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CALCULATION OF STRETCH FROM BALL BURSTING STRENGTH DATA

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ABSTRACT

Methods are given for calculating elongation of the diameter of a circular test specimen, and increase in area of the specimen, from data obtained in the ball burst test. A table is given for obtaining elongation from plunger rise when the orifice diameter is 0.75″ and the plunger diameter is 0.25″.

INTRODUCTION

The official American Leather Chemists Association method for measuring stretch or elongation is Method E17. This method specifies the use of a tensile strength specimen (unless the sample is too narrow) and measurement of stretch by means of a tensile strength testing machine either at failure of the specimen or at some lower load.

The ball bursting strength testing machine, developed by the Quartermaster Leather Laboratory, was designed to measure stretch as well as strength, but the official method, E14, does not include the stretch measurement, nor is it included in Method E17. The illustration, Figure E14A, shows a thickness gage mounted on the lower anchor. This gage measures the movement or rise of the plunger during a test, and this rise is related to stretch of the specimen. It is not, however, directly proportional to the stretch.

Distension of the specimen or stretch has frequently been observed when making burst measurements. Bradley (2) apparently was the first to apply this type of test to leather. He devised a tester in which the leather was clamped over an orifice and pressure was applied to the lower side of the leather by rise of a steel ball. For interpreting his results he used the expression $Z = a\, p^n$, where Z is the height of rise of the ball, p is the pressure on the specimen, and a and n are constants characteristic of the leather.

Merrill (3) used a modified Mullen tester with hydraulic pressure under the rubber diaphragm. In this test the distorted leather is more like a segment of a sphere rather than a truncated cone with a spherical tip as in the ball burst test. He measured the vertical height of displacement of the center of the leather specimen, a measurement corresponding to that of rise of the plunger in the ball burst machine, and calculated the increase in area of the distended leather.

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Boor and Niedercorn (1), who used a type of tester quite similar to those of Bradley and the ALCA, calculated both percent elongation* and percent increase in area. Their calculations are equivalent to that described below, but are more complex. They state that since in the range of height of break shown by most commercial leathers (0.3″ - 0.7″) these functions are nearly linear, the reading of height will serve as an index of either elongation or increase in area for routine testing.

The relation is not linear in the region where grain cracking usually occurs, and since it is only approximately linear outside of this region, it is desirable to express the results as percent stretch if possible.

As an illustration of the difference that would result from the use of plunger rise instead of percent stretch, the following data are taken from a test referred to later in this paper. Measurements of ball burst stretch at grain crack were made on cowhide specimens, half of which had been treated in various ways and the remainder left untreated. The stretch values of treated specimens were then divided by the values for corresponding untreated specimens. These ratios ranged from 0.21 to 0.42, whereas if they had been based on plunger rise the range would have been from 0.44 to 0.63. Corresponding ranges for stretch at burst were 0.51 to 0.74 and 0.69 to 0.83.

CALCULATION OF STRETCH FROM PLUNGER RISE

Calculation of stretch from plunger rise must of course be based on the dimensions of the apparatus being used. The calculations below have been made for a tester having the dimensions specified in Method E14, i.e., an orifice diameter of 0.75″ and a plunger ball diameter of 0.25″. In Figure 1

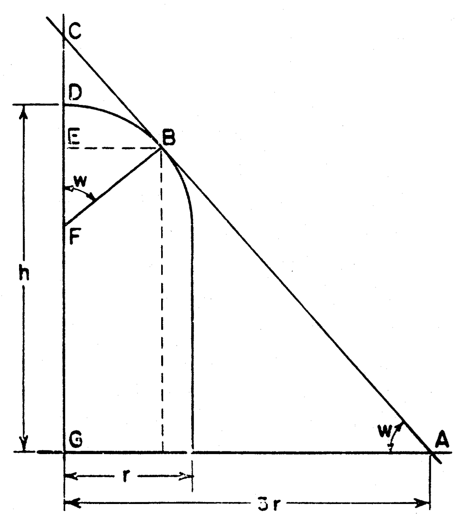


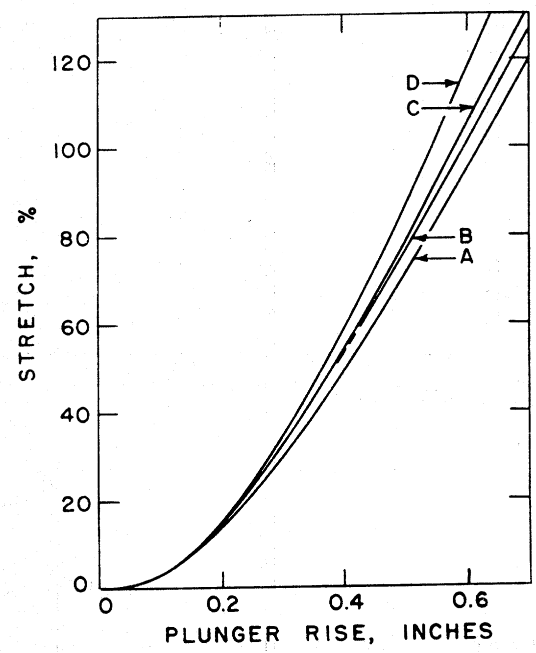
FIGURE 1—Diagram showing stretched length of a radius of the test area when plunger has risen the distance, *h*. Leather assumed to have 0.0 thickness.

