TB 169 (1930) USDA TECHNICAL BULLETINS UPDATA
THE WEARING QUALITY AND OTHER PROPERTIES OF VEGATABLE-TANNED AND OF
FREY, R.W., CLARKE, I.D. 1 OF 1

START

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 169 — JANUARY, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE WEARING QUALITY AND OTHER PROPERTIES OF VEGETABLE-TANNED AND OF CHROME-RETANNED SOLE LEATHER [1]

By R. W. FREY, *Chemist*, and I. D. CLARKE, *Associate Chemist, Industrial Farm Products Division, Chemical and Technological Research, Bureau of Chemistry and Soils*

CONTENTS

INTRODUCTION

During recent years the leather industry has been devoting attention to the development of a sole leather by combining two distinct, well-known processes of tanning—namely, chrome tanning and vegetable tanning. The product is referred to as combination tanned, chrome-retanned, or simply as retan leather.

Though the process may vary in many minor respects, it consists essentially in tanning the hides first with chromium salts and then with vegetable materials. The reverse order of tanning has been followed also. The object is to make a leather resembling vegetable-tanned sole leather in such properties as color, firmness, and substance but having the greater durability of chrome-tanned sole leather.[2]

Forest depletion by man and disease is steadily decreasing the supply of vegetable-tanning raw materials. Chrome tanning, moreover, is a much shorter process than vegetable tanning. Because of these conditions and other factors future developments in the leather industry may depend on chrome tanning. With this possibility in mind, the following experiments were made to obtain fundamental data on the wearing quality and other properties of chrome-retanned sole leather as compared to the long-established, well-known vegetable-tanned sole leather.

---

[1] It is desired to acknowledge hereby the assistance in this work of L. R. Leinbach, formerly of this division, and the cordial cooperation of the Post Office Department, the Washington City Post Office, and the letter carriers of the District of Columbia.

[2] VEITCH, F. P., FREY, R. W., and CLARKE, I. D. WEARING QUALITIES OF SHOE LEATHERS. U. S. Dept. Agr. Bul. 1168, 26 p., illus. 1923. (Rev. 1924.)

HIDES USED IN THE TESTS

An outstanding feature of this study is its strictly comparable nature as the two kinds of leather used were made from alternate right and left halves of the same hides. This fact should be kept in mind throughout the consideration of all the data.

Six steer hides from one lot of shorthorn cattle were used. They were selected at the time of slaughtering and were uniform in size and weight and free from cuts, scores, brands, grubs, and other defects. The hides were salted down in pack on January 27, 1927, and taken up on March 9, 1927.

The uniformity of the weight of these hides is shown by the data given in Table 1 on invoice weights and actual laboratory weights of the green-salted hides. The laboratory weights are higher because of no tare allowances and also because not all the fine salt in which the hides were packed for shipment could be swept off.

TABLE 1.—*Net invoice weight and actual weight of the green-salted hides*

Hide No.	Net invoice weight	Laboratory weight	Hide No.	Net invoice weight	Laboratory weight
	Pounds	*Pounds*		*Pounds*	*Pounds*
1	57.5	61.5	4	58.5	60.5
2	55.5	[1] 65.5	5	57.5	61.0
3	57.5	[2] 60.5	6	57.5	[3] 64.0

[1] Including a manure tare of 7 pounds.
[2] Including a manure tare of 2 pounds.
[3] Including a manure tare of 3 pounds.

DIVIDING, TRIMMING, AND TANNING THE HIDES

Each hide was cut along the median or backbone line into two sides. The two sides of each hide were then superimposed, flesh to flesh. While the sides were held in this position, the head and shank pieces and the edges were closely trimmed off so that the entire outline of one side coincided with that of the other. Holes were punched through the neck and tail ends of each side for identification and for location of points of coincidence. This gave for each hide two sides of practically identical shape and size. The sides were then reweighed.

The trimmed left side of each hide was placed smooth, hair side up, on large sheets of paper, and its outline was traced as carefully as possible for subsequent area measurements.

The left sides of hides 1, 3, and 5 and the right sides of hides 2, 4, and 6 were made into vegetable-tanned sole leather. The remaining sides—that is, the right sides of hides 1, 3, and 5 and the left sides of hides 2, 4, and 6—were made into chrome-retanned sole leather. The products of both tanners selected to make these leathers have a high rating for quality by the trade.

The six sides for vegetable-tanned sole leather were put through the regular tannery process and may be considered as typical, good quality vegetable sole leather. The tanning materials used consisted essentially of chestnut, quebracho, and oak bark.

The six sides for the chrome-retanned sole leather were first put through a regular 1-bath chrome tannage, then neutralized and washed. At this stage they were divided into three pairs of rights and lefts for three degrees of retannage. An effort was made to retan the first pair lightly to show a two-thirds chrome streak in the middle; the second pair to a slightly greater degree, showing a one-third chrome streak; and the third pair to a full retannage, showing no chrome streak. The retanning was done by drumming until practically all the tannin was taken up by the leather. For the vegetable retanning a blend of 3 parts of a 25 per cent tannin chestnut wood extract and 1 part of a 35 per cent tannin sulphited quebracho extract was used. After being retanned and piled for 24 hours, the sides were oiled in a wheel with 1.5 per cent of sulphonated cod oil, set out heavily, tacked, loft dried, and rolled. The grain was not snuffed or buffed, and no waterproofing treatment was applied to the leather.

