Designation: D2210 – 13

Standard Test Method for Grain Crack and Extension of Leather by the Mullen Test[1]

This standard is issued under the fixed designation D2210; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the resistance of leather to grain cracking and for measuring the extension of the leather. It is limited to light leathers such as shoe uppers, garment, gloves, and upholstery. This test method does not apply to wet blue.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1610 Practice for Conditioning Leather and Leather Products for Testing

D1813 Test Method for Measuring Thickness of Leather Test Specimens

3. Terminology

3.1 *Definitions:*

3.1.1 *extension*—the amount of stretch of leather over the diaphragm under pressure.

3.1.2 *grain cracking*—the appearance of cracks on the surface of the leather as the leather is extended over a diaphragm under pressure to form a sphere.

4. Significance and Use

4.1 The test method is designed to measure the force required to crack the grain of leather by steady hydraulic pressure on a diaphragm of definite diameter applied to the flesh side of the specimen to form a sphere. The cracking of the grain is a result of failure under elongation or stretch. The elongation or stretch of the leather can be measured at different loads or at the failure of the grain to determine if the stress leather will withstand under lasting conditions. Cuts, scratches, and other defects will cause considerable variation in the results by concentration of the applied force to the weak points. This test method is excellent for manufacturing control, specification acceptance, and service evaluation in the lasting property of leather. This test method may not apply when the conditions of the test employed differ widely from those specified in the test method.

5. Apparatus

5.1 *Testing Machine,*[3] as shown in Fig. 1. The machine shall be hand- or power-driven. The machine shall hold the specimen firmly, without slippage, between two annular, plane, unpolished (matte) surfaces that may have fine, spiral tool marks not over 0.010 in. (0.25 mm) in depth.

5.2 *Upper Clamping Surface*—The upper clamping surface (clamping ring) shall have a circular opening 1.240 ± 0.010 in. (31.50 ± 0.25 mm) in diameter and shall be connected to the clamping mechanism through a swivel joint to ensure an even clamping pressure.

5.3 *Lower Clamping Surface*—The lower clamping surface (diaphragm plate) shall be 0.219 ± 0.003 in. (5.56 ± 0.08 mm) thick and have an opening of 1.240 ± 0.01 in. (31.50 ± 0.52 mm) in diameter. The circular edges of the openings that come in contact with the specimen and the rubber diaphragm shall be rounded to a radius of not over 0.025 in. (0.64 mm) to prevent any cutting action. During the test, the circular edges of the

[1] This test method is under the jurisdiction of ASTM Committee D31 on Leather and is the direct responsibility of Subcommittee D31.03 on Footwear. This test method was developed in cooperation with the American Leather Chemists Assn. (Standard Method E58 – 1965).

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The sole source of supply of the apparatus known to the committee at this time is B. F. Perkins, 939 Chicopee St., Chicopee, MA 01013-2797, (413) 536-1311. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

FIG. 1 Mullen Tester, Model A

openings in the two clamping plates shall be substantially concentric with no overlapping of any point.

5.4 *Diaphragm,* of rubber, 0.034 ± 0.002 in. (0.86 ± 0.05 mm) thick, clamped under the lower clamping plate so that, before the diaphragm is stretched by pressure underneath it, the center of its upper surface is below the plane of the clamping surface.

5.5 *Dial Gage,* as shown in Fig. 2, to measure the extension of the leather specimen and mounted on the machine through screw shaft or on side of clamps on platform. This gage shall be calibrated to read directly to the nearest 0.001 in. (0.03 mm). It shall be equipped with a flat anvil and a presser foot.

5.6 *Bourdon Tube*—The apparatus shall be equipped with a Bourdon tube, maximum-reading-type, pressure gage graduated in pounds-force per square inch and accurate throughout the entire range of its scale to within a value of 1 % of its maximum capacity. The capacity of the gage shall be such that the individual readings will be not less than 25 % nor more than 75 % of the total capacity of the gage.

