DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 160

EFFECTS OF OILS, GREASES, AND DEGREE OF
TANNAGE ON THE PHYSICAL PROPERTIES
OF RUSSET HARNESS LEATHER

BY

R. C. BOWKER, Assistant Mechanical Engineer

Bureau of Standards

in cooperation with

J. B. CHURCHILL, Director

American Leather Research Laboratory

April 17, 1920

PRICE, 5 CENTS

Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE

1920

EFFECTS OF OILS, GREASES, AND DEGREE OF TANNAGE ON THE PHYSICAL PROPERTIES OF RUSSET HARNESS LEATHER

By R. C. Bowker and J. B. Churchill

CONTENTS

	Page
I. Introduction.....	3
II. Methods.....	4
1. Selection of the leather.....	4
(a) Description of the leather selected.....	4
(b) Preparation of samples.....	6
2. Physical tests.....	7
(a) Tensile strength.....	7
(b) Stretch.....	7
(c) Buckle strength.....	8
3. Chemical tests.....	8
(a) Stuffing content.....	8
(b) Complete analysis.....	8
III. Data and results obtained.....	9
1. Physical tests.....	9
(a) Tensile strength.....	9
(b) Stretch.....	12
(c) Buckle strength.....	13
2. Chemical tests.....	14
(a) Stuffing content.....	14
(b) Complete analysis.....	15
3. Comparison of physical and chemical tests.....	16
(a) Effect of the amount of stuffing content on the physical properties.....	16
(b) Effect of the degree of tannage on the physical properties..	17
(c) Effect of animal and mineral oils on the physical properties.	18
IV. Conclusions.....	18

I. INTRODUCTION

During the war physical and chemical tests of the equipment leather purchased by the War Department were made at the Bureau for the purpose of controlling the quality of the leather furnished by the various tanneries. An opportunity was thus offered for a study of the variations in the physical properties and in the chemical constituents of many kinds of leather. On account of the large quantities used the values of the various

properties for both russet and black harness leathers were of special interest. Russet harness leather is not a regular commercial product in this country and finds little use except for military purposes. Black harness leather, however, is a regular commercial product and is widely used. Besides the difference in color, there are three distinct differences between these two leathers caused by the process of manufacture. The first of these differences occurs in the length of the tanning operation. It is general practice to give hides for black harness leather a short-time tannage, while those for russet harness leather are tanned for a longer time. The average degree of tannage as determined from the chemical analyses of black and russet harness leathers made during the war were 46 and 61, respectively. The second point of difference between these two kinds of leather is shown by the amount of stuffing used. The average amounts found in the above-mentioned black and russet leathers were 29.3 and 15.5, respectively. The third difference is caused by the general practice of adding to black harness leather small amounts of such filling materials as glucose and salts. This procedure is not generally followed in the case of russet harness leather. A better selection of hides is generally used for the latter leather, since the coloring of black harness readily conceals many surface imperfections which do not affect the quality. In order to study more definitely the effects of the amount and kind of stuffing content and also the degree of tannage on the physical properties of harness leather, this investigation was made.

II. METHODS

1. SELECTION OF THE LEATHER

Russet harness leather was used in this investigation. Three hides were prepared, marked butt Nos. 1, 2, and 3, to study the effects of different amounts of stuffing content, of animal and mineral oils, and of medium and heavy tannage, respectively, on the physical properties.

The method of using whole hides or double backs in preparing this leather was used, so that, when split, each single back could be given its special finishing treatment and when tests were made the leather of the two sides compared would come from the same hide. Each side was given a code letter.

(a) DESCRIPTION OF THE LEATHER SELECTED.—The hides from which the leather was produced were treated in the usual manner,

which consisted of soaking, fleshing, liming, unhairing, handling, and then laying away in the yard. The tanning materials used were liquors made from chestnut-oak bark, chestnut wood, and quebracho. After the tanning was completed the hides were split, shaved, scoured, and bleached with a solution of soda and water, sulphuric acid and water, and sumac and water. The leather was then stuffed and later oiled. The finishing was done by hand.

Butt No. 1.—This hide received the regular tannage for this type of leather and, after being split, one side (B) was stuffed with a mixture of cod oil and tallow, using the amount ordinarily used in the particular tannery where the leather was made. The other

FIG. 1.—Division of a side into blocks

side (A) was stuffed with a larger amount of the mixture, equal approximately to that used by some tanners of black harness leather. These two sides were used to study the effects of different amounts of stuffing content on the physical properties.

