บรรณานุกรม

ทรงพล เจริญรักษา และคณะ. **การแยกเส้นใยจากผักตบชวา.** มหาวิทยาลัยเชียงใหม่. 2546.

ธนธร ทองสัมฤทธิ์ และสุชปา เนตรประดิษฐ์, **การผลิตเยื่อและกระดาษจากใบฐูปฤาษีเพื่อนวัตกรรมบรรจุภัณฑ์,** การประชุมวิชาการวิทยาศาสตร์และเทคโนโลยีแห่งประเทศไทย ครั้งที่ 31, มหาวิทยาลัยเทคโนโลยีสุรนารี, จ.นครราชสีมา, 2548.

นัยนา นิยมวัน. **การผลิตกระดาษ.** [ออนไลน์]. สถาบันวิจัยวิทยาศาสตร์และเทคโนโลยีแห่งประเทศไทย. แหล่งที่มา: http://www.tistr.or.th/t/publication/page_area_show_bc.asp?i1=77&i2=7, 30 กรกฎาคม 2552.

นิศากร เจริญดี. 2546. **การผลิตแผ่นชิ้นไม้อัดจากผักตบชวา,** การประชุมการป่าไม้ประจำปี 2545 : ศักยภาพของป่าไม้ต่อการฟื้นฟูเศรษฐกิจไทย . กรมอุทยานแห่งชาติ สัตว์ป่าและพันธุ์พืช, กรุงเทพฯ.

บริษัท ไทยเปเปอร์บอกซ์ จำกัด. **ชนิดของกระดาษคราฟท์.** [ออนไลน์]. สืบค้นจาก http://www. thaipaperbox.com, (15/11/2553).

ปฏิญญ์ อิ่มกระจ่าง และคณะ. **สมบัติของเส้นใยจากผักตบ.** มหาลัยวิทยาลัยราชภัฏวไลยลงกรณ์. 2546.

ปิยพล นาคเบญจพร และ ไตรรงค์ ไกรสุรพงศ์, **การผลิตเยื่อกระดาษด้วยเทคนิคฟอร์มาเซลจากเปลือกปอสา,**มหาวิทยาลัยเกษตรศาสตร์ วิทยาเขตบางเขน คณะวิศวกรรมศาสตร์. 2543

โรงเรียนบางระจันวิทยา. **ศึกษาการใช้ส่วนต่างๆของกล้วยมาเป็นเยื่อประสาน.** อำเภอบางระจัน จังหวัด สิงห์บุรี. 2541.

โรงเรียนสุราษฎร์พิทยา. **การคัดเลือกเยื่อในการทำกระดาษ.** อำเภอเมืองสุราษฎร์ธานี จังหวัดสุราษฎร์ธานี. 2533.

วิขัณฑ์ อรรณพานุรักษ์. **การผลิตเยื่อเคมีจากไม้ยูคาลิปตัสโดยใช้กรดอะซิติคที่ความดันบรรยากาศ,** ใน การประชุมทางวิชาการของมหาวิทยาลัยเกษตรศาสตร์ ครั้งที่ 41: สาขาวิทยาศาสตร์ สาขาการจัดการทรัพยากรและสิ่งแวดล้อม. มหาวิทยาลัยเกษตรศาสตร์, กรุงเทพฯ. 2546.

วิขัณฑ์ อรรณพานุรักษ์และคณะ. **การผลิตเยื่อคราฟท์จากหญ้าแฝก.** [ออนไลน์] งานพัฒนาเคมีผลผลิตป่าไม้. แหล่งที่มา: http://www.forest.go.th/forprod/chemical/pdf/การผลิตเยื่อคราฟท์จากหญ้าแฝก.pdf, 28 กรกฎาคม 2552.

วิทยา ปั้นสุวรรณ. **การวิเคราะห์องค์ประกอบทางเคมีของวัตถุดิบที่ไม่ใช่ไม้สำหรับอุตสาหกรรมเยื่อและกระดาษ.** โครงการถ่ายทอดงานวิจัยเพื่ออุตสาหกรรมเยื่อและกระดาษจากปอสา. แหล่งที่มา: http://posaa.kapi.ku.ac.th/Document/PDF/Final Rep2001_V2/Full_2A-1-1(1).pdf, 20 กรกฎาคม 2552.

วิทยาลัยประมงติณสูลานนท์. **สภาวะการแยกเส้นใยจากต้นธูปฤาษี.** วิทยาลัยประมงติณสูลานนท์ จังหวัด สงขลา. 2552.

วุฒินัน คงทัด. **สารกระจายเยื่อเพื่อช่วยในความสำเสมอ.** [ออนไลน์]. สืบค้นจากhttp:// posaa.kapi.ku.ac.th/Document/PDF, (15/11/2553).

สถาบันค้นคว้าและพัฒนาผลิตผลทางการเกษตรและอุตสาหกรรมเกษตร. **ศึกษาสารกระจายเพื่อความสม่ำเสมอของกระดาษ.** สถาบันค้นคว้าและพัฒนาผลิตผลทางการเกษตรและอุตสาหกรรมเกษตร มหาวิทยาลัยเกษตรศาสตร์ วิทยาเขตบางเขน. 2545.

สุชปา เนตรประดิษฐ์ และคณะ. **การพัฒนากระดาษใบสับปะรดที่เหมาะสมต่อการพิมพ์บรรจุภัณฑ์สำหรับสินค้าหนึ่งตำบลหนึ่งผลิตภัณฑ์,** ใน การประชุมวิชาการวิทยาศาสตร์และเทคโนโลยีแห่งประเทศไทย (วทท.) ครั้งที่ 31. สมาคมวิทยาศาสตร์แห่งประเทศไทยในพระบรมราชูปถัมภ์, 2548.

สุนันท์ ลิ้มตระกูลและคณะ. **การเลือกเทคโนโลยีที่เหมาะสมในการผลิตเยื่อกระดาษจากปอแก้ว.** (รายงานฉบับสมบูรณ์) 2542.

เสาวรจน์ โสภาจารีย์. **การเสริมแรงด้วยเส้นใยผักตบชวา.** ศูนย์ศิลปาชีพบางไทร จังหวัด พระนคร ศรีอยุธยา. 2532.

เสาวรจน์ ช่วยจุลจิตร์ และ อรอุษา สรวารี. **การเสริมแรงยางธรรมชาติด้วยเส้นใยผักตบชวา.** 2532.

อุราวรรณ อุ่นแก้ว. **ถ่านกัมมันต์.** [ออนไลน์]. สืบค้นจาก http://www.napatsarun.com/ carbon.doc (15/11/2553).

_____, **package.** [ออนไลน์]. แหล่งที่มา: http://www.mew6.com/composer/ package/ package_18.php, 30 กรกฎาคม 2552.

_____, **การผลิตกระดาษจากธูปฤาษีและผักตบชวา.** [ออนไลน์]. แหล่งที่มา: http://www.school.net.th/library/webcontest2003/100team/dlbs085/interEx/ informate/ paktob/appear.htm, 28 กรกฎาคม 2552.

_____, **กระบวนการผลิตกระดาษ.** แหล่งที่มา: http://www.supremeprint.net/ index.php?lay =show&ac=article&Id=538771417, 28 กรกฎาคม 2552.

ภาคผนวก

ภาคผนวก ก

การทดสอบสมบัติต่างๆจากเยื่อจากผักตบชวา สับปะรด กล้วย

ตารางที่ ก1 สมบัติทางกายภาพของกระดาษเยื่อผักตบชวา 100 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.361	23	230
2	0.365	21	210
3	0.329	20	240
4	0.336	23	210
5	0.404	19	220
6	0.412	24	240
7	0.375	21	250
8	0.404	20	220
9	0.356	19	270
10	0.328	22	260
ค่าเฉลี่ย	**0.367**	**21**	**235**
R^2	**0.962**	**0.970**	**0.970**

จากตารางที่ ก1 พบว่ากระดาษที่ได้จากเยื่อผักตบ 100 % มีความหนาเฉลี่ย 0.367 มิลลิเมตร ความต้านทานแรงดันทะลุ 21 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 235 มิลลินิวตัน

ตารางที่ ก2 สมบัติทางกายภาพของกระดาษจากเยื่อสับปะรด 100 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.387	22	240
2	0.394	22	250
3	0.391	24	220
4	0.397	23	230
5	0.403	24	250
6	0.412	25	280
7	0.425	21	240
8	0.418	26	260
9	0.415	23	270
10	0.396	26	220
ค่าเฉลี่ย	**0.404**	**24**	**246**
R^2	**0.966**	**0.972**	**0.971**

จากตารางที่ ก2 พบว่ากระดาษที่ได้จากเยื่อสับปะรด 100 % มีความหนาเฉลี่ย 0.404 มิลลิเมตร ความต้านทานแรงดันทะลุ 24 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 246 มิลลินิวตัน

ตารางที่ ก3 สมบัติทางกายภาพของกระดาษจากเยื่อกล้วย 100 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.382	24	240
2	0.374	25	250
3	0.364	24	240
4	0.378	25	270
5	0.406	26	270
6	0.411	27	260
7	0.384	23	250
8	0.412	28	280
9	0.373	26	290
10	0.409	27	280
ค่าเฉลี่ย	**0.389**	**26**	**263**
R^2	**0.928**	**0. 973**	**0.973**