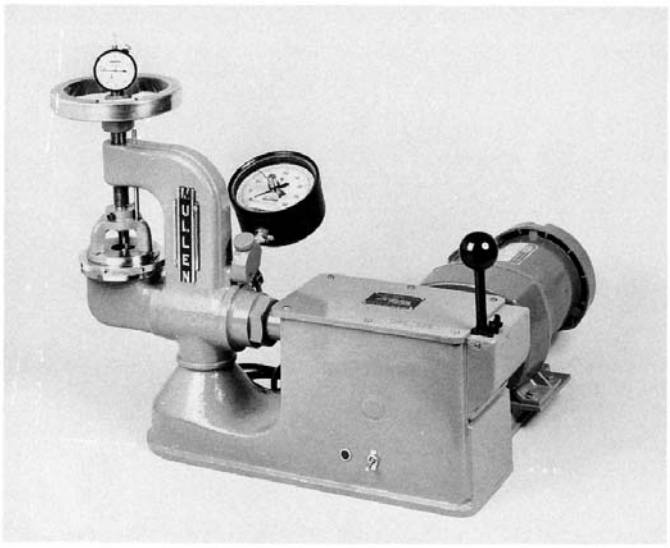

FIG. 2 Mullen Tester with Dial Gage

5.7 *Pressure Control*—The machine shall be equipped with means of applying controlled increasing hydraulic pressure to the underside of the diaphragm until the specimen cracks. This pressure shall be generated by a piston forcing a liquor (usually glycerin) into the pressure chamber of the apparatus. For machines shown in Fig. 1 where the cracking pressure is the only measurement, the pressure will be generated by pumping liquid at a rate of 170 ± 10 mL/min or by turning a handwheel at approximately 30 r/min. Record pumping rate or cranking rate. For machines shown in Fig. 2 where cracking pressure and extension are measured, the pressure will be generated by pumping liquid at a rate of 15 ± 2 mL/min or by turning a handwheel at approximately 3 r/min.

NOTE 1—When equipment does not have a gauge to measure the flow rate or uses a hand crank method, consult the equipment manufacturer or operating manual. Results from the different tester may not be comparable because of the different flow rates.

5.8 *Thickness Gage*—A dead-weight type of thickness gage as described in Test Method D1813.

6. Test Specimen

6.1 The specimen shall be a square of leather 3 by 3 in. (76 by 76 mm) cut from the test unit of leather.

6.2 The specimen shall be free of mechanical damage and surface defects.

7. Conditioning

7.1 All specimens shall be conditioned in accordance with Practice D1610.

8. Procedure

8.1 Determine the thickness of the specimen by taking three measurements in the area to be cracked and determine the average value.

8.2 Place the flesh side of the specimen in contact with the rubber diaphragm of the testing machine.

8.3 Clamp the specimen securely in the apparatus in such a manner that the leather will not be damaged.

8.4 Rest the presser foot of the extension gage on the flat surface of the specimen and set the gage at zero.

8.5 Apply pressure to the specimen until the specimen cracks.

8.6 At the moment the first crack appears in the specimen stop the machine, note the applied pressure from the gage, and record the value as the cracking strength of the specimen.

9. Report

9.1 The report shall include the following:

9.1.1 Cracking pressure to the nearest 5 psi (35 kPa) for each specimen or averaged and reported as the average of the test unit,

9.1.2 Extension of the leather to the nearest 0.001 in. (0.03 mm), converted to percentage (see Annex A1) and reported as percentage stretch, and

9.1.3 Thickness to the nearest 0.001 in. (0.03 mm) reported for each specimen or averaged and reported as the thickness of the sample.

9.1.4 Speed the liquid was pumped to build pressure to the nearest 10 % (see 5.7). Record revolutions per minute.

10. Precision and Bias

10.1 The following criteria may be used to judge the acceptability of the results if at least 15 units have been tested:

10.1.1 *One Operator, Duplicate Specimens, Same Skin*—Results by the same operator in duplicate adjacent specimens in a skin taken from the official sampling position should not be considered suspect unless the coefficient of variation exceeds:

Leathers	Cracking Pressure, psi	Extension at Grain Crack, %
Shoe upper	26	13
Upholstery	17	14
Calfskin[A]	16	22
Glove	11	20

[A] 3 ± 1 oz, 0.0468 ± 0.0156 in. (1.189 ± 0.396 mm).

10.1.2 *Two Laboratories, Duplicate Specimens, Same Skin*—Results for the same group of light leathers listed in 10.1.1 submitted by each of two laboratories on duplicate adjacent specimens in a skin taken from the official sampling position should not be considered suspect unless the two average results differ by more than 5 %.

NOTE 2—The reproducibility reported in 10.1.2 is based on data obtained at two laboratories, and a different operator. The results show close correlation between laboratories.

NOTE 3—The results given in Section 10 are based on tests on 30 sides of leather and do not apply to findings and cut parts.