Butt No. 2.—The leather produced by this hide was used to study the effects of a medium and heavy tannage on the physical properties. The hide, after receiving the regular tanning treatment, was split and one side (C) removed, while the other side (D) was allowed to remain in the vats a month longer in order to receive a heavier tannage.

Butt No. 3.—This hide, after being tanned as regular russet harness leather, was split and one side (E) was stuffed with a mixture of 50 per cent cod oil and 50 per cent tallow. The other side (F) was stuffed with a mixture of 50 per cent Breton mineral oil and 50 per cent tallow. This leather was prepared to determine, if possible, the effects of the use of mineral and animal oils on the physical properties of leather.

(b) PREPARATION OF SAMPLES.—Each side of leather was divided into 40 blocks, as shown in Fig. 1, beginning at the butt end, near the root of the tail, with block No. 1 and running across the hide from back to belly. The blocks running from the butt end to the shoulder end were numbered in steps of four. The size of each block was approximately 8 inches in length and 7 inches in width. Each was divided into samples for the various tests, as

FIG. 2.—Division of a block into samples for the different tests

shown in Fig. 2. Three samples from each block, designated by T_1 , T_2 , and T_3 , were prepared for the tensile strength and elongation tests, and three samples, designated by B_1 , B_2 , and B_3 , were used for the buckle tests. That part of each block used for the chemical tests is designated by the letter C . Each sample cut from any block carried the code letter of the bend, the number of the block, and the letter representing the test for which the sample was to be used.

2. PHYSICAL TESTS

The physical tests generally made on samples of harness leather for determining the quality are for tensile strength and percentage elongation. In addition, a buckle or shearing test was made.

(a) TENSILE STRENGTH.—This is the test most commonly made, the results being expressed in pounds per square inch. Test pieces were cut with a metal die from each individual strip. The shape and size of the resulting sample are shown in Fig. 3. The ends are enlarged and the central portion is reduced to a width of one-half inch over a gage length of 2 inches. This shape usually insures that the sample will break within the reduced section and prevents tearing in the grips of the testing machine. The breaking strength, in pounds, of each sample was determined with a tension machine the jaws of which separated at a rate of approx-

FIG. 3.—Shape and size of tensile strength specimens

imately 6 inches per minute. With this value and the area, as determined by the width and thickness of the reduced section, the tensile strength in pounds per square inch was calculated.

The breaking strength, in pounds per inch of width, was also determined. There were three values for each of these properties for each block and an average of the three for each property was used as representing the value for the particular location on the side indicated by the block number.

(b) STRETCH.—The stretch, or percentage elongation, of each tension test piece was determined at the breaking strength. The method consisted of first marking on the reduced section parallel lines 2 inches apart. A convenient method of noting the stretch, used in this test, consisted of following the parallel lines on the test pieces, as they separated under the tension, with a pair of dividers. The elongation was then measured with a scale and the percentage increase calculated. In this case also the average of three values represented the value for the block.

(c) BUCKLE STRENGTH.—There are many parts of a harness which are used in conjunction with a buckle. It is common knowledge that the failure of a particular strap or part of a harness often occurs at one of the holes through which the tongue of the buckle passes. It was thought desirable to study the variation on the hide in the buckle or shearing strength of new harness leather with the idea in view of showing what portions of the hide might be most suitable for those straps which are used with a buckle. Three samples for this test were prepared from each block, as shown in Fig. 4. A hole of the proper size for the buckle tongue was punched 1 inch from the end of the test piece. An ordinary $1\frac{1}{4}$ -inch harness buckle with a tongue approximately eighteen-hundredths of an inch in diameter was secured to a strap which was placed in one jaw of the testing

FIG. 4.—Shape and size of buckle strength specimens

machine. The punched end of the test piece was then inserted in the buckle and the free end secured in the other jaw of the machine. The number of pounds required to pull the test piece through the buckle was then noted.

3. CHEMICAL TESTS

(a) STUFFING CONTENT.—It was considered possible that the variation in the amount of stuffing content over the hide might have some effect on the physical properties. For this reason, and also to study the distribution of the stuffing content over the hide, a chemical determination was made of this property for each block of each side.

(b) COMPLETE ANALYSIS.—In order to aid in the interpretation of the physical results, and also to have all the data possible for the identification of the several sides, a complete chemical analysis was made of each, using a composite sample prepared by taking an equal quantity from each block.