WEIGHT AND AREA OF UNTANNED SIDES AND OF TANNED SIDES

The actual weights of the trimmed sides before being tanned and after being tanned are given in Table 2. They afford some interesting data on yield, a factor of interest and importance to the tanner. In the table are given constant weights of the sides of finished leather after they had been conditioned for five days at 70° F. and 50 per cent relative humidity.

TABLE 2.—*Actual weight of trimmed sides before tanning and after tanning*

Hide No.	Side	Kind of sole leather	Weight of untanned cured side	Weight of tanned finished side [1]	Ratio of finished weight to cured weight
			Pounds	*Pounds*	*Per cent*
1	Left	Vegetable tanned	24.50	14.50	59
1	Right	Chrome retanned (light) [2]	25.25	8.00	32
2	do	Vegetable tanned	27.50	19.00	69
2	Left	Chrome retanned (light) [2]	26.25	9.75	37
3	do	Vegetable tanned	25.00	17.50	70
3	Right	Chrome retanned (medium) [2]	24.25	9.50	39
4	do	Vegetable tanned	24.00	16.25	68
4	Left	Chrome retanned (medium) [2]	24.00	8.50	35
5	do	Vegetable tanned	22.75	15.75	69
5	Right	Chrome retanned (heavy) [2]	23.50	12.00	51
6	do	Vegetable tanned	26.50	16.50	62
6	Left	Chrome retanned (heavy) [2]	25.00	12.00	48
		Average, vegetable tanned	25.00	16.50	66
		Average, chrome retanned	24.75	10.00	40

[1] Constant weight of finished leather after being conditioned for five days at 70° F. and 50 per cent relative humidity.
[2] Degree of retannage.

According to Table 2, 100 pounds of greensalted, cured, untanned hide yields on the average 66 pounds of vegetable-tanned sole leather but only 35.75 pounds of chrome-retanned sole leather of light to medium retannage and 49.5 pounds of heavy retannage.

The data on the area of the sides before tanning and after tanning are assembled in Table 3. Patterns of the trimmed sides and of the leather made from them were cut from outlines carefully traced on post-card bristol. The patterns were measured in duplicate on a leather-measuring machine of the pinwheel type.

TABLE 3.—*Area of sides before tanning and after tanning*

Hide No.	Side	Kind of sole leather	Area of untanned cured side	Area of tanned side	Ratio of tanned to untanned cured side
			Sq. feet	*Sq. feet*	*Per cent*
1	Left	Vegetable tanned	18.875	19.125	101
1	Right	Chrome retanned	18.875	18.000	95
2	do	Vegetable tanned	20.750	21.125	102
2	Left	Chrome retanned	20.750	18.500	89
3	do	Vegetable tanned	19.250	20.500	106
3	Right	Chrome retanned	19.250	18.375	95
4	do	Vegetable tanned	17.375	18.750	108
4	Left	Chrome retanned	17.375	16.500	95
5	do	Vegetable tanned	18.750	(1)	(1)
5	Right	Chrome retanned	18.750	18.000	96
6	do	Vegetable tanned	19.000	19.500	103
6	Left	Chrome retanned	19.000	17.750	93
		Average vegetable tanned	19.000	19.800	104
		Average chrome retanned	19.000	17.850	94

[1] Side 5, vegetable tanned, was stolen from temporary storage before outline tracing was made.

Although the procedure used for determining the area of the sides does not permit highly accurate measurements, the results so obtained are consistent in showing an appreciably smaller area for the chrome-retanned sides. According to these results the area of the cured side is slightly increased when the side is converted into vegetable-tanned sole leather, the average increase being 4 per cent. On the other hand, when made into chrome-retanned sole leather, the area of the cured side decreases, the average decrease being 6 per cent. The averages given in Table 3 show that 19 square feet of cured hide yield 19.8 square feet of vegetable-tanned sole leather and 17.85 square feet of chrome-retanned sole leather. The difference in area between the two sides of hide 2 can be seen in Figure 1. On the left (A) is the chrome-retanned side. Its smaller area as compared with its mate (B) on the right, which is vegetable tanned, is apparent.

From the averages of both Tables 2 and 3, it is calculated that 100 pounds of cured hide has an area of 76 square feet and yields 66 pounds or 79 square feet of vegetable-tanned sole leather; or 49.5 pounds or 71.8 square feet of chrome-retanned sole leather of heavy retannage; or 35.75 pounds or 71 square feet of that of light to medium retannage. In other words, 1 pound of the vegetable-tanned sole leather has an area of 1.2 square feet; 1 pound of the chrome-retanned sole leather of heavy retannage has an area of 1.45 square feet; and 1 pound of the light to medium retanned leather has an area of 2 square feet.

LOCATION OF HALF SOLES AND TEST PIECES IN THE HIDE

The bend portion of each side of leather—that is, the nearly rectangular part extending along the backbone line from the root of the tail to just back of the shoulder and down from this line to the "breaks" or soft spots above the legs—was laid off into half soles and test pieces as shown in Figure 1. The half soles, laid off as alternate rights and lefts, were cut out with a die. After certain measurements of the half soles were made, they were paired, one vegetable-tanned half sole with the exactly corresponding chrome-retanned half sole, as, for example, V–2–11 with C–2–11, V–2–12 with C–2–12, and so on. (Fig. 1.) This not only gave an equal number of right and left half soles for each kind of leather but also permitted rigid control of what is known as the "position" factor,

FIGURE 1.—Arrangement of half soles and test pieces: A, Chrome-retanned side of hide 2; B, vegetable-tanned side of hide 2. Half sole C–2–11 was paired with V–2–11, C–2–12 with V–2–12, C–2–13 with V–2–13, and so on

or the influence of the part of the hide from which the sole is cut. Experience and experiments [3] have shown this to be a very important factor in the wearing quality of soles. The half soles, paired as described, were issued for actual wear tests, the details of which will be given further on in the bulletin.

