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LAMPIRAN I

GAMBAR ALAT PENELITIAN

1. Wadah

2. Gunting

3. Timbangan digital

4. Gelas ukur 5000 ml

5. Jangka sorong

6. Masker karbon

7. Sarung tangan latex

8. Cetakan

9. Kempa panas

10. Oven

11. UTM (*Universal Testing Machine*)

12. ITM (*Impact Testing Machine*)

LAMPIRAN II

GAMBAR BAHAN PENELITIAN

1. Serat daun nanas

2. Resin *Polyester*

3. Katalis

4. Wax

5. Aluminium foil

6. NaOH

7. Aquades

LAMPIRAN III
DOKUMENTASI PENELITIAN

1. Pengambilan daun nanas

2. Pengerokan daun nanas

3. Perendaman serat daun nanas

4. Pencucian serat daun nanas

5. Pengeringan serat daun nanas

6. Pemotongan serat daun nanas

7. Pencampuran resin *polyester* dengan matriks

8. Pencetakan

LAMPIRAN IV

DOKUMENTASI PENGUJIAN

1. Pengujian densitas

2. Pengujian tarik

3. Pengujian lengkung

4. Pengujian Impak

LAMPIRAN V

HASIL PENGUJIAN

1. **Pengukuran Densitas**

Sampel A

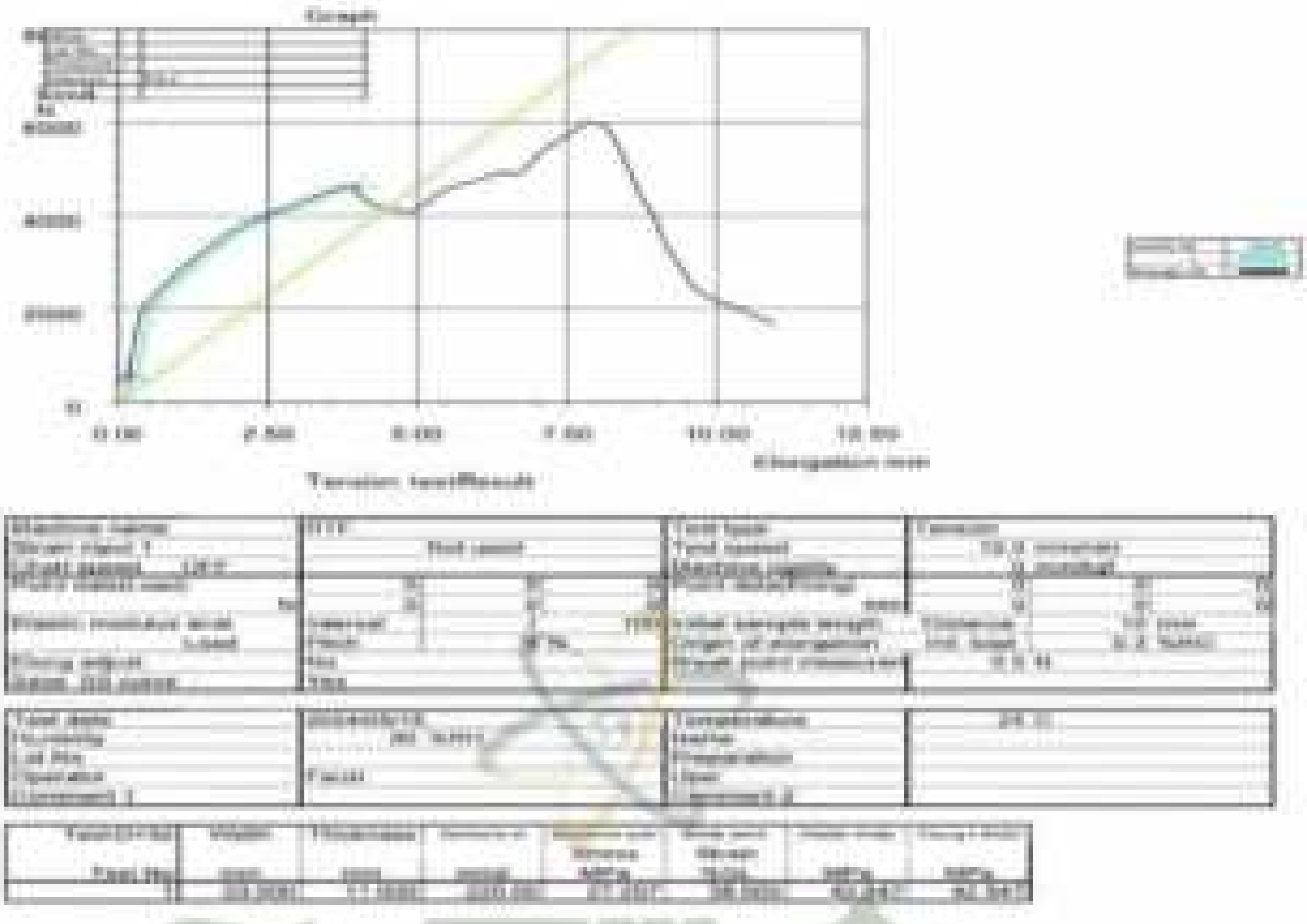
Sampel B

Sampel C

Sampel D

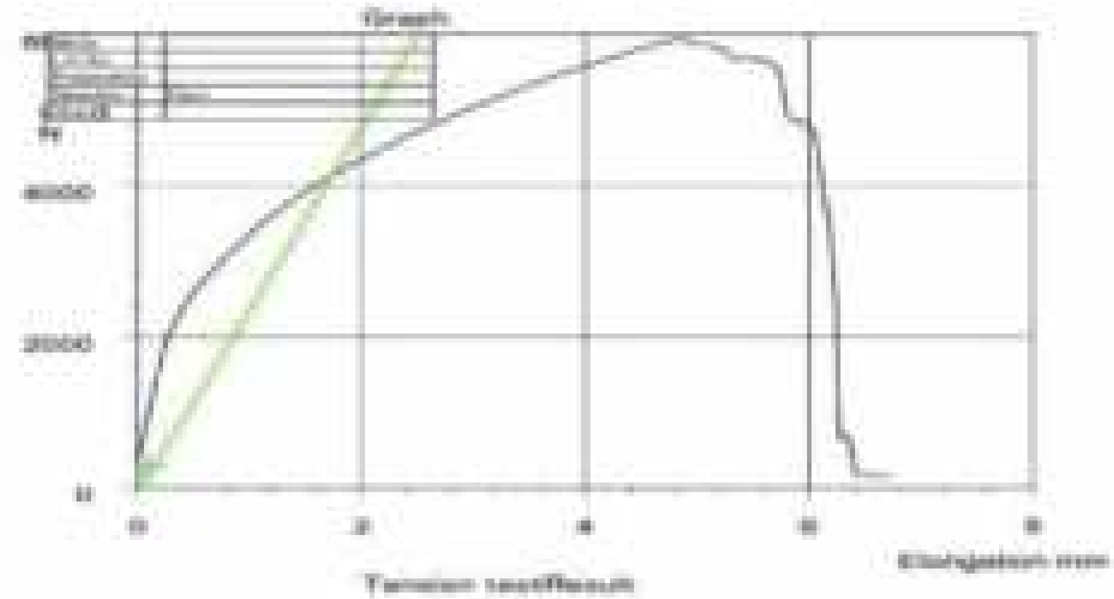
2. Pengujian Tarik

Sampel A



Sampel B

Sampel C

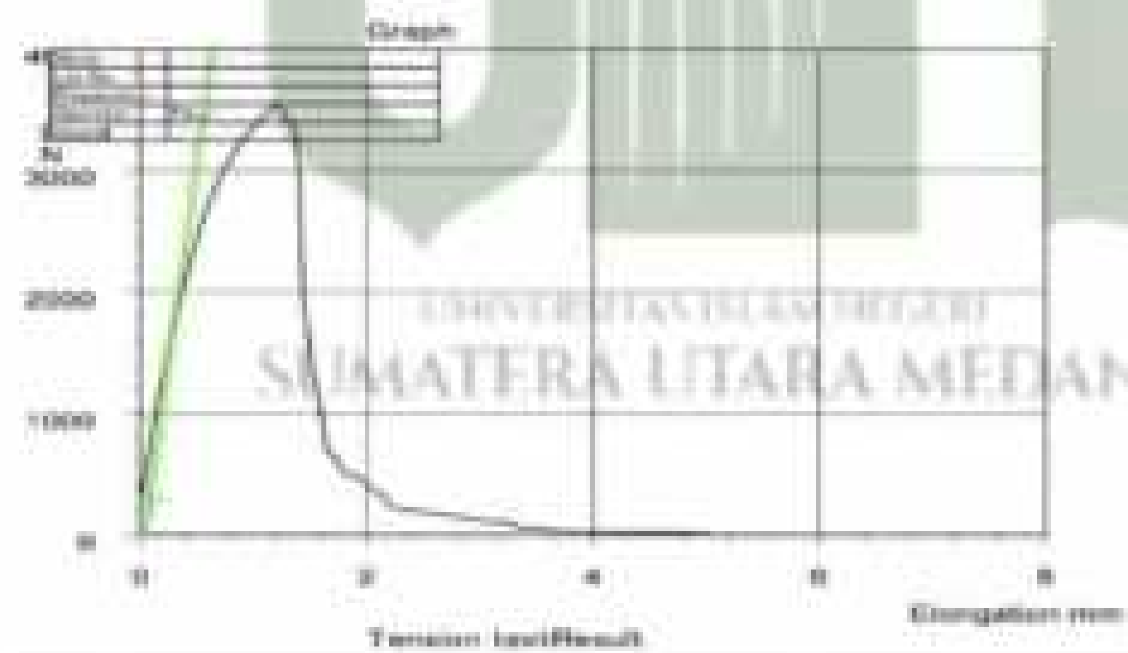


Machine name	RTF	Test type	Tension
Strain input 1	Not used	Test speed	10.0 mm/min
Chart speed OFF		Machine rigidity	0 mm/kgf
Point detect.vert	0 0 0	Point detect(Elong)	0 0 0
N	0 0 0	mm	0 0 0
Elastic modulus anal	Interval 1 100	Initial sample length	Distance 10 mm
Load	Pitch 5 N	Origin of elongation	Init. load 0.5 %RO
Elong adjust	No	Break point measured	0.5 N
Save SS curve	Yes		