NOTE 4—The precision data for between skins are not included because the results were based on different skins from several production lots. The variables in leather for between skins will give a higher variation of the results, but this factor should not affect the precision of the method.

11. Keywords

11.1 burst strength extension; grain crack; leather; Mullen

ANNEX

(Mandatory Information)

A1. DERIVATION OF EQUATION FOR PERCENTAGE STRETCH

A1.1 Referring to Fig. A1.1,

h = deflection (measured by Mullen tester), and

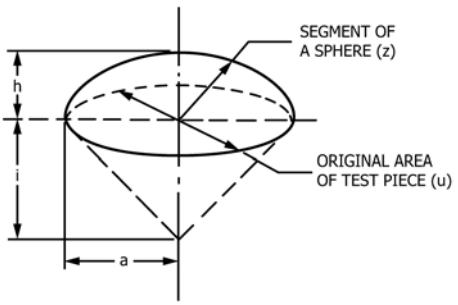

FIG. A1.1 Geometry for Derivation of Equation for Percentage Stretch

TABLE A1.1 Conversion Table From *h* to Percentage Stretch ($2.56h^2 \times 100$) (for Values of *h* Between 0.2 and 0.5 in.)

h, in.	Stretch, %	*h*, in.	Stretch,%	*h*, in.	Stretch, %	*h*, in.	Stretch, %
200×10^{-3}	10.24	276×10^{-3}	19.50	352×10^{-3}	31.72	428×10^{-3}	46.90
201	10.34	277	19.64	353	31.90	429	47.11
202	10.45	278	19.78	354	32.08	430	47.33
203	10.55	279	19.93	355	32.26	431	47.55
204	10.65	280	20.07	356	32.44	432	47.78
205	10.76	281	20.21	357	32.63	433	48.00
206	10.86	282	20.36	358	32.81	434	48.22
207	10.97	283	20.50	359	32.99	435	48.44
208	11.08	284	20.65	360	33.18	436	48.66
209	11.18	285	20.70	361	33.36	437	48.89
210	11.29	286	20.94	362	33.55	438	49.11
211	11.40	287	21.09	363	33.73	439	49.34
212	11.51	288	21.23	364	33.92	440	49.56
213	11.61	289	21.38	365	34.11	441	49.79
214	11.72	290	21.53	366	34.29	442	50.01
215	11.83	291	21.68	367	34.48	443	50.24
216	11.94	292	21.83	368	34.67	444	50.47
217	12.08	293	21.98	369	34.86	445	50.69
218	12.17	294	22.13	370	35.05	446	50.92
219	12.28	295	22.28	371	35.24	447	51.15
220	12.39	296	22.43	372	35.43	448	51.38
221	12.50	297	22.58	373	35.62	449	51.61
222	12.62	298	22.73	374	35.81	450	51.84
223	12.73	299	22.89	375	36.00	451	52.07
224	12.85	300	23.04	376	36.19	452	52.30
225	12.96	301	23.19	377	36.39	453	52.53
226	13.08	302	23.35	378	36.58	454	52.77
227	13.19	303	23.50	379	36.77	455	53.00
228	13.31	304	23.66	380	36.97	456	53.23
229	13.42	305	23.81	381	37.16	457	53.47
230	13.54	306	23.97	382	37.36	458	53.70
231	13.66	307	24.13	383	37.55	459	53.93
232	13.78	308	24.29	384	37.75	460	54.17
233	13.90	309	24.44	385	37.95	461	54.41
234	14.02	310	24.60	386	38.14	462	54.64
235	14.14	311	24.76	387	38.34	463	54.88
236	14.26	312	24.92	388	38.54	464	55.12
237	14.38	313	25.08	389	38.74	465	55.35
238	14.50	314	25.24	390	38.94	466	55.59
239	14.62	315	25.40	391	39.14	467	55.83
240	14.75	316	25.56	392	39.34	468	56.07
241	14.87	317	25.73	393	39.54	469	56.31
242	14.99	318	25.89	394	39.74	470	56.55
243	15.12	319	26.05	395	39.94	471	56.79
244	15.24	320	26.21	396	40.14	472	57.03
245	15.37	321	26.38	397	40.35	473	57.27
246	15.49	322	26.54	398	40.55	474	57.52
247	15.62	323	26.71	399	40.76	475	57.76
248	15.75	324	26.87	400	40.96	476	58.00
249	15.87	325	27.04	401	41.17	477	58.25
250	16.00	326	27.21	402	41.37	478	58.49
251	16.13	327	27.37	403	41.58	479	58.73
252	16.26	328	27.54	404	41.78	480	58.98
253	16.39	329	27.71	405	41.99	481	59.23
254	16.52	330	27.88	406	42.20	482	59.47
255	16.65	331	28.05	407	42.41	483	59.72
256	16.78	332	28.22	408	42.61	484	59.97
257	16.91	333	28.39	409	42.82	485	60.22
258	17.04	334	28.56	410	43.03	486	60.47
259	17.17	335	28.73	411	43.24	487	60.72
260	17.31	336	28.90	412	43.45	488	60.96
261	17.44	337	29.07	413	43.67	489	61.21
262	17.57	338	29.35	414	43.88	490	61.47
263	17.71	339	29.42	415	44.09	491	61.72
264	17.84	340	29.59	416	44.30	492	61.97
265	17.98	341	29.77	417	44.52	493	62.22
266	18.11	342	29.94	418	44.73	494	62.47
267	18.25	343	30.12	419	44.94	495	62.73
268	18.39	344	30.29	420	45.16	496	62.98
269	18.52	345	30.47	421	45.37	497	63.23
270	18.66	346	30.65	422	45.59	498	63.49
271	18.80	347	30.82	423	45.81	499	63.74
272	18.94	348	31.00	424	46.02	500	64.00
273	19.08	349	31.18	425	46.24	...	...
274	19.22	350	31.36	426	46.46	...	...
275	19.36	351	31.54	427	46.68	...	...