---

[3] VEITCH, F. P., and ROGERS, J. S. THE WEAR RESISTANCE OF LEATHER FROM DIFFERENT PARTS OF THE HIDE. Jour. Amer. Leather Chem. Assoc., 13:80–90, 1918. VEITCH F. P., FREY, R. W., and HOLMAN, H. P. LEATHER SHOES: SELECTION AND CARE. U. S. Dept. Agr. Farmers' Bul. 1523, 22 p., illus., 1927.

AVERAGE THICKNESS OF THE HALF SOLES

The thickness of each half sole was measured at five symmetrically located points, and from these measurements the average thickness of the entire bend section of each side was calculated. These figures, together with the figures showing the average thickness of the thickest and thinnest half sole of each bend, are given in Table 4, in thousandths of an inch and in calculated equivalents in irons, one iron being equal to one forty-eighth inch.

TABLE 4.—*Thickness of bend section of tanned sole leather*

Hide No.	Side	Kind of sole leather	Thickness					
			Average	Maximum	Minimum	Average	Maximum	Minimum
			Inch	*Inch*	*Inch*	*Irons* [1]	*Irons*	*Irons*
1	Left	Vegetable tanned	0.156	0.191	0.126	7.49	9.17	6.05
1	Right	Chrome retanned (L [2])	.138	.173	.094	6.63	8.30	4.51
2	do	Vegetable tanned	.171	.205	.138	8.21	9.84	6.62
2	Left	Chrome retanned (L)	.153	.180	.136	7.35	8.64	6.53
3	do	Vegetable tanned	.167	.213	.124	8.02	10.22	5.95
3	Right	Chrome retanned (M [3])	.156	.192	.130	7.48	9.22	6.24
4	do	Vegetable tanned	.168	.200	.133	8.07	9.60	6.38
4	Left	Chrome retanned (M)	.148	.179	.120	7.10	8.59	5.76
6	Right	Vegetable tanned	.178	.212	.144	8.55	10.18	6.91
6	Left	Chrome retanned (H [4])	.184	.210	.144	8.82	10.08	6.91

[1] 1 iron equals 1/48 or 0.02083 inch.
[2] (L) = light tannage.
[3] (M) = medium tannage.
[4] (H) = heavy tannage.

In Table 4 also is indicated the effect of the degree of retannage, the thickness of the heavily retanned side from hide 6 being practically the same as that of the corresponding vegetable-tanned side. The average thickness of the vegetable-tanned bends from the first four sides is 0.165 inch or 7.95 irons; that of the chrome-retanned bends from the same hides is 0.149 inch or 7.14 irons. From these same bends the thickness of the half soles of vegetable-tanned leather ranges from 5.95 to 10.22 irons and of the chrome-retanned leather from 4.51 to 9.22 irons. These data indicate that a long-haired 55 to 60 pound green-salted steer hide will yield from the bend section vegetable-tanned sole leather of an average thickness of practically 8 irons, or chrome-retanned sole leather, of light or medium retannage, of an average thickness of about 7 irons.

AVERAGE BREAKING STRENGTH AND STRETCH OF THE LEATHERS

Test pieces for determination of the breaking strength and stretch of the two leathers were cut out with a die having a test area with parallel sides 2 centimeters wide and 5 centimeters long. The shape of these test pieces and the locations in the hide from which they were cut are shown in Figure 1. Previous to being broken, the test pieces were conditioned for three days at 70° F. and 50 per cent relative humidity, weighed, and measured for thickness at five points equally spaced over the test length.

The test pieces were broken in a motor-driven Schopper machine with jaws set 10 centimeters apart. The rate of separation of the jaws without load was practically 5 centimeters per minute. Stretch was determined by measuring the elongation of the section of the test piece having parallel sides. From the individual results the average breaking load for the bend section of each side was calculated. These figures are given in Table 5 as kilograms per centimeter width, pounds per inch width, kilograms per square centimeter cross section, and pounds per square inch cross section. The stretch is given as the percentage elongation at the breaking load.

TABLE 5.—*Strength and stretch of leather in bend section*

Hide No.	Kind of sole leather	Kilograms per centimeter width	Pounds per inch width	Kilograms per square centimeter	Pounds per square inch	Per cent stretch
1	Vegetable tanned	140	783	341	4,850	22
1	Chrome retanned	94	528	263	3,741	24
2	Vegetable tanned	154	865	343	4,878	20
2	Chrome retanned	106	593	271	3,854	31
3	Vegetable tanned	139	780	317	4,500	19
3	Chrome retanned	94	526	234	3,328	26
4	Vegetable tanned	138	768	313	4,452	17
4	Chrome retanned	81	453	214	3,044	26
6	Vegetable tanned	142	796	306	4,352	19
6	Chrome retanned	94	524	198	2,816	24
	Average, vegetable tanned	142	798	324	4,608	19
	Average, chrome retanned	94	524	236	3,357	26

Considering the common hide basis for these two leathers, the figures in the columns headed "kilograms per centimeter width" and "pounds per inch width" are probably the most interesting as they represent the strength of the leather as is. They show the vegetable-tanned leather to be much stronger than the chrome retanned, the former having a breaking strength of from 45 to 55 kilograms more per centimeter of width. In other words, a strap of the vegetable-tanned leather 1 inch wide would withstand a pull of from 257 pounds to 315 pounds more than a similar strap of the chrome-retanned leather before breaking. When the results are calculated to unit cross section, or pounds required to break a piece of the leather having a cross-section area of 1 square inch, the vegetable-tanned leather is still decidedly stronger than the chrome retanned, showing that the difference in strength of these two leathers is not owing primarily to their difference in thickness.