Test date	2024/05/15	Temperature	25 C
Humidity	60 %RH	Name	
Lot No.		Preparation	
Operator	Fauzi	User	
Comment 1		Comment 2	

Test/Grade Test No	Width mm	Thickness mm	[illegible] mm2	[illegible] Strain %GL	[illegible] MPa	[illegible] MPa	Maximum point Stress MPa
1	18.200	11.800	217.20	0.0002	114.30	114.30	38.190

Sampel D



Machine name	RTF	Test type	Tension
Strain input 1	Not used	Test speed	10.0 mm/min
Chart speed OFF		Machine rigidity	0 mm/kgf
Point detect.vert	0 0 0	Point detect(Elong)	0 0 0
N	0 0 0	mm	0 0 0
Elastic modulus anal	Interval 1 100	Initial sample length	Distance 10 mm
Load	Pitch 5 N	Origin of elongation	Init. load 0.5 %RO
Elong adjust	No	Break point measured	0.5 N
Save SS curve	Yes		

Test date	2024/04/29	Temperature	25 C
Humidity	60 %RH	Name	
Lot No.		Preparation	
Operator	Fauzi	User	
Comment 1		Comment 2	

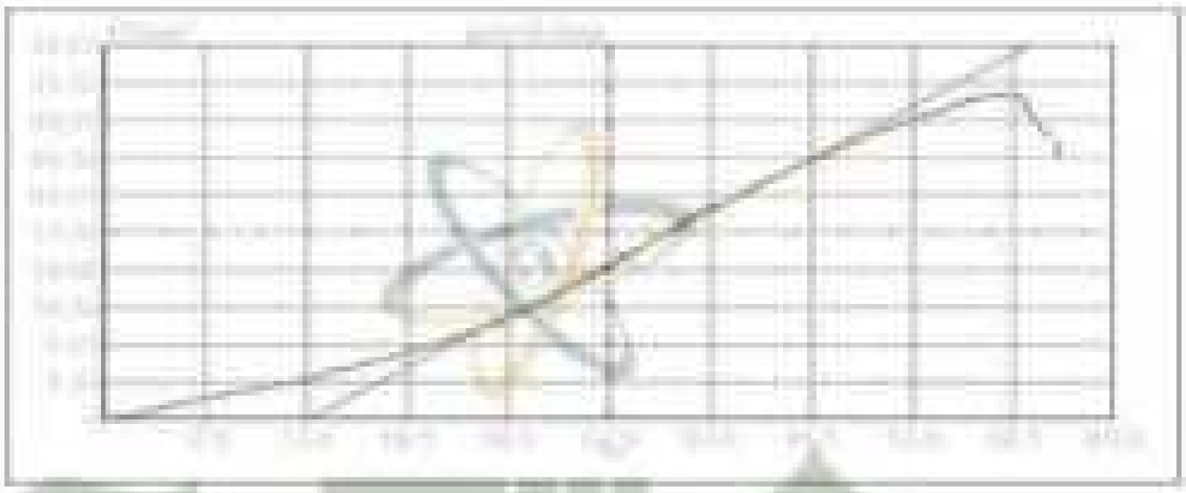
Test/Grade Test No	Width mm	Thickness mm	[illegible] mm2	Maximum point Stress MPa	Break point Strain %GL	[illegible] MPa	Young MPa	[illegible] mm2
1	19.400	10.200	197.88	17.803	-0.4	338.56	338.56	197.88

3. Pengujian Lengkung

Sampel A

Tensile Test

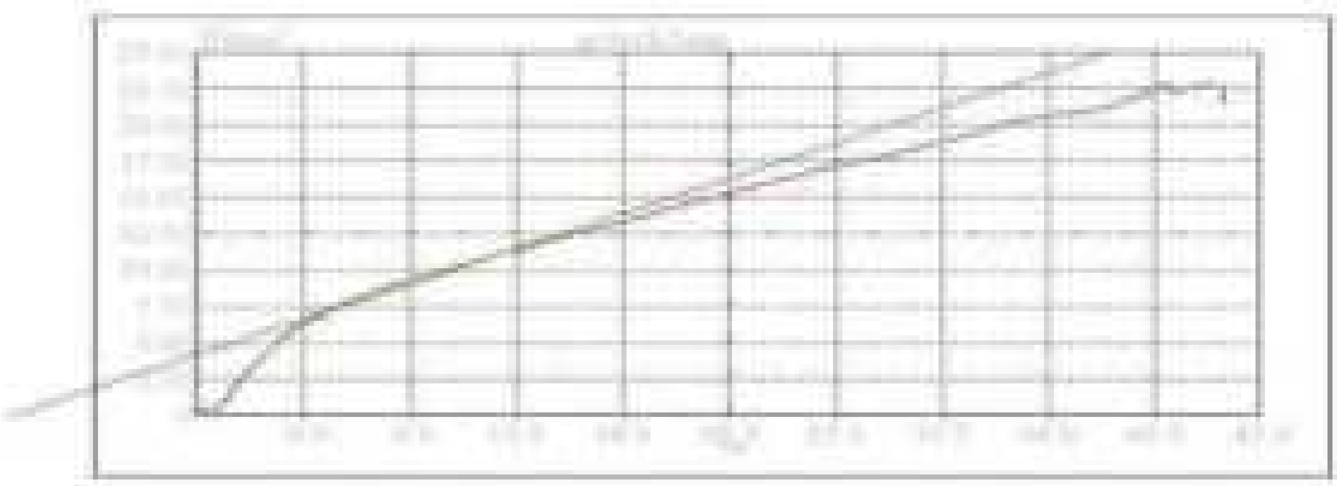
Test No.	Max. Load kgf	Break	Flex Str MPa	MOE MPa
1	78.790	-	39.475	42.620
----	----	----	----	----
----	----	----	----	----
----	----	----	----	----
SD(n-1)	0.000	0.000	0.000	0.000
SD(n)	0.012	0.000	0.001	0.001
Maximum	78.790	0.000	39.475	42.620
Minimum	78.790	0.000	39.475	42.620



Sampel B

Tensile Test

Test No.	Max. Load kgf	Break	Flex Str MPa	MOE MPa
1	55.271	-	27.138	144.732
----	----	----	----	----
----	----	----	----	----
SD(n-1)	0.000	0.000	0.000	0.000
SD(n)	0.011	0.000	0.005	0.010
Maximum	55.271	0.000	22.138	144.532
Minimum	55.271	0.000	22.138	144.532



Sampel C

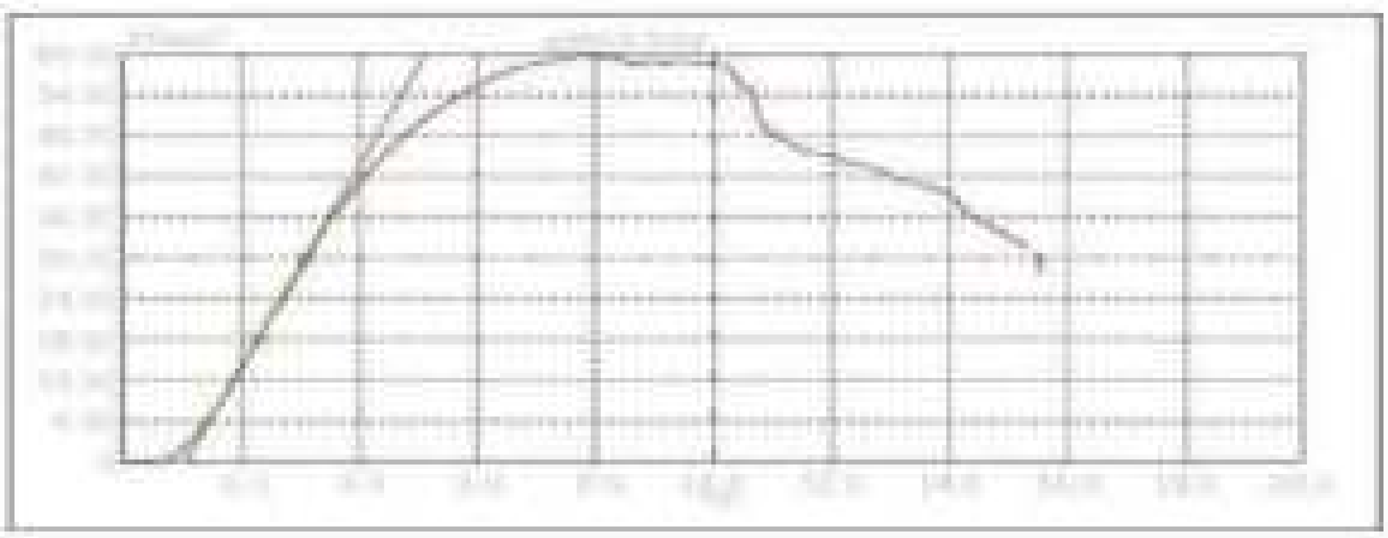
Tensile Test

Test No	Max. Load kgf	Break	Flex Str MPa	MOE MPa
1	91.837	-	59.730	147.118
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
SD(n-1)	0.000	0.000	0.000	0.000
SD(n)	0.008	0.000	0.006	0.016
Maximum	91.837	0.000	59.730	147.118
Minimum	91.837	0.000	59.730	147.118

Sampel D

Tensile Test

Test No	Max. Load kgf	Break	Flex Str MPa	MOE MPa
1	138.187		59.902	18.741
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
SD(n-1)	0.000	0.000	0.000	0.000
SD(n)	8.029	0.000	0.010	0.004
Maximum	138.187	0.000	59.902	18.741
Minimum	138.187	0.000	59.902	18.741