III. DATA AND RESULTS OBTAINED

1. PHYSICAL TESTS

(a) TENSILE STRENGTH.—The results of the tensile-strength tests, expressed in pounds per square inch, are shown graphically in Figs. 5, 6, and 7. Each individual curve of the graphs represents

FIG. 5.—Variation of tensile strength in pounds per square inch over the side for samples A and B

the values obtained from four blocks running from the backbone edge to the belly edge. The values for the tensile strength, in pounds per inch of width, are shown graphically in Figs. 8, 9, and 10. For that portion of any side represented by blocks 1 to 28, inclusive, the strength is generally greater on the backbone edge, decreasing in value toward a point near the belly edge, beyond

FIG. 6.—Variation of tensile strength in pounds per square inch over the side for samples C and D

which it generally increases to either an equal or greater value than occurred on the backbone. That portion of the sides represented by blocks 29 to 40, inclusive, is the shoulder area. The strength in that part is more irregular than in the other portion, but has a general tendency to be greater at the backbone edge

and to decrease steadily to the belly edge. A glance at Figs 8, 9, and 10 will show that the average tensile strength, in pounds per inch of width, for any given section of four blocks across a side is generally low at the butt end, increasing in value up to locations 17 to 20, or about half the length of the side, then decreasing in value, ending with the first shoulder section 29 to 32,

FIG. 7.—Variation of tensile strength in pounds per square inch over the side for samples E and F

where it is lowest, and then slightly increasing in value again for the remaining two sections. This same variation applies to the values for tensile strength, in pounds per square inch, but is not so marked, due to the fact that the thickness is variable, which greatly affects these values. As an illustration, considering Fig. 5, it appears that there is a large difference between sides A and B in tensile strength in pounds per square inch. Fig. 8 shows

FIG. 8.—Variation of tensile strength in pounds per inch of width over the side for samples A and B

the values of the tensile strength, in pounds per inch of width, for these two sides, and it will be noted that there is not such a marked difference between the values as in the case of Fig. 5. The difference shown in Fig. 5 is due to the fact that the average thickness over the side was greater for one than for the other.

Thus, it is conceivable that the products of two different tanners might have equal strength per inch of width, but due to the different methods used the thickness of one tanner's leather might be considerably less or greater than that of the other tanner, and the results would be that, although the amount of fiber substance was the same, the tensile strength as expressed in pounds per

FIG. 9.—Variation of tensile strength in pounds per inch of width over the side for samples C and D

square inch would be quite different for the two leathers. The functions of the various parts of a harness are to withstand a definite strain or pull in tension which depends more upon the strength of the leather per inch of width than upon the strength per square inch of cross section. One tanner might furnish a thick leather of the required strength and another a thinner leather of the same strength. Both would have the same work

FIG. 10.—Variation of tensile strength in pounds per inch of width over the side for samples E and F

to do. In view of these facts, it would seem desirable for specifications to require a strength in pounds per inch of width rather than in pounds per square inch.

The graphs show that there is a great variation in the strength in pounds per square inch over the hide, and for this reason it is difficult to set a standard value. The generally accepted requirement has been 4000 pounds per square inch and these tests justify

the choice, although in the two butt-end sections of all the sides the value is somewhat less. The results also show that the strength of the more open texture, looser, long-fibered belly and shoulder portions is equal to or greater than the strength of any other

FIG. 11.—Variation in per cent stretch over the side for samples A and B

portions of the side. The quality of the leather from these portions, however, is inferior to the more closely fibered and firmer area extending approximately 15 inches on either side of the back-

FIG. 12.—Variation in per cent stretch over the side for samples C and D

bone. Thus it will be seen that high tensile strength alone does not insure the best quality of leather.

(b) STRETCH.—The results of the stretch tests are shown graphically in Figs. 11, 12, and 13. The value of this property was

FIG. 13.—Variation in per cent stretch over the side for samples E and F

lowest along the backbone edge of the sides and increased toward the belly edge, although in some cases it dropped slightly in value on the extreme belly edge. An interesting fact regarding the stretch shows that in many cases it increases when the strength is

low and decreases when it is high. This does not occur in proportion to the difference in strength, but is clearly shown by the fact that the strength curves for any section of a side generally appear to be concave, while the stretch curves are more convex.

FIG. 14.—Variation in buckle strength over the side for samples A and B

(c) BUCKLE STRENGTH.—The results of the buckle strength tests are shown graphically in Figs. 14, 15, and 16. It will be seen that the value for this property is generally low on the backbone edge, increasing slightly in value toward a point near the

FIG. 15.—Variation in buckle strength over the side for samples C and D,

belly edge, after which it decreases to a minimum at the belly edge for any section of four blocks running across the bend. The average value for the buckle strength for any section is greatest in the butt end and decreases steadily to the shoulder end.