จากตารางที่ ก3 พบว่ากระดาษที่ได้จากเยื่อกล้วย 100 % มีความหนาเฉลี่ย 0.389 มิลลิเมตร ความต้านทานแรงดันทะลุ 26 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 263 มิลลินิวตัน

การทดสอบทางกายภาพของกระดาษจากเยื่อผสมชนิดต่างๆ

ตารางที่ ก4 อัตราส่วนผักตบชวา 70 % สับปะรด 10 % กล้วย 20 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.416	28	270
2	0.450	33	290
3	0.471	30	290
4	0.477	29	320
5	0.485	28	330
6	0.452	31	310
7	0.425	34	300
8	0.462	28	340
9	0.412	33	290
10	0.410	37	350
ค่าเฉลี่ย	**0.445**	**31**	**309**
R^2	**0.946**	**0.925**	**0.966**

จากตารางที่ ก4 พบว่ากระดาษที่ได้จากเยื่อผักตบชวา 70 % เยื่อสับปะรด 10% เยื่อกล้วย 20 % มีความหนาเฉลี่ย 0.445 มิลลิเมตร ความต้านทานแรงดันทะลุ 31 กิโลนิวตันต่อตารางเมตร ความคง ทนต่อแรงฉีกขาด 309 มิลลินิวตัน

ตารางที่ ก5 อัตราส่วนผักตบชวา 70 % สับปะรด 15 % กล้วย 15 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.447	29	250
2	0.434	27	240
3	0.450	24	260
4	0.498	28	290
5	0.486	29	240
6	0.477	31	270
7	0.475	28	230
8	0.432	30	280
9	0.433	31	310
10	0.488	27	280
ค่าเฉลี่ย	**0.462**	**28**	**261**
R^2	**0.969**	**0.908**	**0.972**

จากตารางที่ ก5 พบว่ากระดาษที่ได้จากเยื่อผักตบชวา 70 % เยื่อสับปะรด 15 % เยื่อกล้วย 15 % มีความหนาเฉลี่ย 0.462 มิลลิเมตร ความต้านทานแรงดันทะลุ 28 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 261 มิลลินิวตัน

ตารางที่ ก6 อัตราส่วนผักตบชวา 70 % สับปะรด 20 % กล้วย 10 %

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.441	33	260
2	0.567	27	240
3	0.498	26	270
4	0.471	25	310
5	0.440	23	300
6	0.448	26	280
7	0.415	25	270
8	0.482	28	270
9	0.517	31	280
10	0.581	29	310
ค่าเฉลี่ย	**0.486**	**27**	**279**
R^2	**0.962**	**0.933**	**0.924**

จากตารางที่ ก6 พบว่ากระดาษที่ได้จากเยื่อผักตบชวา 70 % เยื่อสับปะรด 20 % เยื่อกล้วย 10 % มีความหนาเฉลี่ย 0.486 มิลลิเมตร ความต้านทานแรงดันทะลุ 27 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 279 มิลลินิวตัน

การทดสอบประเภทของสารกระจายเยื่อต่อสมบัติทางกายภาพของกระดาษ

ตารางที่ ก7 ใช้กระเจี๊ยบ 5 g/l เป็นสารกระจายเยื่อ

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.485	31	290
2	0.514	34	280
3	0.523	36	350
4	0.512	33	330
5	0.492	32	320
6	0.473	29	340
7	0.468	28	320
8	0.475	29	310
9	0.478	29	310
10	0.493	32	330
ค่าเฉลี่ย	**0.491**	**31**	**311**
R^2	**0.969**	**0.930**	**0.950**

จากตารางที่ ก7 พบว่ากระดาษที่ได้จากการใส่สารกระจายเยื่อ กระเจี๊ยบ 5 g/l มีความหนาเฉลี่ย 0.491 มิลลิเมตร ความต้านทานแรงดันทะลุ 31 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 311 มิลลินิวตัน

ตารางที่ ก8 อัตราส่วนว่านหางจระเข้ 5 g/l เป็นสารกระจายเยื่อ

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.473	28	310
2	0.481	31	320
3	0.498	29	330
4	0.476	27	290
5	0.478	30	280
6	0.494	32	300
7	0.512	28	320
8	0.496	32	330
9	0.482	27	320
10	0.487	29	330
ค่าเฉลี่ย	**0.488**	**29**	**320**
R^2	**0.950**	**0.950**	**0.930**

จากตารางที่ ก8 พบว่ากระดาษที่ได้จากการใส่สารกระจายเยื่อ ว่านหางจระเข้ 5 g/l มีความหนาเฉลี่ย 0.488 มิลลิเมตร ความต้านทานแรงดันทะลุ 29 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 320 มิลลินิวตัน

ตารางที่ ก9 อัตราส่วนสาร Acramin 5 g/l เป็นสารกระจายเยื่อ

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.498	33	330
2	0.487	31	320
3	0.513	34	340
4	0.489	32	320
5	0.496	33	330
6	0.523	35	350
7	0.530	36	340
8	0.518	34	320
9	0.523	34	330
10	0.542	37	350
ค่าเฉลี่ย	**0.512**	**34**	**333**
R^2	**0.930**	**0.969**	**0.932**

จากตารางที่ ก9 พบว่ากระดาษที่ได้จากการใส่สารกระจายเยื่อ สาร Acramin 5 g/l มีความหนาเฉลี่ย 0.512 มิลลิเมตร ความต้านทานแรงดันทะลุ 34 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 333 มิลลินิวตัน

การเพิ่มความแข็งแรงของกระดาษด้วยถ่านกัมมันต์

ตารางที่ ก10 ไม่ใส่ถ่านกัมมันต์

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.487	31	330
2	0.489	32	320
3	0.496	33	340
4	0.498	33	320
5	0.513	34	330
6	0.518	34	350
7	0.523	34	340
8	0.523	35	320
9	0.530	36	330
10	0.542	37	350
ค่าเฉลี่ย	**0.512**	**34**	**333**
R^2	**0.969**	**0.946**	**0.932**

จากตารางที่ ก10 พบว่ากระดาษที่ไม่ได้ใส่ถ่านกัมมันต์ มีความหนาเฉลี่ย 0.512 มิลลิเมตร ความต้านทานแรงดันทะลุ 34 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 333 มิลลินิวตัน

ตารางที่ ก11 อัตราส่วนถ่านกัมมันต์ 5%

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.492	33	330
2	0.497	33	340
3	0.502	36	350
4	0.505	35	350
5	0.518	37	350
6	0.523	37	350
7	0.53	38	360
8	0.531	40	370
9	0.533	39	390
10	0.547	41	410
ค่าเฉลี่ย	**0.519**	**37**	**360**
R^2	**0.972**	**0.926**	**0.933**

จากตารางที่ ก11 พบว่ากระดาษที่ใส่ถ่านกัมมันต์ มีความหนาเฉลี่ย 0.519 มิลลิเมตร ความต้านทานแรงดันทะลุ 37 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 360 มิลลินิวตัน

การทดสอบของสารสะท้อนน้ำ

ตารางที่ ก12 ไม่ใส่สาร Waterproof

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.492	33	330
2	0.497	33	340
3	0.502	36	350
4	0.505	35	350
5	0.518	37	350
6	0.523	37	350
7	0.530	38	360
8	0.531	40	370
9	0.533	39	390
10	0.547	41	410
ค่าเฉลี่ย	**0.519**	**37**	**360**
R^2	**0.972**	**0.926**	**0.933**

จากตารางที่ ก12 พบว่ากระดาษที่ใส่สารสะท้อนน้ำ มีความหนาเฉลี่ย 0.519 มิลลิเมตร ความต้านทานแรงดันทะลุ 37 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 360 มิลลินิวตัน

ตารางที่ ก13 ใส่สาร Waterproof 2 g/l

ครั้งที่	ความหนา (mm)	ความต้านทานแรงดันทะลุ (kN/m^2)	ความคงทนต่อแรงฉีกขาด (mN)
1	0.548	42	410
2	0.534	35	360
3	0.542	36	370
4	0.519	36	340
5	0.523	38	350
6	0.543	35	360
7	0.547	36	370
8	0.529	35	350
9	0.544	37	360
10	0.538	42	360
ค่าเฉลี่ย	**0.540**	**37**	**363**
R^2	**0.939**	**0.913**	**0.908**

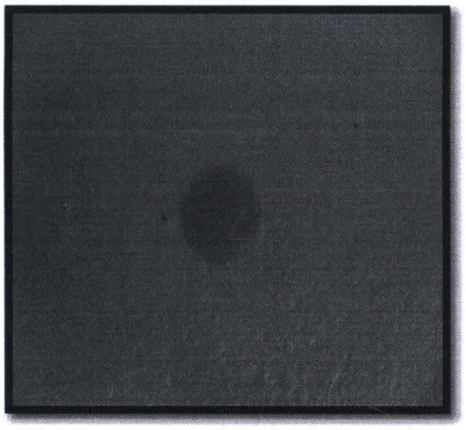
จากตารางที่ ก13 พบว่ากระดาษที่ใส่ถ่านกัมมันต์ มีความหนาเฉลี่ย 0.540 มิลลิเมตร ความต้านทานแรงดันทะลุ 37 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 363 มิลลินิวตัน