4. Pengujian Impak

Sampel A

Sampel B

Sampel C

Sampel D

LAMPIRAN VI

Surat Keteragan Penelitian

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN,
RISET DAN TEKNOLOGI
UNIVERSITAS SUMATERA UTARA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
Jalan Bioteknologi No. 1 Kampus USU Padang Bulan, Medan - 20155
Telepon: (061) 8211050, 8214290 Fax: (061) 8214290
Laman: www.fmipa.usu.ac.id

Nomor : 802/UN5.2.8.D1/SPB/2024
Lampiran : -
H a l : **Izin Penelitian**

Yth. Kepada Laboratorium Kimia Polimer
FMIPA USU
Medan

Sehubungan dengan surat Dekan Fakultas Sains dan Teknologi Universitas Islam Negeri Sumatera Utara Medan No. B.514/ST.I/ST.V.2/PP.00.9/03/2024 tertanggal 4 Maret 2024, perihal Izin Riset untuk memperoleh informasi/keterangan dan data-data yang berhubungan dengan Skripsi (Karya Ilmiah) di Laboratorium yang Bapak/Ibu pimpin oleh Mahasiswa sebagai berikut:

Nama	:	Siti Aulia Harianja
NIM	:	0705202005
Program Studi	:	Fisika
Judul Penelitian	:	Sintesis dan Karakterisasi Material Komposit Berbahan Serat Daun Nanas dengan Perekat Resin Polyester
Dosen Pembimbing	:	1. Ety Jumiati, S.Pd., M.Si 2. Dr. Abdul Halim Daulay, S.T., M.Si

Kami harap Bapak/Ibu dapat memfasilitasi Mahasiswa tersebut untuk pelaksanaan penelitian sesuai dengan peraturan yang berlaku di Laboratorium ini.

Atas perhatian dan kerjasamanya kami ucapkan terima kasih.

Medan, 07 Maret 2024
Ditandatangani secara elektronik oleh:
Wakil Dekan I

Dr. Cut Fatimah Zuhra, S.Si., M.Si.
NIP 197404051999032001

Tembusan :
1. Dekan Fakultas Sains dan Teknologi UINSU Medan
2. Mahasiswa ybs.

KEMENTERIAN AGAMA REPUBLIK INDONESIA
UNIVERSITAS ISLAM NEGERI SUMATERA UTARA MEDAN
FAKULTAS SAINS DAN TEKNOLOGI
Jl.Willem Iskandar Pasar V Medan Estate 20371
Telp. (061) 6615683-6622925 Fax. 6615683

Nomor : B-168/ST.I/ST.V.2/TL.00/02/2024 27 Februari 2024
Lampiran : -
Hal : **Izin Riset**

Yth. Bapak/Ibu Kepala Laboratorium Polimer Departemen Teknik Kimia Universitas Sumatera Utara

Assalamulaikum Wr. Wb.

Dengan Hormat, diberitahukan bahwa untuk mencapai gelar Sarjana Strata Satu (S1) bagi Mahasiswa Fakultas Sains dan Teknologi adalah menyusun Skripsi (Karya Ilmiah), kami tugaskan mahasiswa:

Nama	: **Siti Aulia Hutauruk**
NIM	: **0702203005**
Tempat/Tanggal Lahir	: **Pasar Sorkam, 07 Juli 2002**
Program Studi	: **Fisika**
Semester	: **VIII (Delapan)**
Alamat	: **JL HALAT GG TABIB NO 6 Kelurahan KOTA MATSUM II Kecamatan MEDAN AREA**

untuk hal dimaksud kami mohon memberikan Izin dan bantuannya terhadap pelaksanaan Riset di Jln. Almamater Kampus USU , guna memperoleh informasi/keterangan dan data-data yang berhubungan dengan Skripsi (Karya Ilmiah) yang berjudul:

Sintesis dan Karakterisasi Material Komposit Berbahan Serat Daun Nanas dengan Perekat Resin Polyester

Demikian kami sampaikan, atas bantuan dan kerjasamanya diucapkan terima kasih.

Medan, 27 Februari 2024
a.n. DEKAN
Wakil Dekan Bidang Akademik dan Kelembagaan

Dr. M. Ridwan, M.Ag
NIP. 197608202003121004

Tembusan:
- Dekan Fakultas Sains dan Teknologi UIN Sumatera Utara Medan

LAMPIRAN VII
PERHITUNGAN DENSITAS

Sampel	Panjang (cm)	Lebar (cm)	Tinggi (cm)	Volume (cm^3)	Massa (g)
A1	10,22	1,8	1,02	18,76	16,66
A2	10,22	2,1	1,02	21,89	18,72
A3	10,22	1,8	1,1	20,23	17,47
B1	10,22	2	1,1	22,49	18,52
B2	10,22	2,4	1,02	25,01	19,46
B3	10,22	2,4	1,02	25,01	19,82
C1	10,26	1,8	1,2	22,16	18,20
C2	10,22	1,9	1,2	23,30	17,52
C3	10,22	1,9	1,2	23,30	18,23
D1	10,26	1,8	1,2	22,37	17,24
D2	10,38	1,8	1,2	22,42	17,27
D3	10,22	1,8	1,2	22,07	17,65

Hasil pengukuran nilai densitas diperoleh dengan menggunakan persamaan (2.1).

Pembuktian perhitungan sampel A1

Diketahui :

Massa benda uji (m) = 16,66 g

Volume benda uji (V) = 18,76 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$$\rho = \frac{m}{V}$$

$$\rho = \frac{16,66\ g}{18,76\ cm^3}$$

$$\rho = 0,88\ g/cm^3$$

Pembuktian perhitungan sampel A2

Diketahui :

Massa benda uji (m) = 18,72 g

Volume benda uji (V) = 21,89 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{18,72\ g}{21,89\ cm^3}$

$\rho = 0,85\ g/cm^3$

Pembuktian perhitungan sampel A3

Diketahui :

Massa benda uji (m) = 17,47 g

Volume benda uji (V) = 20,23 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{17,47\ g}{20,23\ cm^3}$

$\rho = 0,86\ g/cm^3$

Pembuktian perhitungan sampel B1

Diketahui :

Massa benda uji (m) = 18,52 g

Volume benda uji (V) = 22,49 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{18,52\ g}{22,49\ cm^3}$

$\rho = 0,82\ g/cm^3$

Pembuktian perhitungan sampel B2

Diketahui :

Massa benda uji (m) = 19,46 g

Volume benda uji (V) = 25,01 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{19,46\ g}{25,01\ cm^3}$

$\rho = 0,77$ g/cm^3

Pembuktian perhitungan sampel B3

Diketahui :

Massa benda uji (m) = 19,82 g

Volume benda uji (V) = 25,01 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{19,82\ g}{25,01\ cm^3}$

$\rho = 0,79$ g/cm^3

Pembuktian perhitungan sampel C1

Diketahui :

Massa benda uji (m) = 18,20 g

Volume benda uji (V) = 22,16 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{18,20\ g}{22,16\ cm^3}$

$\rho = 0,82$ g/cm^3

Pembuktian perhitungan sampel C2

Diketahui :

Massa benda uji (m) = 17,52 g

Volume benda uji (V) = 23,30 cm^3

Ditanya :

Densitas...?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{17,52\ g}{23,30\ cm^3}$

$\rho = 0,75\ g/cm^3$

Pembuktian perhitungan sampel C3

Diketahui :

Massa benda uji (m) = 18,23 g

Volume benda uji (V) = 23,30 cm^3

Ditanya :

Densitas...?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{18,23\ g}{23,30\ cm^3}$

$\rho = 0,78\ g/cm^3$

Pembuktian perhitungan sampel D1

Diketahui :

Massa benda uji (m) = 17,24 g

Volume benda uji (V) = 22,37 cm^3

Ditanya :

Densitas...?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{17,24\ g}{22,37\ cm^3}$

$\rho = 0,77\ g/cm^3$

Pembuktian perhitungan sampel D2

Diketahui :

Massa benda uji (m) = 17,27 g

Volume benda uji (V) = 22,42 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{17,27\ g}{22,42\ cm^3}$

$\rho = 0,77\ g/cm^3$

Pembuktian perhitungan sampel D3

Diketahui :

Massa benda uji (m) = 17,65 g

Volume benda uji (V) = 22,07 cm^3

Ditanya :

Densitas…?

Penyelesaian :

$\rho = \frac{m}{V}$

$\rho = \frac{17,65\ g}{22,07\ cm^3}$

$\rho = 0,79\ g/cm^3$

LAMPIRAN VIII

PERHITUNGAN UJI IMPAK

Sampel	Kuat Impak (J/m^2)	Kuat Impak (kJ/m^2)	Kuat Impak Rata-rata (J/mm^2)
A1	27.686,3	27,6863	
A2	28.221,8	28,2218	27,79
A3	27.479,1	27,4791	
B1	28.852,6	28,8526	
B2	28.840,0	28,8400	29,97
B3	32.246,4	32,2464	
C1	30.443,3	30,4433	
C2	30.455,0	30,4550	30,44
C3	30.455,0	30,4550	
D1	32.248,2	30,4550	
D2	30.712,6	30,7126	30,50
D3	28.853,6	28,8536	