With increasing degree of retannage the strength of the chrome-retanned leather appears to decrease. The data on this point are too few, however, to justify any conclusions.

Although the vegetable-tanned leather is appreciably stronger than the chrome-retanned leather, its percentage stretch at the breaking load is less. It averages 73 per cent of the stretch of the chrome-retanned leather.

DATA ON INDIVIDUAL HALF SOLES AND TEST PIECES ACCORDING TO POSITION IN THE BEND

For those who may be interested in studying the individual data especially in connection with location in the bend, the average breaking load and stretch of each test piece are assembled in Table 6. These data are listed according to their respective location numbers and letters, as illustrated in Figure 1.

TABLE 6.—*Breaking strength and stretch of test pieces*

Position of side	Hide 1				Hide 2				Hide 3				Hide 4				Hide 6			
	Pounds per inch width of—		Per cent stretch of—		Pounds per inch width of—		Per cent stretch of—		Pounds per inch width of—		Per cent stretch of—		Pounds per inch width of—		Per cent stretch of—		Pounds per inch width of—		Per cent stretch of—	
	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]	V [1]	C [2]
A	601	358	23	29	722	454	20	29	661	409	20	23	812	375	21	22	610	353	17	18
B	627	426	27	29	801	554	22	37	650	476	20	27	846	414	18	27	711	520	23	25
C	745	392	22	28	946	605	21	32	778	487	23	29	655	448	16	24	706	437	17	20
D	818	622	23	23	924	577	17	32	806	515	17	21	784	358	18	19	705	571	17	27
E	924	509	28	28	924	661	24	35	840	582	22	27	739	526	18	35	930	594	21	29
F	762	504	25	25	879	666	20	43	868	571	19	28	823	510	20	20	890	543	23	23
G	851	711	20	23	952	700	21	22	790	610	17	24	818	549	16	22	874	683	20	23
H	935	644	24	21	958	668	20	23	913	554	22	23	756	498	19	24	1036	711	24	23
I	857	571	22	20	935	745	22	24	963	571	21	20	851	493	17	21	840	605	19	18
J	795	465	21	22	806	482	20	20	686	532	17	31	689	420	16	30	689	442	19	24
K	885	543	21	23	851	655	18	30	762	549	17	28	689	532	13	31	778	414	18	21
L	829	599	16	22	802	650	17	38	773	510	18	22	840	510	16	28	795	610	14	24
M	706	459	20	25	711	504	15	31	750	431	19	25	678	381	13	20	834	491	18	29
N	695	408	17	20	767	420	18	31	706	493	21	35	658	358	16	35	644	431	19	29
O	746	588	17	22	941	549	17	29	773	594	17	23	902	426	15	21	801	554	14	20

[1] V = vegetable tanned. [2] C = chrome retanned.

DENSITY OF THE LEATHERS

From the portions of each side remaining after the half soles and test pieces had been cut out, samples were taken for the determination of densities. Samples to represent the kidney location were taken from between half sole locations 32 and 43. (Fig. 1.) For the shoulder location they were cut out of the center of the shoulder, and for the belly section they were taken from the soft flanky portion just below and behind the rear "break." These samples should represent the extremes of texture or fiber structure of a side of leather.

Samples for moisture were taken at the same time, and all samples were conditioned at 50 per cent relative humidity and 70° F. before being weighed and measured.

Volume measurements were made by displacement of kerosene. The procedure followed is a material modification of a method recently described by Porter.[4] Glass tubes of 50 cubic centimeter capacity, 1.5 by 44 centimeters, graduated to 0.2 cubic centimeter, were used. Air-free kerosene was placed in the tube and the volume was read. Vacuum applied for five hours caused no significant difference in the volume of the kerosene. The weighed sample of leather was then introduced, and vacuum was applied intermittently until all the air in the leather was removed, a period of from two to four hours, after which the volume was again read. The increase in volume in the tube gives the volume of the leather minus permeable voids [5] or air spaces. The weight of the leather used divided by this volume was taken as the density, or the weight in air of a unit volume of the leather without voids.

[4] PORTER, R. E. SPECIFIC GRAVITY, PER CENT VOIDS, AND "PILE UP" OF LEATHER. Jour. Amer. Leather Chem. Assoc. 24: 30–42. 1929.

[5] This assumes that displacement in kerosene gives the true volume. The density of materials, such as wood, wool, and cotton, has been found to differ by as much as 0.1 gram per cubic centimeter, depending upon the displacing liquids used.

The leather was then taken from the tube, lightly wiped to remove surface kerosene, and put into a tube containing a known volume of kerosene. The resulting increase in volume gives the volume of the leather plus voids. The weight of the leather divided by this volume was taken as the apparent density, or the weight in air of a unit volume of the leather in its usual condition, including the voids or air spaces.

Correction of densities for moisture was made from data obtained by determining densities of an extra set of composite samples conditioned at 35, 50, and 75 per cent relative humidity, respectively.

In Table 7 densities corrected to a 12 per cent moisture basis are given together with voids, which have been calculated from the difference in volume owing to voids and expressed as percentage of the volume of the leather plus voids. Because of lack of refinement in the procedure used, the density figures probably are accurate only to one or two hundredths and consequently are given only to the second decimal.