การทดสอบสมบัติทางกายภาพของสารสะท้อนน้ำ

ตารางที่ ก14 สมบัติทางกายภาพของกระดาษจากการใส่สารสะท้อนน้ำ

สารสะท้อนน้ำ	ความหนา (mm)		ความต้านทานแรงดันทะลุ (kN/m^2)		ความคงทนต่อแรงฉีกขาด (mN)	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
ใส่สารสะท้อนน้ำ 0 g/l	0.52	0.02	36.90	2.73	360	24.04
ใส่สารสะท้อนน้ำ 2 g/l	0.54	0.01	37.20	2.70	363	18.89

จากตางรางที่ ก14 พบว่ากระดาษที่ไม่ใส่สารสะท้อนน้ำ มีความหนาเฉลี่ย 0.52 มิลลิเมตร ความต้านทานแรงดันทะลุ 36.90 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 360 มิลลินิวตัน กระดาษที่ใส่สารสะท้อนน้ำ มีความหนาเฉลี่ย 0.54 มิลลิเมตร ความต้านทานแรงดันทะลุ 37.20 กิโลนิวตันต่อตารางเมตร ความคงทนต่อแรงฉีกขาด 363 มิลลินิวตัน



ภาพที่ ก1 ผลของการไม่ใส่สารสะท้อนน้ำ

จากภาพที่ ก1 พบว่าผลการดูดซึมน้ำ เมื่อหยดน้ำลงไปมีการดูดซึมน้ำทันที เนื่องจากกระดาษทำมาจากเส้นใยธรรมชาติ ซึ่งมีคุณสมบัติในการดูดซึมน้ำได้ดี จึงทำให้เมื่อหยดน้ำลงไปเกิดการดูดซึมทันที

ภาพที่ ก2 ผลของการใส่สารสะท้อนน้ำ

จากภาพที่ ก2 พบว่าผลการดูดซึมน้ำ เมื่อหยดน้ำลงไป พบว่าไม่มีการดูดซึมน้ำแต่เมื่อทิ้งไว้ประมาณ 5 วันแล้วทำการทดสอบหยดน้ำลงไป จะมีการดูดซึมน้ำ ใช้เวลา 8.61 sec เนื่องจากสารสะท้อนน้ำมีโครงสร้างทางเคมีที่เป็นฟลูออโรคาร์บอน เป็นสารที่มีแรงตึงผิวต่ำ จะเกิดเป็นฟิล์มเคลือบอยู่บนผิวของกระดาษ เมื่อใส่ในขั้นตอนการทำกระดาษ ทำให้เมื่อหยดน้ำลงบนกระดาษ น้ำจะไม่สามารถซึมผ่านไปได้ แต่เมื่อทิ้งไว้นานสารเกิดการเสื่อมสภาพทำให้น้ำสามารถซึมผ่านไปได้บางส่วน

ภาคผนวก ข มาตรฐานการทดสอบ

Designation: D 3786 – 01

Standard Test Method for Hydraulic Bursting Strength of Textile Fabrics—Diaphragm Bursting Strength Tester Method[1]

This standard is issued under the fixed designation D 3786; 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.

1. Scope

1.1 This test method describes the measurement of the resistance of textile fabrics to bursting using the hydraulic diaphragm bursting tester. This test method is generally applicable to a wide variety of textile products.

1.2 This test method may also be applicable for stretch woven and woven industrial fabrics such as inflatable restraints.

1.3 The values stated in S. I. Units are to be regarded as the standard.

NOTE 1—For the measurement of the bursting strength by means of a ball burst mechanism, refer to Test Method D 3787.

1.4 *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]

D 123 Terminology Relating to Textiles

D 5034 Test Methods for Breaking Load and Elongation of Textile Fabrics

D 1776 Practice for Conditioning Textiles for Testing

D 3787 Test Method for Bursting Strength of Knitted Textiles—Constant-Rate-of-Traverse (CRT) Ball Burst Test

2.2 *Other Standard:*

TAPPI T 403, OM.91 Bursting Strength of Paper[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *bursting strength, n*—the distending force, which is applied at right angles to the plane of the fabric, under specified conditions, which will result in the rupture of a textile.

3.1.2 *knitted fabric, n*—a structure produced by interlooping one or more ends of yarn or comparable material.

3.1.3 *nonwoven fabric, n*—a textile structure produced by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, thermal or solvent means and combinations thereof.

3.1.3.1 *Discussion*—The term does not include paper or fabrics that are woven, knitted or tufted.

3.1.4 *woven fabric, n*—a structure produced when at least two sets of strands are interlaced, usually at right angles to each other according to a predetermined pattern of interlacing, and such that at least one set is parallel to the axis along the lengthwise direction of the fabric.

3.1.5 *stretch woven fabric, n*—a woven fabric which is capable of at least 20 % stretch in either warp or filling direction, or both, under loads and conditions encountered in use and of almost complete recovery on removal of the load.

3.2 For definitions of other textile terms used in this test method, refer to Terminology D 123.

4. Summary of Test Method

4.1 A is clamped over an expandable diaphragm. The diaphragm is expanded by fluid pressure to the point of specimen rupture. The difference between the total pressure required to rupture the specimen and the pressure required to inflate the diaphragm is reported as the bursting strength.

5. Significance and Use

5.1 This method for the determination of diaphragm bursting strength of knitted, nonwoven and woven fabrics is being used by the textile industry for the evaluation of a wide variety of end uses.

5.2 In cases where test results obtained using the procedures in Test Method D 3786 have not been correlated with actual performance, Test Method D 3786 is considered satisfactory for acceptance testing of commercial shipments of textile

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.59 on Fabric Test Methods, General.

Current edition approved Dec. 10, 2001. Published March 2002. Originally published as D 3786–79. Last previous edition D 3786–87.

[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] Available from Technical Association of the Pulp and Paper Industry, 1 Dunwoody Park, Atlanta, GA 30341.

fabrics for bursting strength since the method has been used extensively in the trade for acceptance testing. In cases where disagreement arising from differences in values reported by the purchaser and the supplier when using Test Method D 3786 for acceptance testing, the statistical bias, if any, between the laboratory of the purchaser and the laboratory of the supplier should be determined with comparison based on testing specimens randomly drawn from one sample of material of the type being evaluated.

NOTE 2—The kind of load transfer and stretch that occur when knitted goods and nonwoven fabrics are worn are prevented by clamping them as described in this method.

6. Apparatus and Materials

6.1 *Hydraulic Diaphram Bursting Tester*[4]— A testing machine that meets the requirements of 6.1.1-6.1.4. In cases of dispute, a motor-driven tester shall be used unless the purchaser and the supplier agree otherwise.

6.1.1 *Clamps*, for firmly and uniformly securing the test specimen between two annular, plane, parallel, and preferably stainless steel surfaces, without slippage during the test. Use sufficient pressure to effect the practicable minimization of slippage.

6.1.1.1 The upper and lower clamping surfaces shall have a circular opening at least 75 mm (3 in.) in diameter and coaxial apertures of 31 ± 0.75 mm (1.22 ± 0.03 in.) in diameter: The surfaces of the clamps between which the specimen is placed shall have concentric grooves spaced not less than 0.8 mm (1/32 in.) apart and shall be of a depth not less than 0.015 mm (0.0006 in.) from the edge of the aperture. The surfaces of the clamps shall be metallic and any edge which might cause a cutting action shall be rounded to a radius of not more than 0.4 mm (1/64 in.). The lower clamp shall be integral with the chamber in which a screw shall operate to force a liquid pressure medium at a uniform rate of 95 ± 5 mL/min against the rubber diaphragm.

NOTE 3—Since the clamping mechanism and clamping surfaces are subject to considerable wear and distortion, they should be examined periodically and repaired or replaced when necessary. The effectiveness of grooving the clamping surfaces in the manner specified has not been determined.

6.1.2 *Diaphragm*[4]—A 48 mm (1.875 in) diaphragm of molded synthetic rubber, 1.80 ± 0.05 mm (0.070 ± 0.002 in.) in thickness with reinforced center, clamped between the lower clamping plate and the rest of the apparatus 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. The pressure required to raise the free surface of the diaphragm plane shall be 30 ± 5 kPa (4.3 ± 0.8 psi). This pressure shall be checked at least once a month. To test, a bridge gage[4] may be used, the test being carried out with the clamping ring removed. The diaphragm should be inspected frequently for permanent distortion and renewed as necessary.

6.1.3 *Pressure Gage*—A maximum-reading pressure gage of the Bourdon type of appropriate capacity graduated in pounds 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.

6.1.4 *Hydraulic Pressure System*—A mean of applying controlled increasing hydrostatic pressure to the underside of the diaphragm until the specimen bursts through a fluid displaced at the rate of 95 ± 5 mL/min. The fluid is displaced by a piston in the pressure chamber of the apparatus. The recommended chamber fluid is USP chemically pure 96 % glycerin. The hydraulic system, including the gages shall be mounted so as to be free of externally induced vibrations. Means shall be provided at the instant of rupture of the specimen for stopping any further application of the loading pressure and for holding unchanged the contents of the pressure chamber until the total bursting pressure and the pressure required to inflate the diaphragm indicated on the gage have been recorded.

NOTE 4—Ethylene glycol may be substituted for the glycerine if desired.