*That is, the percent elongation of a diameter of the circular specimen.

the line *AG* represents one radius of the disk of leather under test before pressure has been applied to it, and the line *ABD* represents this same radius after the plunger has been raised the distance *GD* (denoted by *h*) so that the leather forms the angle *GAB* (*w*) with its original position. Using *r* to denote the radius of the ball (0.125″), the following equations for stretched length, *d*, and plunger rise, *h*, are readily derived:

$$d = AB + BD = (3r - BE)/\cos w + BD = (3r - r \sin w)/\cos w + \pi r w/180$$
$$h = GC - DC = 3r \tan w - (FC - r) = 3r \tan w + r - r/\cos w$$
$$\text{Stretch, } \% = 100\,(d - 3r)/3r = 266.7\,(d - 0.375)$$

FIGURE 2.—Curves showing percent elongation or area increase as a function of plunger rise. Curves *A*, *B*, *C*, elongation calculated for leathers having thicknesses of 0.0, 0.10, or 0.15″ respectively. Curve *D*, percentage area increase for leather of 0.0 thickness.



Values of *d* and *h* for various angles were calculated, after which curve *A*, Figure 2, was drawn. Percentage stretch for various values of *h* can be read from the curve, but a table is easier to use if the number of items is small; therefore, Table I was prepared.

The above calculations assume ideal conditions. They ignore nonhomogeneity of the leather over the test area, thickness of the specimen, indentation of the plunger in the flesh side of the specimen which affects the height measurement, curvature of the specimen at *A* (Figure 3), which results in a small error in the effective orifice diameter measurement, and other effects of less importance. The thickness of the specimen is of the same order of magnitude as the radius of the plunger ball; additional calculations, there-

TABLE I

BALL BURST STRETCH*

Plunger Rise, h, inches	Stretch, %	h, inches	Stretch, %	h, inches	Stretch, %	h, inches	Stretch, %
0.03	0	0.20	14	0.36	41	0.52	76
.04	1	.21	15	.37	43	.53	79
.06	1	.22	17	.38	45	.54	81
.07	2	.23	18	.39	47	.55	83
.08	2	.24	20	.40	50	.56	85
.09	3	.25	21	.41	52	.57	88
.10	4	.26	23	.42	54	.58	90
.11	4	.27	25	.43	56	.59	93
.12	5	.28	26	.44	58	.60	95
.13	6	.29	28	.45	60	.61	97
.14	7	.30	30	.46	62	.62	100
.15	8	.31	32	.47	65	.63	102
.16	9	.32	34	.48	67	.64	104
.17	10	.33	36	.49	69	.65	107
.18	12	.34	37	.50	71	.66	109
.19	13	.35	39	.51	74	.67	112

*These values hold only for tests made with a 0.75″-orifice and 0.25″-diameter plunger, as specified in ALCA Method E14 (1953).

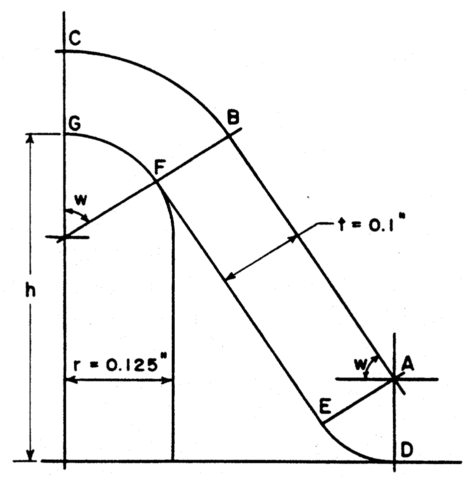


FIGURE 3.—Diagram showing stretched length of a radius of the test area when plunger has risen the distance, h. The leather is assumed to have a thickness of 0.1″.

fore, were made in which leather thickness (t) was included. Figure 3 is similar to Figure 1 except that in this case the leather is assumed to have a thickness of 0.1″. Making the assumptions that BC, DE, and FG (Figure 3) are arcs of circles and that the bend of the leather at *A* is sharp, the following equations were derived:

$$d = [3r - (r + t) \sin w]/\cos w + \pi (r + t) w/180$$
$$h = 3r \tan w + r + t - (r + t)/\cos w$$

The stretched length, *d*, applies to both the grain and flesh sides of the leather because the distance *ABC*, Figure 3, is equal to the distance *DEFG*. This calculation does not take into account compression of the leather by the clamp with shortening of the distance *AD*. From the appearance of the specimens this is quite a localized effect and perhaps has little effect on the stretch behavior. Calculations with the above equations, assuming thicknesses of 0.10″ and 0.15″ were made, and these data are plotted as curves *B* and *C* in Figure 2.