FIG. 16.—Variation in buckle strength over the side for samples E and F

An effort was made to establish a percentage relation between the buckle strength and tensile strength per inch of width. This relation was subject to a variation of from 10 to 50 per cent in one side, so that no satisfactory figure could be accepted as standard. The results, however, show that the belly and shoulder pro-

tions are inferior to the remaining portion of the side for use in straps which are to be used with a buckle. The best portion of a hide for this purpose, as shown by these tests, would be that included in an area about 15 inches either side of the backbone and 30 inches in length from the root of the tail. This test would not be of much value when examining samples of sides for general use as harness leather, but would be valuable in testing a lot of straps cut for use with a buckle. Table 1 gives the average values resulting from the tests.

FIG. 17.—Variation of stuffing content over the side for samples A and B

TABLE 1.—Average Values for Thickness, Tensile Strength, Percentage Stretch and Buckle Strength for each Side

Butt	Side	Thickness, inches	Tensile strength		Per-centage stretch	Buckle strength, pounds
			Pounds per inch of width	Pounds per square inch		
1.....	A	0.196	740	3835	30.8	201
1.....	B	.178	806	4600	29.0	195
2.....	C	.180	865	4920	31.6	170
2.....	D	.198	810	4130	31.1	205
3.....	E	.175	815	4705	28.3	163
3.....	F	.172	795	4605	28.2	180

2. CHEMICAL TESTS

(a) STUFFING CONTENT.—The values for the amount of stuffing content found in each block are shown graphically in Figs. 17, 18, and 19. The average amount for any section is least at the

butt end and then gradually increases to the shoulder, where the stuffing content is greatest. The general tendency is for the stuffing content to be greatest in the more open belly and shoulder portions. In the case of all except bend A the average stuffing

FIG. 18.—Variation of stuffing content over the side for samples C and D

content runs from 10 to 15 per cent and is shown to be fairly evenly distributed over the side, except in the shoulder. When a larger amount of stuffing was used, as in the case of bend A, the distribution over the hide was less uniform, and the greater

FIG. 19.—Variation of stuffing content over the side for samples E and F

part of the stuffing was absorbed by the belly and shoulder portions of the hide.

(b) COMPLETE ANALYSIS.—A complete chemical analysis was made of each side, and the results are given in Table 2.

TABLE 2.—Results of Complete Chemical Analyses for all Sides

[Calculated to 10 per cent moisture]

	Butt No. 1		Butt No. 2		Butt No. 3	
	Side A	Side B	Side C	Side D	Side E	Side F
Moisture.....	10.00	10.00	10.00	10.00	10.00	10.00
Total ash.....	.32	.27	.43	.35	.31	.31
MgSO ₄ /H ₂ O.....	.23	.23	.21	.22	.23	.22
Grease.....	23.35	10.70	13.30	11.46	13.72	15.70
Hide substance.....	32.74	39.92	40.24	39.81	37.32	35.10
Water soluble.....	10.05	10.20	9.88	10.66	10.92	9.77
Nontans.....	2.06	2.07	2.58	2.16	2.27	2.20
Tans.....	7.99	8.13	7.30	8.50	8.65	7.57
Glucose.....	(a)	(a)	(a)	(a)	(a)	(a)
Insoluble ash.....	.12	.14	.14	.14	.14	.22
Combined tannin.....	23.74	29.03	26.44	27.93	27.90	28.20
Degree of tannage ^b	72.51	72.73	65.71	70.16	74.93	78.12
Acidity.....	.50	.52	.35	.32	.55	.37

^a None. ^b Degree of tannage is in each case calculated from the figures given in corresponding table.

3. COMPARISON OF PHYSICAL AND CHEMICAL TESTS

(a) EFFECT OF THE AMOUNT OF STUFFING CONTENT ON THE PHYSICAL PROPERTIES.—The two sides A and B from the same hide were prepared to show the effect of different amounts of stuffing content on the physical properties. Side A contained 23.35 per cent of grease, while side B contained 10.70 per cent. It is apparent from Fig. 5 that side A, which contains the higher percentage of grease, is uniformly lower in tensile strength expressed in pounds per square inch than is side B. The average difference in strength is nearly 20 per cent and since the two sides are as nearly equal in quality in every respect, except grease content, as is possible to obtain it might be assumed that the difference in strength is caused by the different grease contents. The higher stuffing content in side A, however, caused another effect that must be considered, which was to increase materially the thickness of the side so that its average thickness throughout was 10 per cent greater than that of side B. Hence the cross-sectional areas of the various test pieces were greater for side A than for side B. This fact, assuming that the same breaking load would be obtained for test pieces from the same relative location on each side, would cause one test piece from side A to have a lower strength per unit of cross section. Thus, it would appear that about one-half, or 10 per cent, of the difference in strength indicated in Fig. 5 is due to the difference in thickness of the two sides which was caused by the different stuffing contents. The remaining 10 per cent

difference in strength may be attributed directly to the grease content.