6.1.5 *Aluminum Foil For Calibration of Tester*[5]—Pieces of pretested aluminum sheet having a known bursting strength in the range of 70 to 790 kPa (10 to 115 psi) are use for checking the overall performance of the tester.

7. Sampling

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls of fabric directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider rolls of fabric to be the primary sampling units.

NOTE 5—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls of fabric and between specimens from a swatch from a roll of fabric to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take a full width swatch 1 m (1 yd) long from the end of each roll of fabric in the lot sample, after first discarding a minimum of 1 m (1 yd) of fabric from the very outside of the roll. From each roll or piece of circular knit fabric selected from the lot sample, cut a band at least 305 mm (1 ft) wide.

7.3 *Test Specimens*—Cut ten test specimens from each swatch in the laboratory sample with each specimen being 125 mm (5 in.) square.

[4] The Hydraulic Diaphragm Bursting Testers, hand driven Model LC (Fig. 1A) and motor driven Models C (Fig. 1B) and (Fig. 1C), and accessories, manufactured by B. F. Perkins & Son, Inc., have been found satisfactory. The motor driven Model A (Fig. 1D) has been found to be satisfactory for heavyweight fabrics, but may be unsuitable for some lightweight fabrics. Model C and Model A have different pumping rates and different diaphragms therefore it is not likely these two machines will give the same result. The testers also can be obtained from Testing Machines, Inc., 400 Bayview Ave., Amityville NY

[5] Standardized aluminum sheets for this purpose, bursting over the range from 51 to 150 psi (350 to 1035 kPa) may be obtained from the Pulp and Paper Research Institute of Canada, 3420 University St., Montreal, Canada; from Testing Foil Service, 304 N. Stevens St., Rhinelander, WI 54501; and from Testing Machines, Inc., 400 Bayview Ave., Amityville, NY 11701.

Larger differences are likely to occur under all other circumstances. The value of the bursting strength of knitted goods can only be defined in terms of a specific test method.

Within this limitation, the procedure for bursting strength in Test Method D 3786 has no known bias. Sections 14.2-14.4 explain the basis for this summary and for evaluations made under other conditions.

14.2 *Interlaboratory Test Data*[6]—An interlaboratory test was run in 1977 in which randomly drawn specimens of six fabrics were tested in each of four to five laboratories. Three fabrics were circular knit fabrics containing spun yarns and three of the fabrics were tricot knit fabrics containing filament yarns. The components of variance for bursting strength results expressed as standard deviations were calculated to be the values reported in Table 1.

NOTE 9—The difference in variability between the two groups of fabrics is thought to be the result of the differences between the source yarns rather than the type of equipment on which the fabrics were knit. There is no objective evidence to substantiate this belief.

NOTE 10—The interlaboratory test data were obtained with motor-driven testers. The precision of the method using a hand-operated tester has not been determined.

[6] ASTM Research Report No. RR:D13-1061. A copy is available from ASTM Headquarters.

TABLE 1 Components of Variance for Bursting Strength Expressed as Standard Deviations, Percentage Points

	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Spun yarns in circular knit	6.8	1.1	2.5
Filament yarns in tricot knit	2.3	3.1	2.6

14.3 *Critical Differences*—For the components of variance reported in 14.2, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 2 (Note 9).

NOTE 11—The tabulated values of the critical differences should be considered to be a general statement particularly with respect to between-laboratory precision. Before a statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens randomly drawn from a sample taken at random from a lot of the material to be evaluated.

14.4 *Bias*—The procedure in Test Method D 3786 has no known bias because the value of bursting is defined in terms of this test method.

15. Keywords

15.1 diaphragm bursting pressure; knitted fabric; non woven fabric

TABLE 2 Critical Differences for Bursting-Pressure for the Conditions Noted, Percentage Points[A]

	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Spun yarns in circular knit	5	8.4	9.0	11.3
	10	6.0	6.7	9.6
	20	4.2	5.2	8.7
	40	3.0	4.3	8.1
Filament yarns in tricot knit	5	2.9	9.1	11.6
	10	2.0	8.8	11.4
	20	1.4	8.7	11.3
	40	1.0	8.7	11.3

[A] The critical differences were calculated using $t = 1.645$, which is based on infinite degrees of freedom.

8. Calibration

8.1 *Routine Verification of Testing Machine*—Check the operation of the testing machine at least once each month by bursting five specimens of standard aluminum sheet. The average of the indicated bursting resistance for the five specimens of aluminum sheet should be between ±5 % of that marked on the package of the pretested aluminum sheet standard.

8.2 *Calibration of Gage*—Calibrate the gage, while inclined at the same angle at which it is used, by means of a dead-weight tester of the piston type, or by means of a column of mercury. Such calibration is preferably carried out with the gage in its normal position in the tester.

8.3 Where agreement is not attained, check the tester according to the instructions given in Tappi Method T-403 OS-74.

NOTE 6—Possible causes of low readings are gage error (bias or nonlinearity), gage expansivity too high, excessive gage pointer friction, air in hydraulic system or gage, diaphragm collapsed too far at zero, and low pumping rate (hand-driven tester). Possible causes of high readings are: gage error (bias nonlinearity), loose gage pointer (overshoot), gage pointer bent by stop-pin, insufficient clamping force (slipping), nonuniform clamping (partial slipping), stiff or inelastic diaphragm, diaphragm above clamping plate at zero, multiple sheet testing, high pumping rate (hand-driven tester), and double bursts. If a gage is accidently used beyond its capacity, it must be recalibrated before it is used again.

9. Conditioning

9.1 Bring the specimens (or laboratory samples) from the prevailing atmosphere to moisture equilibrium for testing in the standard atmosphere for textile testing as directed in Practice D 1776.

10. Selection and Number of Specimens

10.1 Unless otherwise agreed upon, as when specified in an applicable material specification, take ten specimens of the laboratory sample(s) of fabric. Each specimen shall be at least 125 mm (5 in.) square, or a circle 125 mm (5 in.) in diameter. Specimens need not be cut for testing. No two specimens from knitted fabric should contain the same wale or course yarns. Take no specimens nearer the selvage than one tenth the fabric width. This restriction does not apply to tubular knitted fabric.

11. Procedure

11.1 Make all tests on specimens conditioned in the standard atmosphere for testing textiles as directed in 9.1.

11.2 *Hand Driven Tester*:

11.2.1 Insert the conditioned specimen under the tripod, drawing the specimen taut across the plate, and clamp specimen in place by bringing the clamping lever as far to the right as possible.

NOTE 7—For specimens with considerable stretch, it may be necessary to extend the fabric uniformly over the plate to remove some of the stretch before clamping.

11.2.2 Rotate the hand wheel, clockwise at a uniform speed of 120 rpm until the specimen bursts.

11.2.3 Stop turning the hand wheel at the instant of rupture of the specimen (see Note 8).

11.2.4 Immediately after rupture and in rapid succession, release the clamping lever over the specimen. Immediately release the strain on the diaphragm by turning the wheel counterclockwise to its starting position and record the pressure required to inflate the diaphragm (tare pressure). Record the total pressure required to rupture the specimen.

NOTE 8—If the pressure stops increasing, as indicated by the dial, and the specimen has not broken, push the operating lever to remove the pressure. Record that the stretch of the fabric exceeds the dimensional limitations of the tester. If slippage of the specimen is noted, discard the result and use a new specimen.

11.3 *Motor-Driven Tester*:

11.3.1 Insert the specimen under the tripod, drawing the specimen taut across the plate, and clamp specimen in place by bringing the clamping lever as far to the right as possible (see Note 6).

11.3.2 Inflate the diaphragm by moving the operating handle to the left.

11.3.3 While the diaphragm is inflating, take hold of the latch that is located below, or to the right, of the operating handle. At the instant of rupture of the specimen, swing the latch as far as it will go to bring the operating handle to an idling (neutral) position (see Note 8). Record the total pressure required to rupture the specimen.

11.3.4 Immediately after rupture, and in rapid succession, release the clamping lever over the specimen. Immediately relieve the strain on the diaphragm by dropping the latch back to its normal position, throw the operating handle to the right, and record the pressure required to inflate the diaphragm (tare pressure).

12. Calculation

12.1 Calculate the bursting pressure of each specimen by subtracting the tare pressure required to inflate the diaphragm from the total pressure required to rupture the specimen.

12.2 Report the pressure reading of each individual specimen and the average for each laboratory sampling unit and the lot.

12.3 Report the type of bursting tester used.

13. Report

13.1 State that the specimens were tested as directed in Test Method D 3786 using the Hydraulic Diaphragm Bursting Tester. Describe the material or product sampled and the method of sampling used.

13.2 Report the bursting strength of each individual specimen and their average in kPa (psi).

13.3 Report the type of bursting tester used.

14. Precision and Bias

14.1 *Summary*—In comparing two averages of ten observations each, the difference should not exceed the following critical differences in 95 out of 100 cases when both sets of observations are taken by the same well-trained operator using the same piece of test equipment and specimens randomly drawn from the same sample of material.

Spun yarn in circular knit	41 kPa (6.0 psi)
Filament yarn in tricot knit	14 kPa (2.0 psi)

Designation: D 5734 – 95 (Reapproved 2001)

Standard Test Method for Tearing Strength of Nonwoven Fabrics by Falling-Pendulum (Elmendorf) Apparatus[1]

This standard is issued under the fixed designation D 5734; 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.