TABLE A1.2 Conversion Table From *h* to Percentage Stretch ($2.56h^2 \times 100$) (for Values of *h*Between 5.08 and 12.70 mm)

h, mm	Stretch, %	*h*, mm	Stretch,%	*h*, mm	Stretch, %	*h*, mm	Stretch, %
5.08	10.24	6.99	19.36	8.89	31.36	10.80	46.24
5.11	10.34	7.01	19.50	8.92	31.54	10.82	46.46
5.13	10.45	7.04	19.64	8.94	31.72	10.85	46.68
5.16	10.55	7.06	19.78	8.97	31.90	10.87	46.90
5.18	10.65	7.09	19.93	8.99	32.08	10.90	47.11
5.21	10.76	7.11	20.07	9.02	32.26	10.92	47.33
5.23	10.86	7.14	20.21	9.04	32.44	10.95	47.55
5.26	10.97	7.16	20.36	9.07	32.63	10.97	47.78
5.28	11.08	7.19	20.50	9.09	32.81	11.00	48.00
5.31	11.18	7.21	20.65	9.12	32.99	11.02	48.22
5.33	11.29	7.24	20.70	9.14	33.18	11.05	48.44
5.36	11.40	7.26	20.94	9.17	33.36	11.07	48.66
5.38	11.51	7.29	21.09	9.19	33.55	11.10	48.89
5.41	11.61	7.32	21.23	9.22	33.73	11.13	49.11
5.44	11.72	7.34	21.38	9.25	33.92	11.15	49.34
5.46	11.83	7.37	21.53	9.27	34.11	11.18	49.56
5.49	11.94	7.39	21.68	9.30	34.29	11.20	49.79
5.51	12.08	7.42	21.83	9.32	34.48	11.23	50.01
5.54	12.17	7.44	21.98	9.35	34.67	11.25	50.24
5.56	12.28	7.47	22.13	9.37	34.86	11.28	50.47
5.59	12.39	7.49	22.28	9.40	35.05	11.30	50.69
5.61	12.50	7.52	22.43	9.42	35.24	11.33	50.92
5.64	12.62	7.54	22.58	9.45	35.43	11.35	51.15
5.66	12.73	7.57	22.73	9.47	35.62	11.38	51.38
5.69	12.85	7.59	22.89	9.50	35.81	11.40	51.61
5.72	12.96	7.62	23.04	9.53	36.00	11.43	51.84
5.74	13.08	7.65	23.19	9.55	36.19	11.46	52.07
5.77	13.19	7.67	23.35	9.58	36.39	11.48	52.30
5.79	13.31	7.70	23.50	9.60	36.58	11.51	52.53
5.82	13.42	7.72	23.66	9.63	36.77	11.53	52.77
5.84	13.54	7.75	23.81	9.65	36.97	11.56	53.00
5.87	13.66	7.77	23.97	9.68	37.16	11.58	53.23
5.89	13.78	7.80	24.13	9.70	37.36	11.61	53.47
5.92	13.90	7.82	24.29	9.73	37.55	11.63	53.70
5.94	14.02	7.85	24.44	9.75	37.75	11.66	53.93
5.97	14.14	7.87	24.60	9.78	37.95	11.68	54.17
5.99	14.26	7.90	24.76	9.80	38.14	11.71	54.41
6.02	14.38	7.92	24.92	9.83	38.34	11.73	54.64
6.05	14.50	7.95	25.08	9.86	38.54	11.76	54.88
6.07	14.62	7.98	25.24	9.88	38.74	11.79	55.12
6.10	14.75	8.00	25.40	9.91	38.94	11.81	55.35
6.12	14.87	8.03	25.56	9.93	39.14	11.84	55.59