In the case of the tensile strength in pounds per inch of width (Fig. 8) side *B* has an average value 9 per cent greater than that of side *A*. Since the tensile strength per square inch for side *B* was 20 per cent greater than that for side *A*, half of which was apparently caused by the difference in thickness of the two sides, the remaining 10 per cent can be attributed to the difference of the two sides in the strength per inch of width. The strength in pounds per inch of width is a more nearly true indication of the comparative strength of different leathers, since it does not take into account the thickness, which might vary for leathers on account of any difference in the methods of tanning and finishing by different manufacturers, and expresses the result for the same amount of original hide substance regardless of the treatment of the hide.

The effect of the grease content on the stretch was not appreciable, and the difference between the average values for the two sides was only about 3 per cent.

There did not appear to be any appreciable effect, because of the grease content, on the buckle strength. The difference between the average values for the two sides was about 3 per cent.

It can not be definitely stated from the results of these tests whether the variation in the grease content over the hide has any effect on the strength. It is more likely that any effect produced by the variation is secondary to the effect on the strength caused by the location on the hide from which a sample is taken.

(b) EFFECT OF THE DEGREE OF TANNAGE ON THE PHYSICAL PROPERTIES.—Sides *C* and *D* were prepared for this test. Side *D* was tanned the longer time, but the analysis of both show that side *C* had reached that stage in the tanning process beyond which the increase in the degree of tannage is slow. This is shown by the fact that the difference in the degree of tannage figures for the two sides was approximately 5.

The tensile strength in pounds per square inch (Fig. 6) for side *C* was uniformly greater throughout than for side *D*. This result is what would be expected, since side *C*, having the lighter tannage, was relatively nearer to the raw-hide condition in which condition the strength would be greatest. The average strength, in pounds per square inch, for side *C* was approximately 20 per cent greater than for side *D*, but, as was the case with sides *A* and *B*, side *D* was also 10 per cent thicker than side *C*, thus causing its average

tensile strength in pounds per square inch to be considerably less for the same amount of original hide. The average strength per inch of width for side *C* was 7 per cent greater than for side *D*. Although the degree of tannage values for these two sides was not very different, it would appear that the lower strength of side *D* is due to the longer time in the tanning process.

The stretch of the leather did not appear to be materially affected by the different lengths of tannage, the average value for the stretch being nearly the same in both cases.

The average buckle strength for side *D* (Fig. 15) was approximately 20 per cent greater than the value for side *C*. Thus, it would appear that a long-time tannage would produce a more solid and firmer leather, which would resist a shearing action to a greater degree than a leather tanned for a shorter period of time.

(c) EFFECT OF ANIMAL AND MINERAL OILS ON THE PHYSICAL PROPERTIES.—Sides *E* and *F* were prepared for this test. The average tensile-strength and stretch values were nearly the same for both sides, but the average buckle strength of side *F* was approximately 10 per cent greater than the average value for side *E*. This may be on account of the fact that, although both sides were tanned for the same length of time, side *F* had a higher value for the degree of tannage. The results indicate that there is no essential effect upon the physical properties of new leather caused by the use of mineral instead of animal oils in the stuffing content.

IV. CONCLUSIONS

Although this investigation was somewhat limited in its scope, the following general conclusions have been drawn, based upon the results obtained with the material used in these experiments:

1. That the amount of stuffing content affects the tensile strength of the leather and that there is a point beyond which the amount of stuffing content used does not add to the strength and may actually serve to decrease it.

2. That the tensile strength is greater for leather tanned a short time than for leather given a long-time tannage, and that the degree of tannage also affects the firmness of the leather, the longer-time tannage producing leather more resistant to shear when used with a buckle.

3. That the use of the type of mineral oil with which side *F* was stuffed does not affect the physical properties of new leather in a manner different than that caused by the use of cod oil.

WASHINGTON, October 27, 1919.