1. Scope

1.1 This test method covers the measurement of the average force required to propagate a single-rip tear starting from a cut in a nonwoven fabric using a falling-pendulum (Elmendorf) apparatus.

1.2 This standard Elmendorf tear tester with interchangeable pendulums has become the preferred test apparatus for determining tearing strength up to 6400 grams-force. It is recognized that some older test instruments with augmenting weights continue to be used. As a consequence, these older test instruments may be used when agreed upon between the purchaser and the supplier. The conditions for the older units as used with this test method are included in the appendix. For tearing strength above 6400 grams-force, a high-capacity test instrument is available equipped with augmenting weights to increase the capacity.

1.3 This test method is applicable to most nonwoven fabrics that are treated or untreated, including heavily sized, coated, or resin-treated, provided the fabric does not tear in the direction crosswise to the direction of the force applied during the test. If the tear does not occur in the direction of the test, the fabric is considered untearable in that direction by this test method.

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses may be approximate.

1.5 *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:*

D 123 Terminology Relating to Textiles[2]

D 689 Test Method for Internal Tearing Resistance of Paper[3]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 4848 Terminology of Force and Deformation Properties of Textiles[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *length of tear, n*—in tensile testing, the length of fabric torn, as measured on the fabric before tearing.

3.1.2 *lengthwise direction, n—in textiles*, the direction in a machine-made fabric parallel to the direction of movement the fabric followed in the manufacturing machine.

3.1.2.1 *Discussion*—For nonwovens, an easily distinguishable pattern for orientation may not be apparent, especially if removed from the roll. Care should be taken to maintain the directionality by clearly marking the direction.

3.1.3 *nonwoven fabric, n*—a textile structure produced by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, thermal, or solvent means, or combination thereof.

3.1.4 *tearing energy, n*—in tensile testing of fabrics, the work done in tearing the specimen.

3.1.5 *tearing force, n*—the average force required to continue a tear previously started in a fabric.

3.1.5.1 *Discussion*—For nonwovens, the tearing force is recorded as the maximum force required to continue a tear previously started in a fabric.

3.1.6 *tearing strength, n*—the force required either to start or to continue or propagate a tear in a fabric under specified conditions.

3.1.7 *widthwise direction, n—in textiles*, the direction in a machine-made fabric perpendicular to the direction of movement the fabric followed in the manufacturing machine.

3.1.8 For definitions of other textile terms used in this test method, refer to Terminologies D 123 and D 4848.

4. Summary of Test Method

4.1 The force required to continue a slit previously cut in a nonwoven fabric is determined by measuring the work done in tearing it through a fixed distance. The tester consists of a sector-shaped pendulum carrying a clamp which is in alignment with a fixed clamp when the pendulum is in the raised,

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.90 on Executive.
Current edition approved June 15, 1995. Published September 1995.

[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] *Annual Book of ASTM Standards*, Vol 07.02.

starting position with maximum potential energy. The specimen is fastened in the clamps and the tear is started by cutting a slit in the specimen between the clamps. The pendulum is then released and the specimen is torn as the moving jaw moves away from the fixed one. The scale attached to the pendulum is graduated to read the tearing force of the specimen.

5. Significance and Use

5.1 This test method for the determination of tearing strength by the pendulum method is used in the trade for the acceptance testing of commercial shipments of nonwoven fabrics, but caution is advised since technicians may fail to get good agreement between results on certain fabrics. Comparative tests as directed in 5.1.1 may be needed.

5.1.1 In case of a dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative test to determine if there is a statistical bias between their laboratories. Statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using Students *t*-test and an acceptable probability level chosen by the two parties before the testing began. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results in the view of the known bias.

5.2 Compared to other methods for testing tearing strength this test method has the advantage of simplicity and speed since specimens are cut with a die and results are read directly from the scale on the pendulum. The specimens are relatively small in area and thus, require less fabric. The reading obtained is directly proportional to the length of the material torn, therefore, it is essential that the specimen be prepared to the exact size specified. For best results, the recommended capacity of the tester selected is the one where the specimens tear between 20 and 80 % of the full-scale value.

5.3 Instrument models are available with pneumatically operated clamps and removable pendulums and are recommended for this test. In addition, microprocessor systems for automatic collection of data can provide economical and reliable results when properly calibrated. In any event, the older units without the deep cut-out in the pendulum that allow specimen contact with the sector are not recommended.

6. Apparatus

6.1 *Falling-Pendulum- (Elmendorf) Type Tester*[5], as described in Annex A1 and shown in Fig. A1.1. The tester includes: a stationary clamp, a movable clamp carried on a pendulum formed by a sector of a circle that is free to swing on a bearing, means for leveling, knife mounted on a stationary post for starting a tear, means for holding the pendulum in a raised position, means for instantly releasing the pendulum, and means for registering the maximum arc through which the pendulum swings when released, and a graduated scale mounted on the pendulum.

6.1.1 The tester may have a pointer mounted on the same axis as the pendulum that is used to register the tearing force, or it may be substituted by means of calculating and displaying the required results without the use of a pointer, such as digital display and computer-driven systems. The clamps may preferably be air actuated, but manual clamping is permitted. The pendulum must have a cutout above the clamp that prevents the specimen from coming in contact with the sector during the test.

6.1.2 The standard test instrument should be equipped with an interchangeable pendulum of the required capacity. Interchangeable pendulum models are available in capacities of 1960, 3920, 7840, 15680, 31360, and 62720 mN (200, 400, 800, 1600, 3200, and 6400 gf). The pendulum is equipped with a scale reading directly in percentage of its capacity.

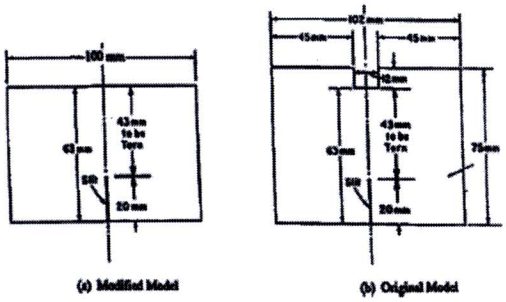
6.1.3 The high-capacity instruments have a 62720-mN (6400-gf) capacity pendulum with available augmenting weights to increase the capacity to 125540, and 250880 mN (12 800 and 25 600 gf). The tester is equipped with scales reading directly in hectograms (100-gf units) for each capacity. See Annex A1.

6.2 *Calibration Weight*, for graduation of 50 % of scale, one required for each capacity pendulum, or,

6.2.1 *Optional, Three-Check-Weight Set*, for 20, 50, and 80 % of scale. Each capacity requires its own set of weights. When required, calibration weights are available from the manufacturer for high-capacity instruments.

NOTE 1—While calibration weights are made with scale values of 20, 50, and 80 % of scale, it is not absolutely necessary to utilize a complete set. It is acceptable to use one calibration weight which is in the range of the expected test results, generally 50 % of the scale in use.

6.3 *Cutting Die*, having essentially the shape and dimensions shown in Fig. 1(*a*) or 1(*b*). Either die provides the basic rectangular test specimen 100 ± 2 mm (4 ± 0.05 in.) long by 63 ± 0.15 mm (2.5 ± 0.005 in.) wide. The critical dimension of the test specimen is the distance 43.0 ± 0.15 mm (1.69 ± 0.005 in.) that is to be torn during the test.



(a) Modified Model (b) Original Model

NOTE 1—All tolerances ± 0.5 %.

FIG. 1 Example of Die For Cutting Notched Specimens

[5] Elmendorf Tear Testers suitable for use and meet the requirements of this test method are available from Thwing-Albert Instrument Co., Philadelphia, PA and Testing Machines, Inc., Amityville, NY.

NOTE 2—The modified die model shown in Fig. 1(*a*) is typically used for nonwoven fabric testing. The original die model shown in Fig. 1(*b*) was that used in woven fabric testing. Either die may be used. These dies can be made to order by most die manufacturers.

6.4 *Air Pressure Regulator*, capable of controlling air pressure between 410 and 620 kPag (60 and 90 psig), when applicable, for air clamps.

6.5 *Setting Gage*, for cutting blade that will provide a cut slit that leaves a 43 ± 0.15-mm (1.69 ± 0.005-in.) specimen tearing distance for a 63 ± 0.15-mm (2.5 ± 0.005-in.) wide specimen, or equivalent.

6.6 *Jaw Spacing Gage*, 2.8 ± 0.3-mm (0.125 ± 0.012-in.) width, or equivalent.

6.7 *Oil*, lightweight, non-gumming clock type.

6.8 *Silicone Grease*, when applicable, for air clamp lubrication.

6.9 *Vacuum Cleaner*, when applicable, for cleaning dust and fiber from pendulum scale sensor, or equivalent.

7. Sampling and Test Specimens

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls, or pieces, of nonwoven fabric directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider the rolls, or pieces, of nonwoven fabric to be the primary sampling units. In the absence of such an agreement, take the number of nonwoven fabric rolls specified in Table 1.

NOTE 3—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls or pieces of fabric and between specimens from a swatch from a roll or pieces of fabric to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—For the laboratory sample, take a swatch extending the width of the fabric and approximately 1 m (1 yd) along the lengthwise direction from each roll, or piece, in the lot sample. For rolls of fabric, take a sample that will exclude fabric from the outer wrap of the roll or the inner wrap around the core.