Pembuktian perhitungan sampel A1

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 27.686,3\ J/m^2$

$= \frac{27.686,3\ m^2}{1.000\ kJ}$

Nilai Impak $= 27,6863\ kJ/m^2$

Pembuktian perhitungan sampel A2

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak = 28.221,8 J/m^2

$= \frac{28.221,8\ m^2}{1.000\ kJ}$

Nilai Impak = 28,2218 kJ/m^2

Pembuktian perhitungan sampel A3

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak = 27.479,1 J/m^2

$= \frac{27.479,1\ m^2}{1.000\ kJ}$

Nilai Impak = 27,4791 kJ/m^2

Pembuktian perhitungan sampel B1

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak = 28.852,6 J/m^2

$= \frac{28.852,6\ m^2}{1.000\ kJ}$

Nilai Impak = 28,8526 kJ/m^2

Pembuktian perhitungan sampel B2

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 28.840{,}0\ J/m^2$

$= \frac{28.840{,}0\ m^2}{1.000\ kJ}$

Nilai Impak $= 28{,}8400\ kJ/m^2$

Pembuktian perhitungan sampel B3

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 32.246{,}4\ J/m^2$

$= \frac{32.246{,}4\ m^2}{1.000\ kJ}$

Nilai Impak $= 32{,}2464\ kJ/m^2$

Pembuktian perhitungan sampel C1

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 30.443{,}3\ J/m^2$

$= \frac{30.443{,}3\ m^2}{1.000\ kJ}$

Nilai Impak $= 30{,}443{,}3\ kJ/m^2$

Pembuktian perhitungan sampel C2

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 30.445,0 \text{ J/m}^2$

$= \frac{30.455,0 \ m^2}{1.000 \ kJ}$

Nilai Impak $= 30,4450 \text{ kJ/m}^2$

Pembuktian perhitungan sampel C3

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 30.445,0 \text{ J/m}^2$

$= \frac{30.455,0 \ m^2}{1.000 \ kJ}$

Nilai Impak $= 30,4450 \text{ kJ/m}^2$

Pembuktian perhitungan sampel D1

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 32.248,2 \text{ J/m}^2$

$= \frac{32.240,2 \ m^2}{1.000 \ kJ}$

Nilai Impak $= 32,2482 \text{ kJ/m}^2$

Pembuktian perhitungan sampel D2

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 30.712,6\ J/m^2$

$= \frac{30.712,6\ m^2}{1.000\ kJ}$

Nilai Impak $= 30,7126\ kJ/m^2$

Pembuktian perhitungan sampel D3

Diketahui :

Pembebanan : IZOD 03

Energi : 5,5 J

Kecepatan : 3,46 m/s

Ditanya :

Nilai Impak.....?

Penyelesaian

Nilai Impak $= 28.853,6\ J/m^2$

$= \frac{28.853,6\ m^2}{1.000\ kJ}$

Nilai Impak $= 28.853,6\ kJ/m^2$

LAMPIRAN VIII

1. ASTM D638-03 Standar Uji Tarik

Designation: D 638 – 03

Standard Test Method for Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D 638; 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 Department of Defense.

1. Scope*

1.1 This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed.

1.2 This test method can be used for testing materials of any thickness up to 14 mm [0.55 in.]. However, for testing specimens in the form of thin sheeting, including film less than 1.0 mm [0.04 in.] in thickness, Test Methods D 882 is the preferred test method. Materials with a thickness greater than 14 mm [0.55 in.] must be reduced by machining.

1.3 This test method includes the option of determining Poisson's ratio at room temperature.

NOTE 1—This test method and ISO 527-1 are technically equivalent.

NOTE 2—This test method is not intended to cover precise physical procedures. It is recognized that the constant rate of crosshead movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate of crosshead movement and rate of strain between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

NOTE 3—This test method may be used for testing phenolic molded resin or laminated materials. However, where these materials are used as electrical insulation, such materials should be tested in accordance with Test Methods D 229 and Test Method D 651.

NOTE 4—For tensile properties of resin-matrix composites reinforced with oriented continuous or discontinuous high modulus >20-GPa [>3.0 × 10[6]-psi] fibers, tests shall be made in accordance with Test Method D 3039/D 3039M.

1.4 Test data obtained by this test method are relevant and appropriate for use in engineering design.

1.5 The values stated in SI units are to be regarded as the standard. The values given in brackets are for information only.

1.6 *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 229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D 618 Practice for Conditioning Plastics for Testing

D 651 Test Method for Tensile Strength of Molded Electrical Insulating Materials

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting

D 883 Terminology Relating to Plastics

D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials

D 3039/D 3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials

D 4000 Classification System for Specifying Plastic Materials

D 4066 Classification System for Nylon Injection and Extrusion Materials

D 5947 Test Methods for Physical Dimensions of Solid Plastic Specimens

E 4 Practices for Force Verification of Testing Machines

E 83 Practice for Verification and Classification of Extensometer

E 132 Test Method for Poisson's Ratio at Room Temperature

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard:* [3]

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[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties. Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1941. Last previous edition approved in 2002 as D 638 - 02a.

[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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

*A Summary of Changes section appears at the end of this standard.

1

ISO 527-1 Determination of Tensile Properties

3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D 883 and Annex A2.

4. Significance and Use

4.1 This test method is designed to produce tensile property data for the control and specification of plastic materials. These data are also useful for qualitative characterization and for research and development. For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 in Classification D 4000 lists the ASTM materials standards that currently exist.

4.2 Tensile properties may vary with specimen preparation and with speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

4.2.1 It is realized that a material cannot be tested without also testing the method of preparation of that material. Hence, when comparative tests of materials per se are desired, the greatest care must be exercised to ensure that all samples are prepared in exactly the same way, unless the test is to include the effects of sample preparation. Similarly, for referee purposes or comparisons within any given series of specimens, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4.3 Tensile properties may provide useful data for plastics engineering design purposes. However, because of the high degree of sensitivity exhibited by many plastics to rate of straining and environmental conditions, data obtained by this test method cannot be considered valid for applications involving load-time scales or environments widely different from those of this test method. In cases of such dissimilarity, no reliable estimation of the limit of usefulness can be made for most plastics. This sensitivity to rate of straining and environment necessitates testing over a broad load-time scale (including impact and creep) and range of environmental conditions if tensile properties are to suffice for engineering design purposes.

NOTE 3—Since the existence of a true elastic limit in plastics (as in many other organic materials and in many metals) is debatable, the propriety of applying the term "elastic modulus" in its quoted, generally accepted definition to describe the "stiffness" or "rigidity" of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are highly dependent on such factors as rate of application of stress, temperature, previous history of specimen, etc. However, stress-strain curves for plastics, determined as described in this test method, almost always show a linear region at low stresses, and a straight line drawn tangent to this portion of the curve permits calculation of an elastic modulus of the usually defined type. Such a constant is useful if its arbitrary nature and dependence on time, temperature, and similar factors are realized.

4.4 *Poisson's Ratio*—When uniaxial tensile force is applied to a solid, the solid stretches in the direction of the applied force (axially), but it also contracts in both dimensions lateral to the applied force. If the solid is homogeneous and isotropic, and the material remains elastic under the action of the applied force, the lateral strain bears a constant relationship to the axial strain. This constant, called Poisson's ratio, is defined as the negative ratio of the transverse (negative) to axial strain under uniaxial stress.

4.4.1 Poisson's ratio is used for the design of structures in which all dimensional changes resulting from the application of force need to be taken into account and in the application of the generalized theory of elasticity to structural analysis.

NOTE 4—The accuracy of the determination of Poisson's ratio is usually limited by the accuracy of the transverse strain measurements because the percentage errors in these measurements are usually greater than in the axial strain measurements. Since a ratio rather than an absolute quantity is measured, it is only necessary to know accurately the relative value of the calibration factors of the extensometers. Also, in general, the value of the applied loads need not be known accurately.

5. Apparatus

5.1 *Testing Machine*—A testing machine of the constant-rate-of-crosshead-movement type and comprising essentially the following:

5.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

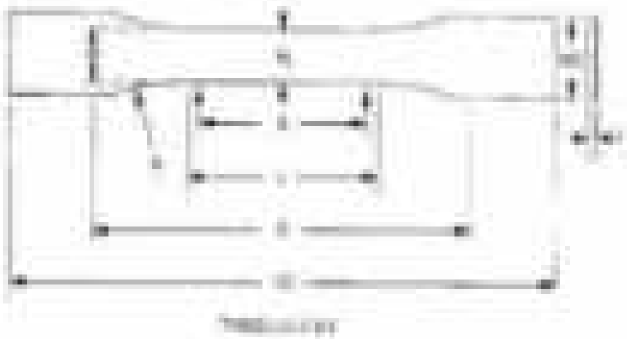
5.1.2 *Movable Member*—A movable member carrying a second grip.

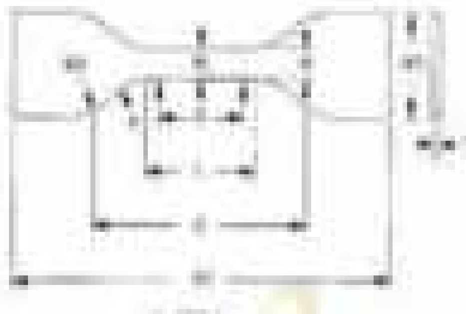
5.1.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member of the testing machine can be either the fixed or self-aligning type.

5.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the testing machine. When this type of grip is used extreme care should be taken to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the center line of the grip assembly.

5.1.3.2 Self-aligning grips are attached to the fixed and movable members of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. The specimens should be aligned as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

5.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 2.4 mm [0.09 in.] apart and about 1.6 mm [0.06 in.] deep, have been found satisfactory for most thermoplastics. Finer serrations have been found to be more satisfactory for harder plastics, such as the thermosetting materials. The serrations should be kept clean and sharp. Breaking in the grips may occur at times, even when deep serrations or abraded specimen surfaces are used; other techniques must be used in these cases. Other techniques that have been found useful, particularly with smooth-faced grips, are abrading that portion of the surface of the specimen that will be in the grips, and interposing thin





Specimen Dimensions for Thickness, T, mm [in.][A]

Dimensions (see drawings)	7 [0.28] or under		Over 7 to 14 [0.28 to 0.55], incl	4 [0.16] or under		Tolerances
	Type I	Type II	Type III	Type IV[B]	Type V[C,D]	
W—Width of narrow section[E,F]	13 [0.50]	6 [0.25]	19 [0.75]	6 [0.25]	3.18 [0.125]	±0.5 [±0.02][B,C]
L—Length of narrow section	57 [2.25]	57 [2.25]	57 [2.25]	33 [1.30]	9.53 [0.375]	±0.5 [±0.02][C]
WO—Width overall, min[G]	19 [0.75]	19 [0.75]	29 [1.13]	19 [0.75]	...	+ 6.4 [+ 0.25]
WO—Width overall, min[G]	...	...	...	...	9.53 [0.375]	+ 3.18 [+ 0.125]
LO—Length overall, min[H]	165 [6.5]	183 [7.2]	246 [9.7]	115 [4.5]	63.5 [2.5]	no max [no max]
G—Gage length[I]	50 [2.00]	50 [2.00]	50 [2.00]	...	7.62 [0.300]	±0.25 [±0.010][C]
G—Gage length[I]	...	...	...	25 [1.00]	...	±0.13 [±0.005]
D—Distance between grips	115 [4.5]	135 [5.3]	115 [4.5]	65 [2.5][J]	25.4 [1.0]	±5 [±0.2]
R—Radius of fillet	76 [3.00]	76 [3.00]	76 [3.00]	14 [0.56]	12.7 [0.5]	±1 [±0.04][C]
RO—Outer radius (Type IV)	...	...	...	25 [1.00]	...	±1 [±0.04]