TABLE 7.—*Densities and voids of tanned sole leather*

[Corrected to 12 per cent moisture]

Location and hide No.	Apparent density or weight of 1 cubic centimeter of leather and voids of—		Density or weight of 1 cubic centimeter of void-free leather of—		Percentage of voids in—	
	Vegetable tanned	Chrome retanned	Vegetable tanned	Chrome retanned	Vegetable tanned	Chrome retanned
Kidney:	*Grams*	*Grams*	*Grams*	*Grams*		
1	1.04	0.70	1.39	1.39	25	49
2	1.04	.72	1.40	1.39	25	47
3	1.04	.71	1.39	1.40	25	48
4	1.07	.74	1.40	1.40	23	47
6	1.03	.84	1.40	1.41	25	40
Shoulder:						
1	1.08	.66	1.38	1.41	21	52
2	1.06	.73	1.37	1.40	22	47
3	1.05	.75	1.36	1.40	22	46
4	1.09	.71	1.37	1.42	20	49
6	1.01	.79	1.38	1.44	26	44
Belly:						
1	.91	.60	1.37	1.41	34	57
2	.92	.62	1.38	1.40	33	55
3	.93	.64	1.39	1.42	33	54
4	.86	.69	1.37	1.41	37	50
6	.93	.65	1.37	1.44	32	54

The values for density of the void-free leather are in surprisingly close agreement, the two types of leather showing no significant differences. The density of the leather from the three locations—kidney, shoulder, and belly—also is practically the same.

The apparent densities, however, and consequently the voids of the products of the two tannages are materially different, the chrome-retanned leather being much lighter and having a much higher percentage of voids. For the kidney area the average apparent density of the vegetable-tanned leather is 1.044 grams per cubic centimeter, whereas that of the chrome-retanned leather ranges from 0.7 to 0.84 gram per cubic centimeter, the latter being the figure for the chrome-retanned leather of the highest degree of retannage. In other words, a sole of the chrome-retanned leather, depending upon the extent of retannage, weighs only from 0.67 to 0.80 as much as a sole of the vegetable-tanned leather of the same area and thickness.

There is also an appreciable difference in apparent density in sections of the same side, at least between the kidney and belly sections, the latter being of a lower apparent density for both tannages.

The data throw no light on relation between wearing quality and density. Although the density of the two types of leather is practically the same, their wear resistance is markedly different. Regarding apparent density, the chrome-retanned leather, which has the greater wear resistance, has a lower apparent density, but for both tannages leather from the belly section has a lower apparent density than that from the kidney section, and yet soles from the belly region are known to have much less wear resistance than those from the kidney section.

The figures for voids are of interest in showing the empty nature of the leather or the volume of air spaces, which in the chrome-retanned leather is roughly one-half the volume of a piece of the leather.

CHEMICAL ANALYSIS OF THE LEATHERS

The composition of the leathers used in these experiments is given in Table 8. The following composite samples were prepared from the broken test pieces from the bend: One to represent the five sides of vegetable-tanned leather; another to represent the two chrome-retanned sides from hides 1 and 2; a third to represent the retanned sides from hides 3 and 4; and a fourth for the heavily retanned side from hide 6. These samples are identified as V, CR 1–2, CR 3–4, and CR 6, respectively.

TABLE 8.—*Chemical composition of the leathers*

Item	Leather samples			
	V	CR 1-2	CR 3-4	CR 6
Moisture .... per cent	7.2	7.7	7.0	7.9
Insoluble ash .... do	0.2	3.6	3.4	2.0
Petroleum ether extract .... do	4.9	2.5	1.7	2.1
Hide substance (N by 5.62) .... do	37.0	62.7	63.2	46.0
Combined tannin .... do	24.1	22.1	20.1	32.2
Water solubles .... do	26.6	1.4	3.7	9.8
Soluble tannin .... do	14.1	0.2	1.4	5.9
Soluble nontannins .... do	12.5	1.2	2.3	3.9
Sugars .... do	4.1	0.1	0.1	0.3
Total ash .... do	1.9	3.8	3.7	2.4
Magnesium sulphate ($MgSO_4 7H_2O$) .... do	4.1	....	....	....
Total chromic oxide (Cr_2O_3) .... do	....	3.0	3.2	2.0
Acidity [1] .... do	0.4	....	....	....
Total sulphates (SO_3)[1] .... do	....	3.2	2.9	1.1
Neutral sulphates (SO_3)[2] .... do	....	1.5	1.4	0.9
PH value [3] .... do	3.4	2.7	2.7	2.7

[1] Procter and Searle method. Methods of Analysis, Amer. Leather Chem. Assn.
[2] Thomas' method. Methods of Analysis, Amer. Leather Chem. Assn.
[3] Kohn and Crede procedure. See the following publication: KOHN, S., and CREDE, E. THE ACIDITY OF VEGETABLE-TANNED LEATHER. Jour. Amer. Leather Chem. Assoc., 18: 189–194, 1923.

As previously mentioned, the analyses show, particularly by comparison of the data on combined tannin and total chromic oxide (Cr_2O_3), that the chrome-retanned sides from hides 1 to 4, inclusive, were practically of the same degree of retannage and that only the side from hide 6 was of a materially higher degree of retannage. They also show that neither the vegetable-tanned nor the chrome-retanned leather had been waterproofed or treated for this purpose with oil or grease preparations.