7.3 *Test Specimens*—From each laboratory sampling unit, take five specimens from the lengthwise direction and five specimens from the widthwise direction, for each test condition described in 8.1-8.3 as applicable to a material specification or contract order. Use the cutting die described in 6.3 and shown in Fig. 1(*a*) and 1(*b*).

7.3.1 *Direction of Test*—Consider the short direction as the direction of the test.

7.3.2 *Cutting Test Specimens*—Cut the specimens for the measurement of the lengthwise direction from different positions across the fabric width with the shorter dimension parallel to the lengthwise direction. Cut the specimens for the measurement of the widthwise direction from different positions along the length of the fabric with the shorter dimension parallel to the widthwise direction. When specimens are to be tested wet, cut from areas adjacent to the dry test specimens. Label to maintain specimen identity.

7.3.2.1 Cut specimens representing a broad distribution across the width of the laboratory sample and no nearer the edge than one tenth its width. Ensure specimens are free of folds, creases, or wrinkles. Avoid getting oil, water, grease, and so forth, on the specimens when handling.

TABLE 1 Number of Rolls or Pieces, of Nonwoven Fabric in the Lot Sample

Number of Rolls, Pieces in Lot, Inclusive	Number of Rolls or Pieces in Lot, Sample
1 to 3	all
4 to 24	4
25 to 50	5
over 50	10 % to a maximum of ten rolls or pieces

8. Preparation of Apparatus and Calibration

8.1 For the standard test instrument, select the pendulum such that the tear occurs between 20 and 80 % of the full-scale range. Secure the pendulum to the instrument, spacing the clamps as directed in A2.4.

8.1.1 For the high-capacity test instrument, when required, select the augmenting weight such that the tear occurs between 20 and 80 % of the full-scale range. Secure the augmenting weight to the pendulum.

8.2 When equipped with a registering sensor, examine the scale and the complementary black sensor strip along the bottom edge of the pendulum. Using care and without touching the sensor, vacuum away any loose fibers and dust.

8.3 Examine the knife edge for sharpness, wear, and central alignment as directed in A2.5-A2.7.

8.4 For air clamps, set the air pressure to the clamps to about 550 kPag (80 psig).

8.4.1 Maximum pressure should be no more than 620 kPag (90 psig) and minimum pressure no less than 410 kPag (60 psig).

8.5 When using microprocessor automatic data gathering systems, set the appropriate parameters as defined in the manufacturer's instructions.

8.6 Verify the calibration of the selected capacity pendulum scale using the one check weight method described in A3.2, unless otherwise specified.

8.6.1 The scale may be verified either by the relatively simple procedure which uses one Elmendorf check weight, or alternatively by the three-check-weight procedure, or the potential energy procedure. The same accuracy and effectiveness are claimed for each procedure. The one- and three-check-weight sets are available from the manufacturer. The single-weight procedure described in this section has been recommended for use to 80 % of scale. See Annex A3.

9. Conditioning

9.1 *Condition 1, Unspecified Testing Conditioning*—No conditioning is required unless otherwise specified in a material specification or contract order.

9.2 *Condition 2, Standard Testing Conditioning*:

9.2.1 When specified, precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776.

9.2.2 After preconditioning, bring the test specimens to moisture equilibrium for testing in the standard atmosphere for testing textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed.

9.3 *Condition 3, Wet Specimen Testing Conditioning*:

9.3.1 Place the specimens in a container and submerge in distilled or deionized water at ambient temperature until thoroughly soaked. (See 9.3.1.1.)

9.3.1.1 The time of immersion must be sufficient to wet out the specimens, as indicated by no significant change in tearing force followed by longer periods of immersion. For most fabrics this time period will be about one hour. For fabrics not readily wet out with water, such as those treated with water-repellent or water resistant materials, add a 0.01 % solution of a nonionic wetting agent to the water bath.

10. Procedure

10.1 Test the specimens in the atmosphere as directed in an applicable material specification or contract order.

10.2 Raise the pendulum to the starting position and set the pointer against its stop.

10.3 *For Tester-Slit Specimens*:

10.3.1 Place the long sides of the specimen centrally in the clamps with the bottom edge carefully set against the stops and the upper edge parallel to the top of the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.3.2 Push down on the handle of the built-in knife blade cutting a 20 ± 0.15-mm (0.787 ± 0.006-in.) slit in the specimen using the pendulum knife extending from the bottom edge and leaving a balance of fabric 43.0 ± 0.15 mm (1.69 ± 0.005 in.) remaining to be torn.

10.4 *For Die-Cut or Manually Slit Specimens*:

10.4.1 If a die without a slit is used, manually cut a 20 ± 0.15-mm (0.787 ± 0.006-in.) long slit in the center of one edge of the long direction of the specimen. Ensure that the balance of the fabric remaining to be torn is 43 ± 0.15 mm (1.69 ± 0.005 in.). The length of the cut is important when tearing energy is determined.

10.4.2 Place the parallel, unslit sides of the specimen in the clamps with the bottom edge carefully set against the stops, the upper edge parallel to the top of the clamp and the slit centrally located between the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.5 For wet specimens, remove the specimens from the water and immediately mount it on the testing machine in the normal set up. Perform the test within two minutes after removal of the specimen from the water.

10.6 Depress the pendulum stop downward to its limit and hold it until the tear is completed and the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return to its locked starting position for additional test. When equipped, be careful not to disturb the position of the pointer.

10.6.1 The decision to discard the results of a tear shall be based on observation of the specimen during a test and upon the inherent variability of the material. In the absence of other criteria, such as in a material specification, if an unusual cause is detected, the value may be discarded and another specimen tested.

10.6.2 Reject readings obtained where the specimen slips in the jaw or where the tear deviates more than 6 mm (0.25 in.) away from the projection of the original slit. Note when puckering occurs during test.

10.6.3 For microprocessor systems, follow the manufacturer's directions for removing values from memory when the decision to discard a tear value has been made, otherwise for some test instruments, manual calculation of the average is required.

10.6.4 If, during application of the tearing force to the specimen, the force does not reach 20 % or reaches over 80 % of full-scale range, change to the next lower or higher full-scale range, as applicable. See 8.6.

10.6.5 Record if the tear was crosswise to the normal (parallel) direction of tear and describe that specimen, or that sample, as applicable, as untearable.

10.7 Remove the torn specimen and continue until five tears have been recorded for each principal direction, as required, from each laboratory sampling unit.

10.8 When all samples have been tested and calculations completed, place the pendulum in the rest position (free hanging).

11. Calculation

11.1 *Tearing Force, Individual Specimens*:

11.1.1 *Standard Test Instrument*—Determine the Elmendorf tearing force for individual specimens to the nearest millinewton (gram-force) using Eq 1:

$$F = R \times C/100 \quad (1)$$

where:

F = tearing force, mN (gf),
R = scale reading, and
C = full-scale capacity, mN (gf).

11.1.2 *High-Capacity Test Instrument*—Determine the Elmendorf tearing force for individual specimens to the nearest mN (gf) using Eq 2:

$$F = R \times 1000 \quad (2)$$

where:

F = tearing force, mN (gf), and
R = scale reading, mN (gf).

NOTE 4—mN = gf/9.81.

11.2 *Tearing Strength*—Calculate Elmendorf tearing strength as the average tearing force for each principal direction of the laboratory sampling unit and for the lot.

11.3 *Standard Deviation and Coefficient of Variation*—Calculate when required.

11.4 *Computer Processed Data*—When data is automatically computer processed, calculations are generally contained in the associated software. Record values as read from the direct reading scale to the nearest millinewton (gram-force). In

any event, it is recommended that computer processed data be verified against known values and its software described in the report.

12. Report

12.1 Report that the Elmendorf tearing strength was determined as directed in this test method. Describe the material or product sampled and the method of sampling used.

12.2 Report the following information for both the laboratory sampling unit and the lot as applicable to a material specification or contract order:

12.2.1 Elmendorf tearing strength for each principal direction, as requested,

12.2.2 Condition of test, ambient air, or wet,

12.2.3 Puckering, if it occurs during the test,

12.2.4 Number of tests rejected because of crosswise tearing,

12.2.5 Any specimens or samples that were untearable (crosswise tears),

12.2.6 When calculated, the standard deviation or the coefficient of variation,

12.2.7 For computer-processed data, identify the program (software) used,

12.2.8 Make, model, and capacity of testing machine,

12.2.9 Type of clamps used,

12.2.10 Test room conditioning, and

12.2.11 Any modification of the test method.

13. Precision and Bias

13.1 *Summary*—Preliminary interlaboratory test data have shown that the variance in tear strength testing by this test method is dependent upon the manufacturing method of the material under evaluation; therefore, no general statement can be made concerning least critical differences. The following data were generated during the interlaboratory test and are presented for reference. In comparing two averages of five observations, the difference between averages should not exceed the following values in 95 out of 100 cases when all the observations are taken by the same well-trained operator using the same piece of equipment and specimens are randomly drawn from the same sample:

Manufacturing Method	Tearing Force (gf) Difference
Machine Direction	
Dry Laid	45
Resin Bonded	35
Thermal	54
Wet Laid	37
Transverse Direction	
Dry Laid	54
Resin Bonded	46
Thermal	33
Wet Laid	35

Larger differences are likely to occur under all other circumstances. This procedure for determining tearing force has no other known bias and is considered a referee method.