[A] Thickness, T, shall be 3.2 ± 0.4 mm [0.13 ± 0.02 in.] for all types of molded specimens, and for other Types I and II specimens where possible. If specimens are machined from sheets or plates, thickness, T, may be the thickness of the sheet or plate provided this does not exceed the range stated for the intended specimen type. For sheets of nominal thickness greater than 14 mm [0.55 in.] the specimens shall be machined to 14 ± 0.4 mm [0.55 ± 0.02 in.] in thickness, for use with the Type III specimen. For sheets of nominal thickness between 14 and 51 mm [0.55 and 2 in.] approximately equal amounts shall be machined from each surface. For thicker sheets both surfaces of the specimen shall be machined, and the location of the specimen with reference to the original thickness of the sheet shall be noted. Tolerances on thickness less than 14 mm [0.55 in.] shall be those standard for the grade of material tested.

[B] For the Type IV specimen, the internal width of the narrow section of the die shall be 6.00 ± 0.05 mm [0.250 ± 0.002 in.]. The dimensions are essentially those of Die C in Test Methods D 412.

[C] The Type V specimen shall be machined or die cut to the dimensions shown, or molded in a mold whose cavity has these dimensions. The dimensions shall be:

W = 3.18 ± 0.03 mm [0.125 ± 0.001 in.],

L = 9.53 ± 0.08 mm [0.375 ± 0.003 in.],

G = 7.62 ± 0.02 mm [0.300 ± 0.001 in.], and

R = 12.7 ± 0.08 mm [0.500 ± 0.003 in.].

The other tolerances are those in the table.

[D] Supporting data on the introduction of the L specimen of Test Method D 1822 as the Type V specimen are available from ASTM Headquarters. Request RR:D20-1038.

[E] The width at the center W_c shall be +0.00 mm, −0.10 mm [+0.000 in., −0.004 in.] compared with width W at other parts of the reduced section. Any reduction in W at the center shall be gradual, equally on each side so that no abrupt changes in dimension result.

[F] For molded specimens, a draft of not over 0.13 mm [0.005 in.] may be allowed for either Type I or II specimens 3.2 mm [0.13 in.] in thickness, and this should be taken into account when calculating width of the specimen. Thus a typical section of a molded Type I specimen, having the maximum allowable draft, could be as follows:

[G] Overall widths greater than the minimum indicated may be desirable for some materials in order to avoid breaking in the grips.

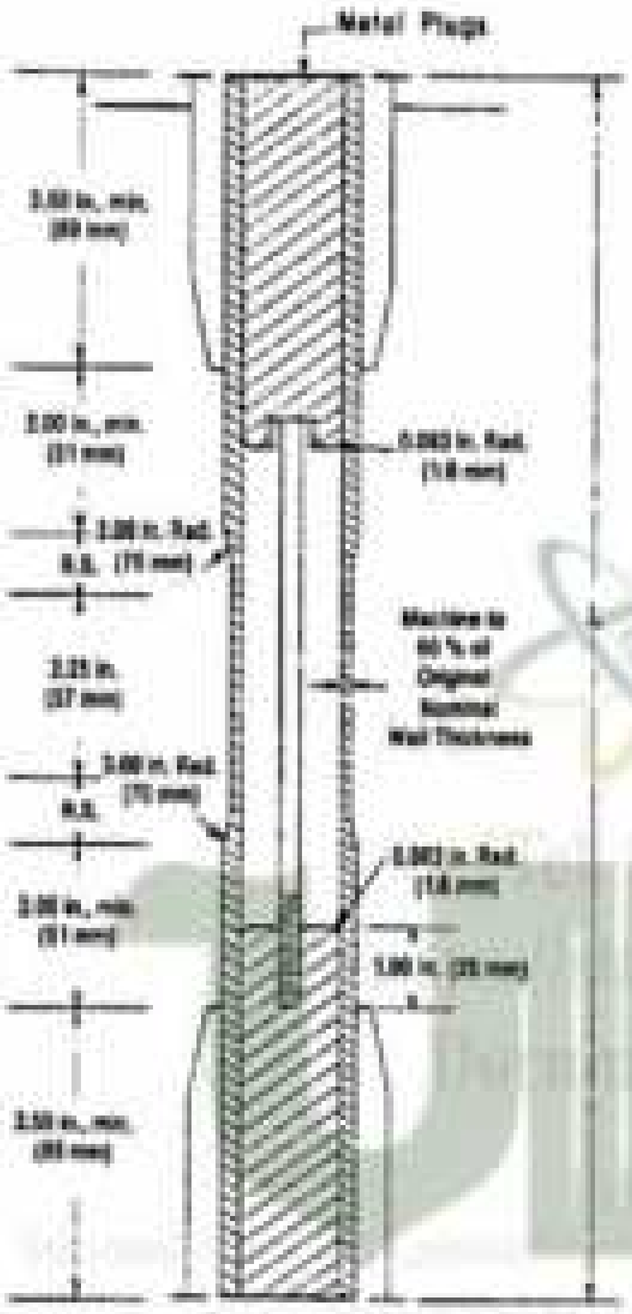
[H] Overall lengths greater than the minimum indicated may be desirable either to avoid breaking in the grips or to satisfy special test requirements.

[I] Test marks or initial extensometer span.

[J] When self-tightening grips are used, for highly extensible polymers, the distance between grips will depend upon the types of grips used and may not be critical if maintained uniform once chosen.

FIG. 1 Tension Test Specimens for Sheet, Plate, and Molded Plastics

in.] must be machined to 14 mm [0.55 in.] for use as Type III specimens. Specimens can also be prepared by molding the material to be tested.



DIMENSIONS OF TUBE SPECIMENS

Nominal Wall Thickness	Length of Radial Sections, 2R.S.	Total Calculated Minimum Length of Specimen	Standard Length, L, of Specimen to Be Used for 89-mm [3.5-in.] Jaws[A]
	mm [in.]		
0.79 [1/32]	13.9 [0.547]	350 [13.80]	381 [15]
1.2 [3/64]	17.0 [0.670]	354 [13.92]	381 [15]
1.6 [1/16]	19.6 [0.773]	358 [14.10]	381 [15]
2.4 [3/32]	24.0 [0.946]	361 [14.22]	381 [15]
3.2 [1/8]	27.7 [1.091]	364 [14.34]	381 [15]
4.8 [3/16]	33.9 [1.333]	370 [14.58]	381 [15]
6.4 [1/4]	39.0 [1.536]	376 [14.79]	400 [15.75]
7.9 [5/16]	43.6 [1.719]	380 [14.96]	400 [15.75]
9.5 [3/8]	47.8 [1.875]	384 [15.12]	400 [15.75]
11.1 [7/16]	51.3 [2.019]	388 [15.27]	400 [15.75]
12.7 [1/2]	54.7 [2.154]	391 [15.40]	419 [16.5]

[A] For other jaws greater than 89 mm [3.5 in.], the standard length shall be increased by twice the length of the jaws minus 178 mm [7 in.]. The standard length permits a slippage of approximately 6.4 to 12.7 mm [0.25 to 0.50 in.] in each jaw while maintaining the maximum length of the jaw grip.

FIG. 2 Diagram Showing Location of Tube Tension Test Specimens in Testing Machine

NOTE 9—Test results have shown that for some materials such as glass cloth, SMC, and BMC laminates, other specimen types should be considered to ensure breakage within the gage length of the specimen, as mandated by 7.3.

NOTE 10—When preparing specimens from certain composite laminates such as woven roving, or glass cloth, care must be exercised in cutting the specimens parallel to the reinforcement. The reinforcement will be significantly weakened by cutting on a bias, resulting in lower laminate properties, unless testing of specimens in a direction other than parallel with the reinforcement constitutes a variable being studied.

NOTE 11—Specimens prepared by injection molding may have different tensile properties than specimens prepared by machining or die-cutting because of the orientation induced. This effect may be more pronounced in specimens with narrow sections.

6.2 *Rigid Tubes*—The test specimen for rigid tubes shall be as shown in Fig. 2. The length, *L*, shall be as shown in the table in Fig. 2. A groove shall be machined around the outside of the specimen at the center of its length so that the wall section after machining shall be 60 % of the original nominal wall thickness. This groove shall consist of a straight section 57.2 mm [2.25 in.] in length with a radius of 76 mm [3 in.] at each end joining it to the outside diameter. Steel or brass plugs having diameters such that they will fit snugly inside the tube and having a length equal to the full jaw length plus 25 mm [1 in.] shall be placed in the ends of the specimens to prevent crushing. They can be located conveniently in the tube by separating and supporting them on a threaded metal rod. Details of plugs and test assembly are shown in Fig. 2.

6.3 *Rigid Rods*—The test specimen for rigid rods shall be as shown in Fig. 3. The length, *L*, shall be as shown in the table in Fig. 3. A groove shall be machined around the specimen at the center of its length so that the diameter of the machined portion shall be 60 % of the original nominal diameter. This groove shall consist of a straight section 57.2 mm [2.25 in.] in length with a radius of 76 mm [3 in.] at each end joining it to the outside diameter.