WEARING QUALITY OF THE LEATHERS

The half soles, cut out and matched as described on pages 4 and 5 with one vegetable-tanned half sole against its corresponding chrome-retanned mate, were issued for actual wear tests to United States mail carriers in the city and suburbs of Washington, D. C., and to messengers in the Department of Agriculture. They were worn from April to December, inclusive. All the half soles were sewed on in the same way by the same shoe repairer without buffing, sanding, or staining. Weekly calendar cards were issued to each wearer, on which records were kept of the hours the shoes were worn each day. These cards were collected, the records checked, and the shoes inspected every week or two. The first half sole of each pair to wear through was replaced by another, and the wearing of the shoes was continued until the other half sole of the test pair was worn through.

The number of hours required by different persons to wear through a pair of test half soles was found, of course, to vary widely, being influenced among other things by the activity of the wearer, the manner of walking, and the nature of the surfaces walked upon. From these individual wear records the average relative wearing quality of the two kinds of leather was calculated for each group of test half soles from each hide. The ratios showing how much longer the chrome-retanned sole leather wore than the vegetable-tanned sole leather are given in Table 9.

TABLE 9.—*Relative wear resistance: Wear of chrome-retanned half soles as compared to wear of vegetable-tanned half soles, the latter in all cases being taken as 1*

Hide No.	Number of test pairs	Wear resistance of chrome-retanned half soles on basis of—			
		Leather as is	Unit thickness of 9 irons	Unit hide substance per unit area	Unit leather substance per unit area
1	14	1.6	1.8	1.6	1.9
2	14	1.8	2.1	1.8	2.1
3	18	1.6	1.8	1.5	1.8
4	18	1.7	1.9	1.7	2.0
6	18	1.3	1.3	1.3	1.2

In 74 out of a total of 82 test pairs the chrome-retanned half sole wore longer than its exactly corresponding vegetable-tanned half sole. In only three cases did the chrome-retanned half sole wear through first. In five instances it wore the same length of time as the vegetable tanned. These 5 were among the 18 test pairs from hide 6, the hide from which the chrome-retanned side of the highest degree of retannage was made, and the only side that in this respect differed markedly from the others, as shown by the chemical analyses.

On the basis of the leather as is, without regard for the difference in thickness between the two types, the chrome-retanned leather from the first four hides wore on the average from 1.6 to 1.8 times, or from 60 to 80 per cent, longer than the vegetable tanned. That from the heaviest retanned side from hide 6 wore only 1.3 times or 30 per cent longer than the vegetable tanned, showing the decided influence of heavy vegetable retanning of chrome leather in reducing the wear resistance.

The chrome-retanned leather of light or medium retannage is thinner than the vegetable-tanned leather made from the same sides. Consequently, when the wear resistance of the leathers from the first four sides is calculated on the basis of the same thickness, 9 irons for example, instead of expressed on the basis of the leather as is, the results show that the chrome-retanned leather has relatively a still greater wear resistance. In the two leathers from hide 6 the relative wear resistance is the same on both bases because the heavy retanned leather was practically of the same original thickness as the vegetable-tanned side.

Relative wearing quality is also expressed in Table 9 on the basis of unit hide substance per unit area or the ratio of the hours required to wear away a piece of the sole 1 centimeter square and thick enough to contain 1 gram of hide substance. The number of hours wear from which these ratios were calculated was obtained by dividing the number of hours actual wear by the grams of hide substance per piece of leather 1 centimeter square.

The value given in each case in Figure 2 is the grams of hide substance in a piece of leather having an area of 1 square centimeter that had been conditioned at 50 per cent relative humidity and 70° F. This value is the product of per cent hide substance, apparent density, and thickness, all determined on the conditioned leather. Hide substance was calculated from nitrogen determined on individual samples cut from the shank end of each half sole. Apparent density was determined on the test pieces distributed between the half soles.

The data in Figure 2 show that a piece of the vegetable-tanned leather contained practically the same quantity of hide substance as a piece of the chrome-retanned leather of equal area made from the same hide and taken from a corresponding position in the side. This quantity may be influenced by a number of factors, such as unequal losses of hide substance before and during the tanning of the sides, changes in the area of the sides, and variations in thickness. Both these leathers were made from the same hides. It is safe, therefore, to assume that the concentration of hide substance originally was essentially the same in both sides of the hide. Considering this and also the data presented in Figure 2 and the previously noted changes in area during the tanning, the sides made into chrome-retanned leather must have lost, either before or during tanning or at both stages, more hide substance than did those made into vegetable-tanned leather, which greater loss was counterbalanced by the relative shrinkage of the chrome-retanned sides, giving again for the two finished leathers about the same quantity of hide substance per unit area for corresponding positions.

The results given in Figure 2 are typical in their relationship of the same data for the leather from the other hides. They show a wide variation in the total quantity of hide substance in a piece of the leather or in a half sole of a given area depending upon the position in the bend. In the vegetable-tanned leather from hide 2 the largest quantity of hide substance in a half sole is 58 per cent greater than the smallest; in the chrome-retanned leather from the same hide this difference is 46 per cent.