13.2 *Interlaboratory Test Data*—A preliminary interlaboratory test was run in 1992 in which randomly drawn samples of four materials were tested in each of three laboratories. Two operators in each laboratory tested five specimens of each material. The four materials used in this evaluation were all manufactured by different processes as shown in 13.1. Analysis of the data using the adjunct to Practice D 2904 suggested reporting the components of variance and least critical differences based upon the method of manufacturing. The components of variance, expressed as standard deviations, for each method of manufacturing are listed in Table 2 (see Note 5). Further testing is in progress to elucidate the dependence on manufacturing process and possible test method revision.

13.3 *Precision*—For the components of variance listed in Table 2, the averages of two observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 3 (see Note 6). Due to the dependence of the components of variance on the manufacturing process no meaningful statement can be made at this time relative to between material comparisons.

13.4 *Bias*—The procedure in this test method for determining the tearing strength of nonwoven fabrics by this test method has not been checked against accepted reference materials but contains no known bias other than the effect of the manufacturing process, as noted. This test method is accepted as a referee method.

NOTE 5—The square roots of the components of variance are listed in Table 2 so that the variability is expressed in the appropriate units of measure rather than as the square of those units of measure.

NOTE 6—The values of the tabulated differences should be considered to be a general statement, particularly with respect to between-laboratory precision. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as homogeneous as possible, and then randomly assigned in equal numbers to each of the laboratories.

14. Keywords

14.1 Elmendorf; falling pendulum; nonwoven fabric; tearing strength; tear tester

TABLE 2 Components of Variance as Standard Deviations

NOTE 1—Tearing force expressed in grams-force.

Manufacturing Process	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Machine Direction			
Dry Laid	36	36	44
Resin Bonded	28	38	17
Thermal	44	56	0
Wet Laid	30	0	41
Transverse Direction			
Dry Laid	44	0	47
Resin Bonded	37	52	53
Thermal	27	0	16
Wet Laid	28	14	27

TABLE 3 Critical Differences for Conditions Noted 95 % Probability Level

NOTE 1—Tearing strength expressed in grams-force.

Manufacturing Process	Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Machine Direction				
Dry Laid	5	45	45	130
	10	32	32	126
Resin Bonded	5	35	111	121
	10	25	108	118
Thermal	5	54	165	165
	10	38	161	161
Wet Laid	5	37	37	119
	10	26	26	116
Transverse Direction				
Dry Laid	5	54	54	141
	10	38	38	135
Resin Bonded	5	46	153	212
	10	33	149	209
Thermal	5	33	33	54
	10	23	23	49
Wet Laid	5	35	53	92
	10	25	46	88

ANNEXES

(Mandatory Information)

A1. DESCRIPTION OF APPARATUS

A1.1 The Elmendorf tear tester providing means for holding the specimen with two clamps, one stationary and one movable, and for tearing it by the fall of the pendulum due to the force of gravity. The textile model, is basically the standard Elmendorf tester and is used with interchangeable pendulums to provide the required capacity. The instrument includes the following parts (Fig. 1(*b*)).

A1.1.1 The high-capacity Elmendorf tester is a basic 62720-mN (6400-gf) capacity instrument. This capacity can be increased to 125 540 and 250 880-mN (12 800 and 25 600- gf) capacities with the use of augmenting weights available from the manufacturer. It is not equipped with interchangeable pendulums.

A1.1.2 Optionally, test instruments are equipped with a means of calculating and displaying the required results without the use of an autographic recorder, such as computer-driven systems. Also, they may be equipped with air-actuated clamps.

A1.1.3 *Sector-Shaped Pendulum*, carrying a circumferential scale graduated to read the tearing force directly in percent of full-scale capacity for standard test instruments, and in 1000-g units for the high-capacity instruments. The pendulum section has a cutout in the region adjacent to the clamp so that the specimen does not rub against the sector during the test.

A1.1.4 Means for holding the pendulum in a raised position, and means for releasing it instantaneously.

A1.1.5 *Pointer and Pointer-Stop*, for registering the maximum arc through which the pendulum swings when released. The pointer is mounted on the same axis as the pendulum with constant friction just sufficient to stop the pointer at the highest point reached by the swing of the section. The adjustable pointer stop provides means for setting the zero of the instrument.

A1.1.5.1 When equipped with electronic data gathering systems, the pointer and pointer-stop are not required.

A1.1.6 *Knife*, mounted on a stationary post for initial slitting of the specimen. It is centered between the clamps and adjusted in height to give a tearing distance of 43.0 ± 0.15 mm (1.69 ± 0.005 in.); that is, the distance between the end of the slit made by the knife and the upper edge of the specimen is 43.0 ± 0.15 mm (1.69 ± 0.005 in.) when the lower edge of the 63.0-mm (2.5 ± 0.005-in.) wide specimen rests against the bottom of the clamp.

A1.1.7 *Leveling Screw.*

A1.1.8 *Stationary Clamp.*

A1.1.9 *Movable Clamp*, carried on a pendulum formed by a sector of a circle free to swing on a ball-bearing.

A1.1.10 With the pendulum in its initial position ready for a test, the two clamps are separated by a distance of 2.8 ± 0.3 mm (0.10 ± 0.01 in.), and are aligned such that the clamped specimen lies in a plane parallel to the axis of the pendulum, the plane making an angle of 0.480 ± 0.009 rad (27.5 ± 0.5°) with the perpendicular line joining the axis and the horizontal line formed by the top edges of the clamping jaws. The distance between the axis and the top edges of the clamping jaws is 103 ± 0.1 mm (4.055 ± 0.004 in.).

A1.1.11 The clamping surface in each jaw is at least 25 mm (1.0 in.) wide and 15.9 ± 0.1 mm (0.625 ± 0.004 in.) deep.

A2. ADJUSTMENT OF APPARATUS

A2.1 *Instrument Mounting*—Place the tester on a sturdy, level bench (or table). Ensure that there is no perceptible movement of the tester base or bench during the swing of the pendulum. Movement of the instrument during the swinging of the pendulum is a significant source of error.

A2.1.1 Threaded bolt holes are usually provided in the base of the instrument and may be used to secure the instrument to the table. An alternative procedure is to place the instrument on a guide that ensures that the instrument always has the same position on the table. A floor-strip is available from some manufacturers for this purpose.

A2.2 *Instrument Balance*—Level the instrument such, that with the sector free, the line on the sector indicating that vertical from the point of suspension is bisected by the edge of the pendulum stop mechanism. Verify this by holding down the pendulum stop and allowing the pendulum to swing free. When the pendulum comes to rest, the positioning line at the center of the pendulum should be directly above the edge of the pendulum stop. Align, if necessary, by turning the leveling thumb screw at the left end of the tester base.

A2.3 *Clamp Alignment*—Raise the pendulum and position the lower edge against its stop. Visually check the alignment of the clamps. If the clamps are not in alignment, replace the pendulum stop or the pendulum bearing and shaft assembly, or both, following the manufacturer's instructions.

A2.4 *Clamp Space Setting, Interchangeable Pendulums*—Set the jaw spacing to 2.8 ± 0.3 mm (0.125 ± 0.012 in.). Loosen the shoulder head screw on top of the pendulum support. With both clamps in the open position, gently pull the pendulum out until the jaw spacer gage will fit into the grips. Gently push the pendulum in until the jaw spacer gage has just enough clearance to slide out the top of the clamps. With the jaw spacer in place, tighten the shoulder head screw on the pendulum support. Remove the jaw spacer gage.

A2.5 *Knife Sharpness*—Check the sharpness of the knife by inserting a spare specimen in the clamps and cutting a slit with the knife blade in the normal manner. If the knife is dull it will produce a V-notch near the top of the cut and push the material outward. When the knife is determined to be dull, sharpen it with a rough stone, alternately, continuing specimen knife cuts, until no V-notch is observed. Replace the knife blade as necessary.

A2.6 *Knife Alignment*—Check that the knife position is centrally located between the clamps. If the knife cannot be positioned centrally, replace one or any combination thereof: the pendulum bearing and shaft assembly, the cutter handle bearing pin, knife blade.

A2.7 *Specimen Tearing Distance*—Check the specimen tearing distance with the knife setting gage. Place the gage in the stationary specimen clamp in the usual manner for testing material. Ensure the gage is positioned with the wide dimension upwards and the projection extending over the edge of the stationary clamp far enough such that the knife can be adjusted to the bottom edge of the gage. Adjust the knife position such that the highest point of the blade just touches the bottom edge of the gage and then secure it in place. Replace the knife when it no longer can be adjusted to the gage. Or optionally:

A2.7.1 Check the tearing distance by using the die to cut a specimen from coordinate paper graduated in millimetres. Apply a small amount of graphite (from an ordinary lead pencil) to the cutting knife or the edge of the die used for cutting the slit so that when the cut is made some of the graphite transfers to the paper; this serves to contrast the cut from the uncut portion of the paper and facilitates the measurement. Make sure this measurement either with a precision steel rule graduated in 0.2 mm (0.01 in.) or better and under magnification, or alternatively, by use of a go-no-go gage available from the manufacturer of the instrument. If necessary, adjust the height of the knife.