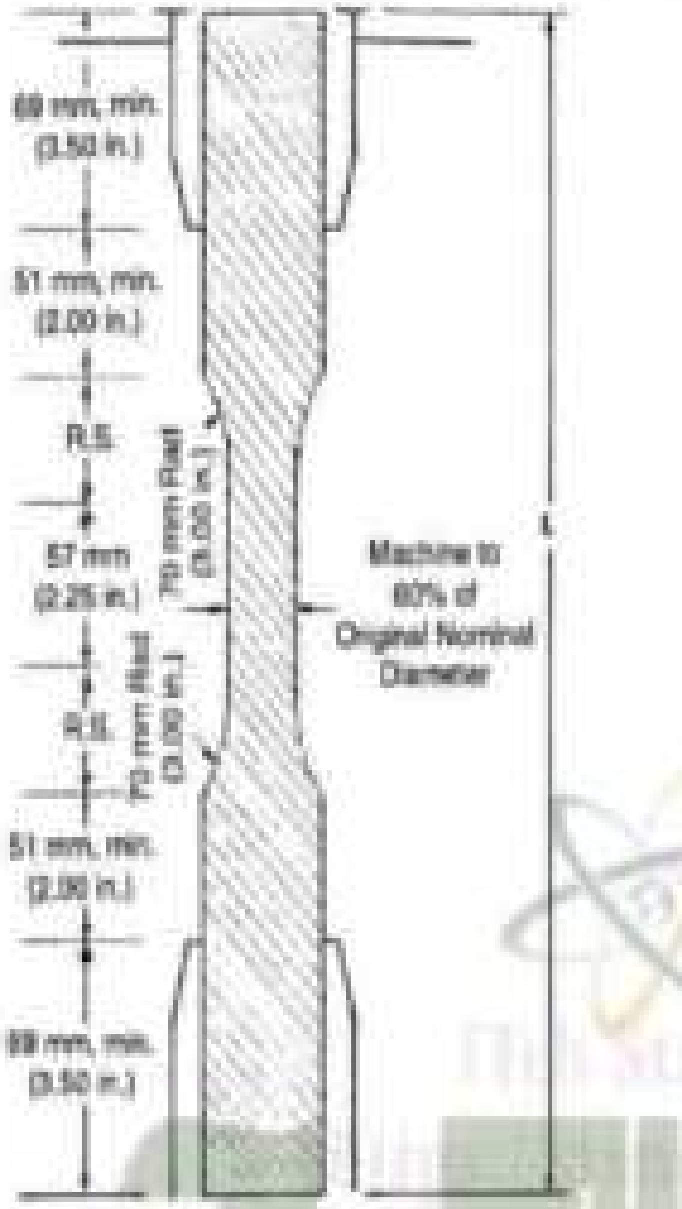
6.4 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). The finishing sanding strokes shall be made in a direction parallel to the long axis of the test specimen. All flash shall be removed from a molded specimen, taking great care not to disturb the molded surfaces. In machining a specimen, undercuts that would exceed the dimensional tolerances shown in Fig. 1 shall be scrupulously avoided. Care shall also be taken to avoid other common machining errors.

6.5 If it is necessary to place gage marks on the specimen, this shall be done with a wax crayon or India ink that will not affect the material being tested. Gage marks shall not be scratched, punched, or impressed on the specimen.

6.6 When testing materials that are suspected of anisotropy, duplicate sets of test specimens shall be prepared, having their long axes respectively parallel with, and normal to, the suspected direction of anisotropy.

7. Number of Test Specimens

7.1 Test at least five specimens for each sample in the case of isotropic materials.



DIMENSIONS OF ROD SPECIMENS

Nominal Diameter	Length of Radial Sections, 2R.S.	Total Calculated Minimum Length of Specimen	Standard Length, L, of Specimen to be Used for 89-mm (3.5-in.) Jaws[A]
		mm [in.]	
3.2 [1/8]	19.6 [0.773]	356 [14.02]	381 [15]
4.7 [3/16]	24.0 [0.946]	361 [14.20]	381 [15]
6.4 [1/4]	27.7 [1.091]	364 [14.34]	381 [15]
9.5 [3/8]	33.9 [1.333]	370 [14.58]	381 [15]
12.7 [1/2]	39.0 [1.536]	376 [14.79]	400 [15.75]
15.9 [5/8]	43.5 [1.714]	380 [14.96]	400 [15.75]
19.0 [3/4]	47.6 [1.873]	384 [15.12]	400 [15.75]
22.2 [7/8]	51.5 [2.019]	388 [15.27]	400 [15.75]
25.4 [1]	54.7 [2.154]	391 [15.40]	419 [16.5]
31.8 [1 1/4]	60.9 [2.398]	398 [15.65]	419 [16.5]
38.1 [1 1/2]	66.4 [2.615]	403 [15.87]	419 [16.5]
42.5 [1 3/4]	71.4 [2.812]	408 [16.06]	419 [16.5]
50.8 [2]	76.0 [2.993]	412 [16.24]	432 [17]

[A] For other jaws greater than 89 mm (3.5 in.), the standard length shall be increased by twice the length of the jaws minus 178 mm (7 in.). The standard length permits a slippage of approximately 6.4 to 12.7 mm (0.25 to 0.50 in.) in each jaw while maintaining the maximum length of the jaw grip.

FIG. 3 Diagram Showing Location of Rod Tension Test Specimen in Testing Machine

7.2 Test ten specimens, five normal to, and five parallel with, the principle axis of anisotropy, for each sample in the case of anisotropic materials.

7.3 Discard specimens that break at some flaw, or that break outside of the narrow cross-sectional test section (Fig. 1, dimension "L"), and make retests, unless such flaws constitute a variable to be studied.

NOTE 13—Before testing, all transparent specimens should be inspected in a polariscope. Those which show atypical or concentrated strain patterns should be rejected, unless the effects of these residual strains constitute a variable to be studied.

8. Speed of Testing

8.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the test. The rate of motion of the driven grip or fixture when the testing machine is running idle may be used, if it can be shown that the resulting speed of testing is within the limits of variation allowed.

8.2 Choose the speed of testing from Table 1. Determine this chosen speed of testing by the specification for the material being tested, or by agreement between those concerned. When the speed is not specified, use the lowest speed shown in Table 1 for the specimen geometry being used, which gives rupture within 1/2 to 5-min testing time.

8.3 Modulus determinations may be made at the speed selected for the other tensile properties when the recorder response and resolution are adequate.

8.4 The speed of testing for Poisson's ratio determination shall be 5 mm/min.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C [73.4 ± 3.6°F] and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, unless otherwise specified by contract or the relevant ASTM material specification. Reference pre-test conditioning, to settle disagreements, shall apply tolerances of ±1°C [1.8°F] and ±2 % relative humidity.

9.2 *Test Conditions*—Conduct the tests at 23 ± 2°C [73.4 ± 3.6°F] and 50 ± 5 % relative humidity, unless otherwise specified by contract or the relevant ASTM material specification. Reference testing conditions, to settle disagreements, shall apply tolerances of ±1°C [1.8°F] and ±2 % relative humidity.

TABLE 1 Designations for Speed of Testing[A]

Classification[B]	Specimen Type	Speed of Testing, mm/min [in./min]	Nominal Strain[C] Rate at Start of Test, mm/mm · min [in./in.·min]
Rigid and Semirigid	I, II, III rods and tubes	5 [0.2] ± 25 %	0.1
		50 [2] ± 10 %	1
		500 [20] ± 10 %	10
	IV	5 [0.2] ± 25 %	0.15
		50 [2] ± 10 %	1.5
		500 [20] ± 10 %	15
	V	1 [0.05] ± 25 %	0.1
		10 [0.5] ± 25 %	1
		100 [5] ± 25 %	10
Nonrigid	III	50 [2] ± 10 %	1
		500 [20] ± 10 %	10
	IV	50 [2] ± 10 %	1.5
		500 [20] ± 10 %	15

[A] Select the lowest speed that produces rupture in 1/2 to 5 min for the specimen geometry being used (see 8.2).

[B] See Terminology D 883 for definitions.

[C] The initial rate of straining cannot be calculated exactly for dumbbell-shaped specimens because of extension, both in the reduced section outside the gage length and in the fillets. This initial strain rate can be measured from the initial slope of the tensile strain-versus-time diagram.

2. ASTM D790-02 Standar Uji Lengkung

Designation: D 790 – 02

Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[1]

This standard is issued under the fixed designation D 790; 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 Department of Defense.

1. Scope *

1.1 These test methods cover the determination of flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semirigid materials. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam. A four-point loading system method can be found in Test Method D 6272.

1.1.1 *Procedure A*, designed principally for materials that break at comparatively small deflections.

1.1.2 *Procedure B*, designed particularly for those materials that undergo large deflections during testing.

1.1.3 Procedure A shall be used for measurement of flexural properties, particularly flexural modulus, unless the material specification states otherwise. Procedure B may be used for measurement of flexural strength only. Tangent modulus data obtained by Procedure A tends to exhibit lower standard deviations than comparable data obtained by means of Procedure B.

1.2 Comparative tests may be run in accordance with either procedure, provided that the procedure is found satisfactory for the material being tested.

1.3 The values stated in SI units are to be regarded as the standard. The values provided in parentheses are for information only.

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.*

NOTE 1—These test methods are not technically equivalent to ISO 178.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]
D 638 Test Method for Tensile Properties of Plastics[2]
D 883 Terminology Relating to Plastics[2]
D 4000 Classification System for Specifying Plastic Materials[3]
D 5947 Test Methods for Physical Dimensions of Solid Plastic Specimens[4]
D 6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending[4]
E 4 Practices for Force Verification of Testing Machines[5]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

3. Terminology

3.1 *Definitions*—Definitions of terms applying to these test methods appear in Terminology D 883 and Annex A1 of Test Method D 638.

4. Summary of Test Method

4.1 A bar of rectangular cross section rests on two supports and is loaded by means of a loading nose midway between the supports (see Fig. 1). A support span-to-depth ratio of 16:1 shall be used unless there is reason to suspect that a larger span-to-depth ratio may be required, as may be the case for certain laminated materials (see Section 7 and Note 8 for guidance).

4.2 The specimen is deflected until rupture occurs in the outer surface of the test specimen or until a maximum strain (see 12.7) of 5.0 % is reached, whichever occurs first.