Calculations also were made of increase in area of the test portion of the leather, basing the calculations on the relations shown in Figure 1. Curve *D*, Figure 2, presents these results. This curve has the same general shape as the stretch curves.

For leather 0.15″ thick (9½-ounce) the inclusion of thickness in the equations would increase the stretch values by 10 or 12%. For example, a value of 56% would be found instead of 50, or 28 instead of 25, as would be found if thickness were ignored. For thinner leathers the differences would be decreased proportionally. Thickness, however, decreases during a test by an unknown amount so that an exact calculation cannot be made.

During a test the dial showing plunger rise can be read only to about 0.01″ because of such factors as operator reaction time and the fact that usually the plunger does not break through instantly but pushes through gradually. A rise of 0.01″ corresponds to a stretch value of approximately 1% in the low stretch range and 2% or more in the high range. Thus it appears that the error resulting from failure to correct for thickness is often little, if any, greater than experimental error. The best procedure therefore appears to be to use the values for stretch given in Table I, recognizing that they may be a trifle low for thick leathers.

RELATION BETWEEN BALL BURST STRETCH AND ELONGATION

Ball burst stretch and elongation are both measures of the ability of leather specimens to increase in length or area under stress. Elongation values, however, should be greater than ball burst stretch values because they are measured on a narrow specimen with cut edges on each side of the test area, whereas the ball burst specimen has no cut edges in this area.*

Some comparative data by the two tests have been obtained in the course of other work and are given below. Results are given for acetone-dehydrated

*When the narrow tensile strength specimen is stretched, its width decreases as its length increases, because the cut edges on each side are not restrained by clamps. This results in greater elongation at grain crack than is obtained in the ball burst test where the specimen is clamped all round and is stretched in all directions, not just in one.

cowhide (untreated hide) and for this hide material after treatment with certain epoxides, aldehydes, or other tanning agents (treated hide). An effort was made to have as small a test area as possible for a given comparison, but the distance between these test locations varied from 1.5″ to 3″. Elongation was measured on a small specimen with a test area 1 cm. instead of 0.5″ wide and 2.5 cm. instead of 2.5″ long. The results are given in Table II.

TABLE II

COMPARISON OF BALL BURST STRETCH AND ELONGATION VALUES FOR UNTREATED AND TREATED COWHIDE

Test No.	UNTREATED HIDE			TREATED HIDE		
	(1) Ball Burst test	(2) Elongation test	Ratio 1:2	(1) Ball Burst test	(2) Elongation test	Ratio 1:2
I Average stretch at rupture,* $\bar{x}$, %	30.9	63.0	0.49	38.5	50.4	0.76
Standard deviation, s	10.2	7.5		10.0	9.4	
Coefficient of variation, $\bar{x}/s$, %	33.0	12.0		26.0	18.7	
II Average stretch at rupture,† $\bar{x}$, %	42.9	60.1	0.71	28.5	42.6	0.67
Standard deviation, s	4.8	6.8		5.1	8.3	
Coefficient of variation, $\bar{x}/s$, %	11.3	11.3		17.9	19.5	
II Average stretch at grain crack, %	31.0	58.3	0.53	12.5	30.6	0.41

*Average of duplicate measurements on 50 specimens (10 treatments).
†Average of duplicate measurements on 44 specimens (11 treatments).

In test I, ball burst stretch results were more variable (higher coefficient of variation) than those for elongation, but in test II there was little difference. For the untreated hide the ratio of stretch to elongation was not constant for the two tests; the ratios were 0.49 and 0.71. Correlation between results by the two tests was low; the coefficient, r, was 0.25 in test I and only 0.08 in test II. This low correlation was not related to direction of measurement of elongation as there was little difference in either standard deviation or correlation coefficient when these were calculated using elongation parallel or perpendicular to the backbone.

For the treated specimens the ratio of ball burst stretch to elongation was 0.76 in test I and 0.67 in test II. The range in ratios for the entire 21 treatments was from 0.61 to 0.79, and the values of r were 0.75 in test I and 0.72 in test II. It therefore appears that for this type of treated material ball burst stretch is approximately 70% of elongation. Whether this value is of general applicability or sufficiently constant for many purposes can only be determined by further, carefully controlled work.

The ratios of stretch to elongation at grain crack varied considerably. For 11 lots of acetone-dehydrated hide, they ranged from 0.44 to 0.63; and for 11 lots of treated hide specimens, from 0.30 to 0.72. These larger variations might be expected because cracks were difficult to observe on a majority of these specimens, which were white untanned skin or white leather. Also, cracks first appear over the tip of the plunger in the burst test, and this area is less than half of that over which they may be found in the tensile specimen.

SUMMARY

Distension of the specimen during a ball burst test measured by height of rise of plunger has been calculated as percent stretch. A few comparisons of such stretch values with elongation values measured on a tensile specimen are reported. Agreement for raw skin specimens was lacking but was fair for tanned specimens.

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