A2.7.2 Do not change the specimen dimensions to adjust the tear distance.

A2.8 *Main Bearing Friction*—Clean, oil, and adjust the bearing. Raise the pendulum to its cocked position. When equipped, set the pointer against its stop. Press and hold down the pendulum stop and let the pendulum swing freely. Ensure the pendulum is free swinging and the calibration can be verified as directed in Annex A3.

A2.9 *Scale Inspection*—When soiled, or calibration cannot be attained, clean the white area at the bottom of the pendulum with mild soap and water. Ensure the mirrored divisions of the scale are clean and free of any foreign matter. Ensure the black sensing strip on the pendulum is clean of fibers and not scratched. Blow off fibers and dust from the black strip using a low-pressure air nozzle. When scratches are evident, touch up with flat black paint enamel.

A2.10 *Pendulum Stop Release*—When a jerky release is observed, check the pendulum or the pendulum stop release for any wear. Adjust the height of the pendulum stop until a smooth release is obtained. If a smooth release cannot be obtained by this adjustment, the pendulum or the pendulum stop may require repair or replacement. If the pendulum stop height is changed, verify clamp alignment and zero position.

A2.11 *Zero Pointer Stop*—Operate the leveled instrument several times with nothing in the clamps, the movable clamp being closed. If zero is not registered, adjust the pointer stop until the zero reading is obtained. Do not change the level to adjust the zero.

A2.12 *Pointer Friction*—Set the pointer at the zero reading on the scale before releasing the sector, and after the release, ensure that the pointer is not pushed more than 3 scale divisions (4 mm or 0.08 in.) or less than two scale divisions (2.5 mm or 1 in.) beyond the zero. If the pointer friction does

not lie between two and three divisions, remove the pointer, wipe the bearing clean, and apply a trace of clock oil to the groove of the bearing. Reassemble and check pointer friction. Recheck zero and readjust the pointer stop if necessary.

A2.13 *Oil and Grease*—Apply a very small amount of clock oil in the groove of the bearing and sleeve assembly. DO NOT oil the flat surfaces of the bearing and sleeve assembly. Apply a small amount of silicone grease to the air clamp plunger rods.

A3. VERIFICATION OF SCALE

NOTE A3.1—Historically, four different check weight systems have been offered by manufacturers and used to verify calibration depending upon the date of manufacture. Early machines consisted of five check weights for scale values of 20, 35, 55, 75, and 90 %. (No longer available from the manufacturer.) Following this, machines were manufactured that utilized three check weights for scale values of 20, 50, and 80 %. Current machines utilize one check weight for a scale value of 50 %. In addition the potential energy method has been used. Use of the 50 % check weight and a working range from 20 to 80 % of full scale is recommended.

A3.1 Verify the scale reading of the test instrument in accordance with A3.2.

A3.1.1 For other methods of verification of the scale reading refer to one of the procedures described in the appendix.

A3.2 *One-Check-Weight Procedure*—Use a one check weight calibrated for a value of 50 % of the Elmendorf tester scale. Each capacity scale requires its own check weight. For example, at 800 g of the 1600-g scale. The check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen and having the bulk of the check weight mass facing downward. The useable portion of the scale is 20 to 80 %.

A3.2.1 Position the pendulum in its cocked position against the stop and set the digital readout, or pointer, to zero.

A3.2.2 Depress the pendulum stop downward to its limit and hold it until the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return it to its locked starting position. The pointer, or when equipped, the digital readout should read 0.00. In any event, do not change the level of the instrument to adjust the zero. (See A3.2.6-A3.2.8 as applicable, if adjustment is required.)

A3.2.2.1 For the pointer system, the pointer should not be pushed less than 2.5 mm nor more than 4.0 mm beyond zero. If zero is not registered, the pointer stop should be adjusted until the zero reading is obtained, otherwise service in accordance with Annex A2.

A3.2.3 With the pendulum in the raised position, open the clamp of the pendulum, slide the 50 % check weight, with the bulk of the mass downward, into position, and fasten it securely in the clamp.

A3.2.4 Depress the pendulum stop downward to its limit and hold it until the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return to its locked starting position. The pointer or, when equipped, the digital readout should read 50 ± 0.5 %. (See A3.2.7 or A3.2.8 as applicable, if adjustment is required.)

A3.2.5 Remove the 50 % calibration weight and close the clamp, and when equipped, set the pointer to zero.

A3.2.6 For the pointer system, if zero (0.00) and 50 % readings are not obtained, clean and oil the bearing and sleeve assembly in accordance with A2.12 and A2.13.

A3.2.7 For digital readout systems, if zero (0.00) and 50 % readings are not obtained, loosen the thumb screw securing the photo sensor to the base and move the whole assembly "Right" to increase reading, or "Left" to decrease reading, as required. Continue in accordance with A3.2.1-A3.2.5, alternately making small adjustments of the photo sensor until the target values of 00.0 and 50 % are obtained.

A3.2.8 If zero (0.00) and 50 % readings cannot be obtained, conduct complete maintenance in accordance with Annex A2 until designated readings are obtained and calibration is verified.

A4. INSTRUMENT FACTORS FOR CALCULATION AND TESTING RANGE

A4.1 For instruments with scales calibrated in percent, use the factors given in Table A4.1 for calculating the tearing force in grams-force. These factors take into account the capacity of the tester.

A4.1.1 The acceptable testing range of between 20 and 80 % of the scale value is shown for the direct-reading scale in Table A4.1.

APPENDIXES

(Nonmandatory Information)

X1. USE OF OLDER STANDARD ELMENDORF TESTERS

X1.1 The oldest standard model that did not have a deep cutout in the pendulum allowed the specimen to come in contact with the sector during the test. Consequently, significantly higher values may be obtained than those obtained with the newer models having a deep pendulum cutout. Also, these older models had different clamp designs which contributed to variations in results. These models are not recommended.

X1.1.1 A second generation standard test instrument provided a deep cutout in the pendulum. This unit like the older unit consisted of a basic 1600-gf capacity. The capacity could be increased to 3200-gf capacity with a NIST augmenting weight, and further to 6400-gf capacity with a textile augmenting weight. These test units and augmenting weights are no longer available from the manufacturer. These instruments may be used when agreed upon between the purchaser and the supplier.

X1.1.2 Differences between older and newer models coupled with differences in testing practices frequently resulted in differences between operators and laboratories.

X2. OTHER VERIFICATION OF SCALE PROCEDURES

X2.1 Historically, three different calibration practices other than the one-check-weight procedure described in A3.2 have been used. They are as follows:

X2.1.1 *Three-Check-Weight Procedure*—Use a set of three check weights calibrated for three values, 20, 50, and 80 % of the Elmendorf Tester scale. Each capacity scale requires its own set of check weights. For example, at 320, 800, and 1280 of the 1600-gf scale. Each check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen having the major portion of the mass of the check weight facing downward. Generally, the usable portion of the scale is 20 to 80 %.

X2.1.1.1 Repeat the procedure described in A3.2 using each of the check weights for the designated percentage of scale.

X2.1.2 *Five-Check-Weight Method*—Use a set of five check weights calibrated for five values, 20, 35, 55, 75, and 90 % of the Elmendorf tester scale. Each capacity scale requires its own set of check weights. For example, at 320, 560, 880, 1200, and 1440 of the 1600-gf scale. Each check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen having the major portion of the mass of the check weight facing upward. Generally the usable portion of the scale is 90 %. These check weights are no longer available from the manufacturer.

X2.1.2.1 Repeat the procedure described in A3.2 using each of the check weights for the designated percentage of the scale.

X2.1.3 *Potential Energy Procedure*—Use a weight of known mass (including its attachment) W and with its previously determined center of gravity (including the means of attachment) marked by a punched dot on the side that is to face the front of the tester. Clamp the weight to the radial edge of the sector beneath the jaws with the punched dot showing. Close the jaws of the clamp to the sector.

X2.1.3.1 Raise and set the sector as for tearing a specimen and, by means of a surface gage or cathetometer, measure to the nearest 0.1 mm, the height, H, of the center of gravity of the weight above a fixed horizontal surface. Then release the sector, allow it to swing, and note the pointer reading. Without touching the pointer, raise the sector until the edge of the pointer meets with its stop, in which position again determine the height, H, of the center of gravity of the weight above the fixed surface.

X2.1.3.2 For equipment with microprocessor systems for recording results, the pointer will need to be in place on the bearing assembly to perform the potential energy procedure of scale verification.

X2.1.3.3 The work done is $W\ (h - H)$ gf/mm. For the standard 1600-gf tester, the pointer reading should be $KW\ (h - H)$, where K is 1/86 mm (that is one divided by twice the distance torn). For other testers graduated for grams-force of greater or lesser capacity, the reading will be factors of two greater or smaller, respectively.

NOTE X2.1—The value of K for Test Method D 689, (1376 mm) differs from the value of K for this test method (86 mm) since it is based on tearing 16 sheets of paper, and therefore, the distance torn is 16 times greater.

X2.1.3.4 One or more weights may be clamped on the edge of the sector for each calibration point, the work done in raising each weight is calculated and added together.

X2.1.3.5 If the deviations of the indicated readings are greater than one-half division, the instrument should be returned to the manufacturer for repair and adjustment.