4.3 Procedure A employs a strain rate of 0.01 mm/mm/min (0.01 in./in./min) and is the preferred procedure for this test method, while Procedure B employs a strain rate of 0.10 mm/mm/min (0.10 in./in./min).

[1] These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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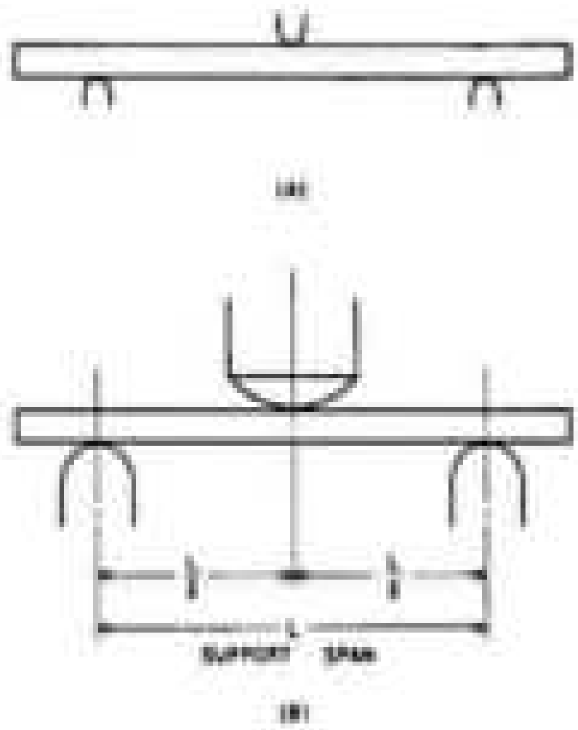
[2] *Annual Book of ASTM Standards*, Vol 08.01.
[3] *Annual Book of ASTM Standards*, Vol 08.02.
[4] *Annual Book of ASTM Standards*, Vol 08.03.
[5] *Annual Book of ASTM Standards*, Vol 03.01.
[6] *Annual Book of ASTM Standards*, Vol 14.02.

*A Summary of Changes section appears at the end of this standard.



NOTE—(a) Minimum radius = 3.2 mm (⅛ in.). (b) Maximum radius supports 1.6 times specimen depth; maximum radius loading nose = 4 times specimen depth.

FIG. 1 Allowable Range of Loading Nose and Support Radii

5. Significance and Use

5.1 Flexural properties as determined by these test methods are especially useful for quality control and specification purposes.

5.2 Materials that do not fail by the maximum strain allowed under these test methods (3-point bend) may be more suited to a 4-point bend test. The basic difference between the two test methods is in the location of the maximum bending moment and maximum axial fiber stresses. The maximum axial fiber stresses occur on a line under the loading nose in 3-point bending and over the area between the loading noses in 4-point bending.

5.3 Flexural properties may vary with specimen depth, temperature, atmospheric conditions, and the difference in rate of straining as specified in Procedures A and B (see also Note 8).

5.4 Before proceeding with these test methods, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, covered in the materials specification shall take precedence over those mentioned in these test methods. If there are no material specifications, then the default conditions apply. Table 1 in Classification System D 4000 lists the ASTM materials standards that currently exist for plastics.

6. Apparatus

6.1 *Testing Machine*— A properly calibrated testing machine that can be operated at constant rates of crosshead motion over the range indicated, and in which the error in the load measuring system shall not exceed ±1 % of the maximum load expected to be measured. It shall be equipped with a deflection measuring device. The stiffness of the testing machine shall be such that the total elastic deformation of the system does not exceed 1 % of the total deflection of the test specimen during

TABLE 1 Flexural Strength

Material	Mean, 10^3 psi	Values Expressed in Units of % of 10^3 psi			
		V_r[A]	V_R[B]	r[C]	R[D]
ABS	9.99	1.59	6.05	4.44	17.2
DAP thermoset	14.3	6.58	6.58	18.6	18.4
Cast acrylic	16.3	1.67	11.3	4.73	32.0
GR polyester	19.5	1.43	2.14	4.05	6.08
GR polycarbonate	21.0	5.16	6.05	14.6	17.1
SMC	26.0	4.76	7.19	13.5	20.4

[A] V_r = within-laboratory coefficient of variation for the indicated material. It is obtained by first pooling the within-laboratory standard deviations of the test results from all of the participating laboratories: $S_r = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$ then V_r = (S_r divided by the overall average for the material) × 100.

[B] V_R = between-laboratory reproducibility, expressed as the coefficient of variation: $S_R = (S_r^2 + S_L^2)^{1/2}$ where S_L is the standard deviation of laboratory means. Then: V_R = (S_R divided by the overall average for the material) × 100.

[C] r = within-laboratory critical interval between two test results = 2.8 × V_r.

[D] R = between-laboratory critical interval between two test results = 2.8 × V_R.

testing, or appropriate corrections shall be made. The load indicating mechanism shall be essentially free from inertial lag at the crosshead rate used. The accuracy of the testing machine shall be verified in accordance with Practices E 4.

6.2 *Loading Noses and Supports*—The loading nose and supports shall have cylindrical surfaces. In order to avoid excessive indentation, or failure due to stress concentration directly under the loading nose, the radii of the loading nose and supports shall be 5.0 ± 0.1 mm (0.197 ± 0.004 in.) unless otherwise specified or agreed upon between the interested clients. When other loading noses and supports are used they must comply with the following requirements: they shall have a minimum radius of 3.2 mm (⅛ in.) for all specimens, and for specimens 3.2 mm or greater in depth, the radius of the supports may be up to 1.6 times the specimen depth. They shall be this large if significant indentation or compressive failure occurs. The arc of the loading nose in contact with the specimen shall be sufficiently large to prevent contact of the specimen with the sides of the nose (see Fig. 1). The maximum radius of the loading nose shall be no more than 4 times the specimen depth.

NOTE 2—Test data have shown that the loading nose and support dimensions can influence the flexural modulus and flexural strength values. The loading nose dimension has the greater influence. Dimensions of the loading nose and supports must be specified in the material specification.

6.3 *Micrometers*— Suitable micrometers for measuring the width and thickness of the test specimen to an incremental discrimination of at least 0.025 mm (0.001 in.) should be used. All width and thickness measurements of rigid and semirigid plastics may be measured with a hand micrometer with ratchet. A suitable instrument for measuring the thickness of nonrigid test specimens shall have: a contact measuring pressure of 25 ± 2.5 kPa (3.6 ± 0.36 psi), a movable circular contact foot 6.35 ± 0.025 mm (0.250 ± 0.001 in.) in diameter and a lower fixed anvil large enough to extend beyond the contact foot in all directions and being parallel to the contact foot within 0.005 mm (0.002 in.) over the entire foot area. Flatness of foot and anvil shall conform to the portion of the Calibration section of Test Methods D 5947.

7. Test Specimens

7.1 The specimens may be cut from sheets, plates, or molded shapes, or may be molded to the desired finished dimensions. The actual dimensions used in Section 4.2, Calculation, shall be measured in accordance with Test Methods D 5947.

NOTE 3—Any necessary polishing of specimens shall be done only in the lengthwise direction of the specimen.

7.2 *Sheet Materials (Except Laminated Thermosetting Materials and Certain Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass Bonded Mica)*:

7.2.1 *Materials 1.6 mm ($^{1}/_{16}$ in.) or Greater in Thickness*—For flatwise tests, the depth of the specimen shall be the thickness of the material. For edgewise tests, the width of the specimen shall be the thickness of the sheet, and the depth shall not exceed the width (see Notes 4 and 5). For all tests, the support span shall be 16 (tolerance ±1) times the depth of the beam. Specimen width shall not exceed one fourth of the support span for specimens greater than 3.2 mm ($^{1}/_{8}$ in.) in depth. Specimens 3.2 mm or less in depth shall be 12.7 mm ($^{1}/_{2}$ in.) in width. The specimen shall be long enough to allow for overhanging on each end of at least 10 % of the support span, but in no case less than 6.4 mm ($^{1}/_{4}$ in.) on each end. Overhang shall be sufficient to prevent the specimen from slipping through the supports.

NOTE 4—Whenever possible, the original surface of the sheet shall be unaltered. However, where testing machine limitations make it impossible to follow the above criterion on the unaltered sheet, one or both surfaces shall be machined to provide the desired dimensions, and the location of the specimens with reference to the total depth shall be noted. The value obtained on specimens with machined surfaces may differ from those obtained on specimens with original surfaces. Consequently, any specifications for flexural properties on thicker sheets must state whether the original surfaces are to be retained or not. When only one surface was machined, it must be stated whether the machined surface was on the tension or compression side of the beam.

NOTE 5—Edgewise tests are not applicable for sheets that are so thin that specimens meeting these requirements cannot be cut. If specimen depth exceeds the width, buckling may occur.

7.2.2 *Materials Less than 1.6 mm ($^{1}/_{16}$ in.) in Thickness*—The specimen shall be 50.8 mm (2 in.) long by 12.7 mm ($^{1}/_{2}$ in.) wide, tested flatwise on a 25.4-mm (1-in.) support span.

NOTE 6—Use of the formulas for simple beams cited in these test methods for calculating results presumes that beam width is small in comparison with the support span. Therefore, the formulas do not apply rigorously to these dimensions.

NOTE 7—Where machine sensitivity is such that specimens of these dimensions cannot be measured, wider specimens or shorter support spans, or both, may be used, provided the support span-to-depth ratio is at least 14 to 1. All dimensions must be stated in the report (see also Note 6).

7.3 *Laminated Thermosetting Materials and Sheet and Plate Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass-Bonded Mica*—For paper-base and fabric-base grades over 25.4 mm (1 in.) in nominal thickness, the specimens shall be machined on both surfaces to a depth of 25.4 mm. For glass-base and nylon-base grades, specimens over 12.7 mm ($^{1}/_{2}$ in.) in nominal depth shall be machined on both surfaces to a depth of 12.7 mm. The support span-to-depth ratio shall be chosen such that failures occur in the outer fibers of the specimens, due only to the bending moment (see Note 8). Therefore, a ratio larger than 16:1 may be necessary (32:1 or 40:1 are recommended). When laminated materials exhibit low compressive strength perpendicular to the laminations, they shall be loaded with a large radius loading nose (up to four times the specimen depth to prevent premature damage to the outer fibers.

