	XXXX X	X

Correlation Coefficient (R) 0.31

*Average of two measurements on two butt specimens.

†Average of three measurements in butt area. Horizontal broken line is the penetrometer cutoff; vertical broken line is the ball burst cutoff (see Figs. 4 and 5). Each "X" represents a test side from Test #2.

TABLE II

INFLUENCE OF HIDE STRUCTURE ON TEST VALUES (TEST #2)

Fiber Structure		Ball Burst Value (lbs./in.)		Penetrometer Value (lbs./in.)	
Type	No.	Average	Range	Average	Range
Vertical	6	1289	940–1625	112	91–150
Intermed.	15	1791	1580–2205	123	94–159
Normal	69	2472	1825–3260	132	83–176
Corium Fat					
Score*	No.				
5	6	2368	2085–2615	113	100–140
4	35	2342	940–3145	128	92–164
3	36	2234	1075–3260	131	83–176
2	12	2245	1580–2830	138	96–168
1	1	2265	—	124	—

*Arbitrary subjective estimate ranging from 0 (none) to 5 (maximum).

split off, this had no effect on leather strength but did show a depressing effect on hide penetrometer values, which confused the results.

Testing in the Blue

It was mentioned in the introduction that a preliminary penetration test had been performed on soaked hides, showing only fair correlation with ball burst on the crust leather. In this trial the penetration test was repeated at the blue-split stage to show whether the correlation would be improved. Unfortunately it was not, since the sorting results were almost identical with the hide test. Later it was realized that this was an unusually poor lot, with over half of the 90 sides testing below 1600 lbs./in. ball burst. The correlations of penetrometer in the raw stock and in the blue *vs.* ball burst in the crust gave almost flat lines, which are very unsuitable for selective sorting. Apparently the test was being influenced by other factors in addition to the fiber structure. Maeser's distortion, penetration, and compression tests in the blue (8) were correlated with a "lasting factor" calculated from semi-ball-burst tests in the finish, and are not quite comparable to our approach. He claimed good correlation with the first two tests: distortion and penetration.

DISCUSSION

Reasons for failure of the hide penetrometer test as an accurate predictor of leather strength are believed to involve the undesirable inclusion of the lower corium in the test. To obviate this interference it is planned to modify the penetrometer for a partial penetration, stopping the needle before it breaks through the lowermost layer. Maeser (8) utilized this approach in his Instron penetration procedure on unsplit blue stock with apparent success. It seems likely that the penetration can be set for a constant depth and thus do away with the need for a thickness measurement and calculation step. The thickness measurement constitutes a major disadvantage of the present procedure. It is not only time-consuming but is also inaccurate because of variability in firmness of the hide and thickness of hair coat and surface debris. Several new needles with accurately formed, reproducible, angular tapers are first being tested to indicate how this affects the sensitivity of the test.

When applied to rawstock the needle penetrations are actually nondestructive in the sense that they cannot be detected in the leather. When applied to wet blue or crust leather, of course, many of the tiny holes will persist, depending on the type of leather made. However, since the needle does not sever the fibers, no particular harm is done by the test.

Choice of a cutoff point for the penetrometer test should be based on some logical evidence of a separation between normal and abnormal hides, such as a break in the distribution curve as used here. In practice, this point can be adjusted to provide a better selection of sides with strength properties within a desired range, to fit the needs of a given line of leather.

CONCLUSIONS

1. The nondestructive experimental penetrometer, when applied on a pilot scale to cured hides to detect abnormal fiber structure, failed to predict resultant leather strength with sufficient accuracy for practical use, but results were promising for future development.

2. Even in its present form the instrument appears to be the best device available for the intended purpose. No better system has been reported.

3. When the instrument was applied directly to leather in conjunction with standard tests, the good correlations found recommend the procedure as a proposed new test for leather strength. This study is the subject of a subsequent report.

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