6.15	14.99	8.05	25.73	9.96	39.34	11.86	55.83
6.17	15.12	8.08	25.89	9.98	39.54	11.89	56.07
6.20	15.24	8.10	26.05	10.01	39.74	11.91	56.31
6.22	15.37	8.13	26.21	10.03	39.94	11.94	56.55
6.25	15.49	8.15	26.38	10.06	40.14	11.96	56.79
6.27	15.62	8.18	26.54	10.08	40.35	11.99	57.03
6.30	15.75	8.20	26.71	10.11	40.55	12.01	57.27
6.32	15.87	8.23	26.87	10.13	40.76	12.04	57.52
6.35	16.00	8.26	27.04	10.16	40.96	12.07	57.76
6.38	16.13	8.28	27.21	10.19	41.17	12.09	58.00
6.40	16.26	8.31	27.37	10.21	41.37	12.12	58.25
6.43	16.39	8.33	27.54	10.24	41.58	12.14	58.49
6.45	16.52	8.36	27.71	10.26	41.78	12.17	58.73
6.48	16.65	8.38	27.88	10.29	41.99	12.19	58.98
6.50	16.78	8.41	28.05	10.31	42.20	12.22	59.23
6.53	16.91	8.43	28.22	10.34	42.41	12.24	59.47
6.55	17.04	8.46	28.39	10.36	42.61	12.27	59.72
6.58	17.17	8.48	28.56	10.39	42.82	12.29	59.97
6.60	17.31	8.51	28.73	10.41	43.03	12.32	60.22
6.63	17.44	8.53	28.90	10.44	43.24	12.34	60.47
6.65	17.57	8.56	29.07	10.46	43.45	12.37	60.72
6.68	17.71	8.59	29.35	10.49	43.67	12.40	60.96
6.71	17.84	8.61	29.42	10.52	43.88	12.42	61.21
6.73	17.98	8.64	29.59	10.54	44.09	12.45	61.47
6.76	18.11	8.66	29.77	10.57	44.30	12.47	61.72
6.78	18.25	8.69	29.94	10.59	44.52	12.50	61.97
6.81	18.39	8.71	30.12	10.62	44.73	12.52	62.22
6.83	18.52	8.74	30.29	10.64	44.94	12.55	62.47
6.86	18.66	8.76	30.47	10.67	45.16	12.57	62.73
6.88	18.80	8.79	30.65	10.69	45.37	12.60	62.98
6.91	18.94	8.81	30.82	10.72	45.59	12.62	63.23
6.93	19.08	8.84	31.00	10.74	45.81	12.65	63.49
6.96	19.22	8.86	31.18	10.77	46.02	12.67	63.74
						12.70	64.00

a = radius of test area (0.625 in. = ⅝ in.)

From geometry, $z = 2\pi rh$, $u = \pi a^2$, and $h + i = r$. but:

$$i = \sqrt{r^2 - a^2} \quad \text{(A1.1)}$$

then:

$$h + \sqrt{r^2 - a^2} = r \quad \text{(A1.2)}$$

solving for r:

$$r = (a^2 + h^2)/2h \quad \text{(A1.3)}$$

then:

$$\begin{aligned} \text{Stretch, \%} &= 100\,[(z - u)/u] \\ &= 100\,[(2\pi rh - \pi a^2)/\pi a^2] \\ &= 100\left(\frac{2h\left[(a^2 + h^2)/2h\right] - a^2}{a^2}\right) \\ &= 100\,(h^2/a^2) = 100\,h^2/(25/64) = 100 \times (64/25)h^2 \\ &= 100\,(2.56\,h^2) \end{aligned}$$