The data for all the hides are consistent in showing that the half soles containing the most hide substance are from the kidney and butt region and that those containing the least are from the forward end

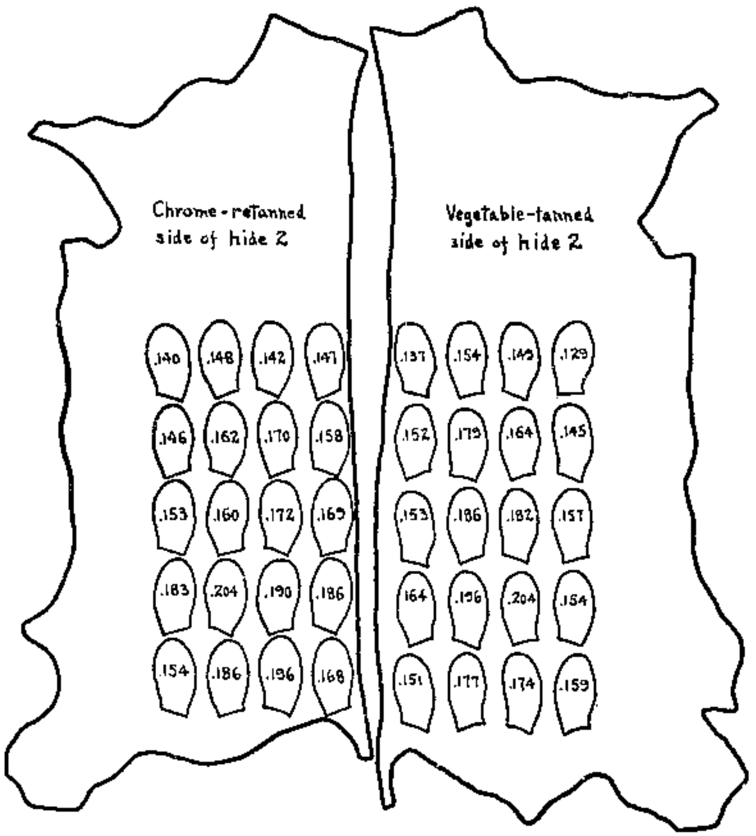

FIGURE 2.—Weight in thousandths of a gram of hide substance per piece of leather 1 centimeter square

of the bend along the shoulder and belly edges. These variations in the quantity of hide substance per half sole from different locations in the bend do not reflect differences in the percentage of hide substance alone, since the quantity is dependent also upon variations in thickness and apparent density.

The data presented in Table 9 on relative wear expressed on the basis of unit hide substance per unit area, considered together with those in Figure 2, show that wearing quality or resistance is not dependent entirely upon the total quantity of hide substance in a sole or piece of leather, since half soles of the two types of leather, from the same relative position in the bend, were shown to have practically the same quantity of hide substance per unit area but materially different wear resistance.

In comparing the wearing quality of sole leathers, especially leathers of different types or of unknown history, it is desirable to express the results for all leathers on a unit or common basis. There are several bases on which relative wear may be expressed, each of which may be objected to on one ground or another. In Table 9 results have been expressed on four different bases, including that of unit leather substance per piece of leather of unit area, or, in other words, on the basis of a piece of leather 1 centimeter square and of such thickness as to contain 1 gram of leather substance, leather substance in the vegetable tannage being taken as hide substance plus combined tannin and in the chrome-retanned leather as the sum of hide substance, chromic oxide, sulphates associated with the chrome, and combined tannin. Such a basis, as a common one for expressing comparative or relative wear of various leathers, is suggested for consideration as possibly least subject to the influence of such factors as loading and filling materials that do not affect the actual wear, and extent and pressure of rolling. For example, two pieces of leather identical in all respects except that one is rolled until it is thinner than the other will wear through in the same time if it is assumed that rolling does not affect the wear, yet if the wear is expressed on the basis of unit thickness the thinner piece of leather will appear to be more wear resistant. A similar condition would be brought about by filling and loading materials that affect the thickness of the leather but not its wear resistance. For practical purposes it is probably best to express wear data on the basis of the leather as is, but for comparative studies and investigational work on fundamental factors that really influence the wear, some common or unit basis to which to refer all results is more desirable.

The rate of wear or wear resistance of shoe-soling materials is not their only property to be considered. Although the data show consistently longer wear for the chrome-retanned leather, especially that of a light retannage, frequent objections were raised against this leather on other grounds. The most important of these were slipperiness and absorption of water during wet weather. Objection was also made, but not so frequently, to the difference between the two leathers in affording protection to the foot when walking. The vegetable-tanned half soles were better in this respect, especially after about one-half the sole was worn away.

An idea of the comparative permeability of the two leathers to water may be gained from the data in Table 10 on water absorption tests. For these tests a piece of leather was cut from the same position in each shoulder along the edge immediately next to the bend. The pieces were conditioned to constant weight at 50 per cent relative humidity and 70° F., and then each one was immersed in 500 cubic centimeters of water for one hour, and flexed ten times by hand at the end of each 15-minute period. After the pieces had soaked for one hour, the excess of water was lightly wiped off with a towel, and each piece was weighed. The pieces were again immersed and left undisturbed for 23 hours, after which they were wiped and weighed as before. The pieces were then allowed to air-dry and were finally reconditioned to constant weight at 50 per cent relative humidity and 70° F. Apparent absorption of water is given as the difference between the weight after soaking one hour and the original conditioned weight, expressed as percentage of the latter. Actual absorption of water is given as the difference between the weight after 24 hours soaking and the final reconditioned weight, stated as percentage of the latter. The results show both a decidedly greater absorption of water by the chrome-retanned leather and the influence of retanning in reducing the absorption.

TABLE 10.—*Comparative absorption of water by tanned leathers*

[Test piece from shoulder-bend edge]

Hide No.	Apparent absorption in 1 hour by —		Actual absorption in 24 hours by —	
	Vegetable tanned	Chrome retanned	Vegetable tanned	Chrome retanned
	Per cent	*Per cent*	*Per cent*	*Per cent*
1	31	70	56	92
2	33	79	55	90
3	34	85	53	97
4	31	88	59	98
6	37	64	60	69

CONCLUSIONS

The data presented afford a number of interesting comparisons of vegetable-tanned sole leather and chrome-retanned sole leather made from the same hides.

According to these data 100 pounds of long-haired, green-salted, cured hide yields 66 pounds of vegetable-tanned sole leather but only from 32 to 51 pounds of chrome-retanned sole leather, depending upon the degree of retannage.

When converted into vegetable-tanned sole leather the area of the cured side was slightly increased, the average increase being 4 per cent. When made into chrome-retanned sole leather the area was slightly decreased, the average decrease being 6 per cent.

Calculations based upon the averages of the weight and area data show that 1 pound of the vegetable-tanned sole leather has an area of 1.2 square feet; 1 pound of the chrome-retanned sole leather of heavy retannage an area of 1.45 square feet, and 1 pound of the chrome-retanned sole leather of light to medium retannage an area of 2 square feet.

Chrome-retanned sole leather of light or medium retannage is appreciably thinner than vegetable-tanned sole leather made from the same hide. For the hides used, the average thickness of the vegetable-tanned sole leather from the bend section was practically 8 irons, whereas that from the chrome-retanned leather of light or medium retannage was about 7 irons. Heavy retannage increases the thickness to practically the same as that of the vegetable-tanned leather.

As measured over the bend section, the tensile strength of the vegetable-tanned leather is much greater than that of the chrome-retanned, being from 45 to 55 kilograms more per centimeter of width. In spite of this fact, the strength of the chrome-retanned leather appears to decrease with increasing degree of retannage. The data on this point, however, are too few to justify any conclusions.

Although the vegetable-tanned sole leather is appreciably stronger than the chrome-retanned leather, its percentage stretch at the breaking load is less, being on the average but 73 per cent of the stretch of the chrome-retanned leather.

The density, or the weight in air of unit volume of the leather minus permeable voids, is practically the same for the two types of leather. Also, it is the same for the leather from the kidney, shoulder, and belly regions of the sides.

The apparent density, or the weight in air of unit volume of the leather as is, including voids or air spaces, is, however, materially different for the two leathers. For the kidney area the average apparent density of the vegetable-tanned leather is 1.044 grams per cubic centimeter; that of the chrome-retanned ranges from 0.70 to 0.84 gram per cubic centimeter. Leather from different sections of the same side also shows a difference in apparent density, that from the belly section being of a lower apparent density than leather from the kidney section.

The results for percentage voids show a large volume of voids or air in the leather. The percentage is greater in the chrome-retanned leather, being roughly one-half the volume of this leather.

On the average the light to medium retanned chrome sole leather, even though thinner than the vegetable-tanned leather, wore from 1.6 to 1.8 times, or from 60 to 80 per cent longer.

The wear resistance of chrome retanned sole leather decreases with increasing degree of retannage. The chrome-retanned half soles from the bend of heaviest retannage wore but 1.3 times, or 30 per cent, longer than the corresponding vegetable-tanned half soles. Out of a total of 82 test pairs, 74 of the chrome-retanned half soles wore longer. Only 3 of the chrome-retanned half soles wore through in less time than the vegetable-tanned half soles, and but 5 of them in the same length of time as the vegetable-tanned. These 5 were all from the most heavily retanned side.

The data do not show that wearing quality is indicated by tensile strength nor that it is dependent primarily or entirely upon the total quantity of hide substance present per unit area of the leather. Moreover, no relationship is evident between either density or apparent density and wearing quality.

Although the chrome-retanned sole leather wore appreciably longer than the vegetable tanned, it showed several seriously objectionable features. It was quickly penetrable by water, it was slippery in wet weather, and it frequently lacked sufficient solidity to protect the foot against uneven surfaces, especially after about one-half the sole had been worn away. These tendencies were inversely proportional to the degree of retannage and consequently also to their wearing quality. The more heavily the leather was retanned the less readily it became wet, the less it slipped, and the greater was its solidity, but also the less was its relative wearing quality.

A number of different processes are followed in making both vegetable and chrome-retanned sole leather, particularly the latter, including variations in the order and extent of tanning, the time of tanning, and the presence or absence of constituents other than leather substance. Because of these variations and their possible influence on the quality or properties of the resulting products, the data presented here should be considered as applicable only to leather of the types described and not as invariably true of the properties of all vegetable-tanned and chrome-retanned sole leather. It should be borne in mind especially that the chrome-retanned sole leather used was not of the filled or waterproofed type.

From these experiments, from other work, and from practical observations, there can be no doubt of the longer wear of leather entirely or predominately of a chrome tannage. Likewise, there is, as a rule, no question regarding the superiority of vegetable-tanned sole leather in respects other than wear resistance. The development of an entirely satisfactory product combining the good properties of both by a process comparing favorably in speed with that of the chrome-tanning or chrome-retanning processes, is, indeed, worthy of the serious and concerted effort of the industry. Such a process should be attractive particularly to the progressive tanner of vegetable heavy leathers in helping him to solve one of his most serious problems—that is, an extremely slow turnover—to say nothing of the possibility of producing a leather having both a lower production cost and greater serviceability.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

December 14, 1929

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	LEE A. STRONG, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	———, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Chemical and Technological Research	C. A. BROWNE, *Chief.*
Industrial Farm Products Division	F. P. VEITCH, *Principal Chemist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1929

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 5 cents

END