7.4 *Molding Materials (Thermoplastics and Thermosets)*—The recommended specimen for molding materials is 127 by 12.7 by 3.2 mm (5 by $^{1}/_{2}$ by $^{1}/_{8}$ in.) tested flatwise on a support span, resulting in a support span-to-depth ratio of 16 (tolerance ±1). Thicker specimens should be avoided if they exhibit significant shrink marks or bubbles when molded.

7.5 *High-Strength Reinforced Composites, Including Highly Orthotropic Laminates*—The span-to-depth ratio shall be chosen such that failure occurs in the outer fibers of the specimens and is due only to the bending moment (see Note 8). A span-to-depth ratio larger than 16:1 may be necessary (32:1 or 40:1 are recommended). For some highly anisotropic composites, shear deformation can significantly influence modulus measurements, even at span-to-depth ratios as high as 40:1. Hence, for these materials, an increase in the span-to-depth ratio to 60:1 is recommended to eliminate shear effects when modulus data are required, it should also be noted that the flexural modulus of highly anisotropic laminates is a strong function of ply-stacking sequence and will not necessarily correlate with tensile modulus, which is not stacking-sequence dependent.

NOTE 8—As a general rule, support span-to-depth ratios of 16:1 are satisfactory when the ratio of the tensile strength to shear strength is less than 8 to 1, but the support span-to-depth ratio must be increased for composite laminates having relatively low shear strength in the plane of the laminate and relatively high tensile strength parallel to the support span.

8. Number of Test Specimens

8.1 Test at least five specimens for each sample in the case of isotropic materials or molded specimens.

8.2 For each sample of anisotropic material in sheet form, test at least five specimens for each of the following conditions. Recommended conditions are flatwise and edgewise tests on specimens cut in lengthwise and crosswise directions of the sheet. For the purposes of this test, "lengthwise" designates the principal axis of anisotropy and shall be interpreted to mean the direction of the sheet known to be stronger in flexure. "Crosswise" indicates the sheet direction known to be the weaker in flexure and shall be at 90° to the lengthwise direction.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618 unless otherwise specified by contract or the relevant ASTM material specification. Reference pre-test conditioning, to settle disagreements, shall apply tolerances of ±1°C (1.8°F) and ±2 % relative humidity.

9.2 *Test Conditions*—Conduct the tests at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity unless otherwise specified by contract or the relevant ASTM material specification. Reference testing conditions, to settle disagreements, shall apply tolerances of ±1°C (1.8°F) and ±2 % relative humidity.

10. Procedure

10.1 *Procedure A:*

10.1.1 Use an untested specimen for each measurement. Measure the width and depth of the specimen to the nearest 0.03 mm (0.001 in.) at the center of the support span. For specimens less than 2.54 mm (0.100 in.) in depth, measure the depth to the nearest 0.003 mm (0.0005 in.). These measurements shall be made in accordance with Test Methods D 5947.

10.1.2 Determine the support span to be used as described in Section 7 and set the support span to within 1 % of the determined value.

10.1.3 For flexural fixtures that have continuously adjustable spans, measure the span accurately to the nearest 0.1 mm (0.004 in.) for spans less than 63 mm (2.5 in.) and to the nearest 0.3 mm (0.012 in.) for spans greater than or equal to 63 mm (2.5 in.). Use the actual measured span for all calculations. For flexural fixtures that have fixed machined span positions, verify the span distance the same as for adjustable spans at each machined position. This distance becomes the span for that position and is used for calculations applicable to all subsequent tests conducted at that position. See Annex A2 for information on the determination of and setting of the span.

10.1.4 Calculate the rate of crosshead motion as follows and set the machine for the rate of crosshead motion as calculated by Eq 1:

$$R = ZL^2/6d \quad (1)$$

where:
R = rate of crosshead motion, mm (in.)/min,
L = support span, mm (in.),
d = depth of beam, mm (in.), and
Z = rate of straining of the outer fiber, mm/mm/min (in./in./min). Z shall be equal to 0.01.

In no case shall the actual crosshead rate differ from that calculated using Eq 1, by more than ±10 %.

10.1.5 Align the loading nose and supports so that the axes of the cylindrical surfaces are parallel and the loading nose is midway between the supports. The parallelism of the apparatus may be checked by means of a plate with parallel grooves into which the loading nose and supports will fit when properly aligned (see A2.3). Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading nose and supports.

10.1.6 Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data. Measure deflection either by a gage under the specimen in contact with it at the center of the support span, the gage being mounted stationary relative to the specimen supports, or by measurement of the motion of the loading nose relative to the supports. Load-deflection curves may be plotted to determine the flexural strength, chord or secant modulus or the tangent modulus of elasticity, and the total work as measured by the area under the load-deflection curve. Perform the necessary toe compensation (see Annex A1) to correct for seating and indentation of the specimen and deflections in the machine.

10.1.7 Terminate the test when the maximum strain in the outer surface of the test specimen has reached 0.05 mm/mm (in./in.) or at break if break occurs prior to reaching the maximum strain (Notes 9 and 10). The deflection at which this strain will occur may be calculated by letting r equal 0.05 mm/mm (in./in.) in Eq 2:

$$D = rL^2/6d \quad (2)$$

where:
D = midspan deflection, mm (in.),
r = strain, mm/mm (in./in.),
L = support span, mm (in.), and
d = depth of beam, mm (in.).

NOTE 9—For some materials that do not yield or break within the 5 % strain limit when tested by Procedure A, the increased strain rate allowed by Procedure B (see 10.2) may induce the specimen to yield or break, or both, within the required 5 % strain limit.

NOTE 10—Beyond 5 % strain, this test method is not applicable. Some other mechanical property might be more relevant to characterize materials that neither yield nor break by either Procedure A or Procedure B within the 5 % strain limit (for example, Test Method D 638 may be considered).

10.2 *Procedure B:*

10.2.1 Use an untested specimen for each measurement.

10.2.2 Test conditions shall be identical to those described in 10.1, except that the rate of straining of the outer surface of the test specimen shall be 0.10 mm/mm (in./in.)/min.

10.2.3 If no break has occurred in the specimen by the time the maximum strain in the outer surface of the test specimen has reached 0.05 mm/mm (in./in.), discontinue the test (see Note 10).

11. Retests

11.1 Values for properties at rupture shall not be calculated for any specimen that breaks at some obvious, fortuitous flaw, unless such flaws constitute a variable being studied. Retests shall be made for any specimen on which values are not calculated.

12. Calculation

12.1 Toe compensation shall be made in accordance with Annex A1 unless it can be shown that the toe region of the curve is not due to the take-up of slack, seating of the specimen, or other artifact, but rather is an authentic material response.

12.2 *Flexural Stress (σ_f)*—When a homogeneous elastic material is tested in flexure as a simple beam supported at two points and loaded at the midpoint, the maximum stress in the outer surface of the test specimen occurs at the midpoint. This stress may be calculated for any point on the load-deflection curve by means of the following equation (see Notes 11-13):

$$\sigma_f = 3PL/2bd^2 \quad (3)$$

where:
σ = stress in the outer fibers at midpoint, MPa (psi),
P = load at a given point on the load-deflection curve, N (lbf),
L = support span, mm (in.),
b = width of beam tested, mm (in.), and

3. ASTM D6110-10 Standar Uji Impak

Designation: D6110 – 10

Standard Test Method for Determining the Charpy Impact Resistance of Notched Specimens of Plastics[1]

This standard is issued under the fixed designation D6110; 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 is used to determine the resistance of plastics to breakage by flexural shock as indicated by the energy extracted from standardized (see Note 1) pendulum-type hammers, mounted in standardized machines, in breaking standard specimens with one pendulum swing. This test method requires specimens to be made with a milled notch (see Note 2). The notch produces a stress concentration which promotes a brittle, rather than a ductile, fracture. The results of this test method are reported in terms of energy absorbed per unit of specimen width (see Note 3).

Note 1—The machines with pendulum-type hammers have been standardized in that they must comply with certain requirements including a fixed height of hammer fall, which results in a substantially fixed velocity of the hammer at the moment of impact. Hammers of different initial energies (produced by varying their effective weights) however, are recommended for use with specimens of different impact resistance. Moreover, manufacturers of the equipment are permitted to use different lengths and constructions of pendulums with possible differences in pendulum rigidities resulting (see Section 5). Be aware that other differences in machine design do exist.

Note 2—The specimens are standardized in that they have a fixed length and fixed depth, however, the width of the specimens is permitted to vary between limits. One design of milled notch is allowed. The notch in the specimen serves to concentrate the stress, minimize plastic deformation, and direct the fracture to the part of the specimen behind the notch. Scatter in energy-to-break is thus reduced. Because of differences in the elastic and viscoelastic properties of plastics, however, response to a given notch varies among materials.

Note 3—Caution must be exercised in interpreting the results of this test method. The following testing parameters have been shown to affect test results significantly: method of specimen fabrication, including but not limited to processing technology, molding conditions, mold design, and thermal treatment; method of notching; speed of notching tool; design of notching apparatus; quality of the notch; time between notching and test; test specimen thickness; test specimen width under notch; and environmental conditioning.

1.2 *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.*

Note 4—This standard resembles ISO 179 in title only. The content is significantly different.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D647 Practice for Design of Molds for Test Specimens of Plastic Molding Materials (Withdrawn 1994)[3]

D883 Terminology Relating to Plastics

D4000 Classification System for Specifying Plastic Materials

D4066 Classification System for Nylon Injection and Extrusion Materials (PA)

D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions*—For definitions related to plastics, see Terminology D883.

4. Summary of Test Method

4.1 A notched specimen is supported as a horizontal simple beam and is broken by a single swing of the pendulum with the impact line midway between the supports and directly opposite the notch.

5. Significance and Use

5.1 Before proceeding with this test method, refer to the material specification for the material being tested. Any test specimen preparation, conditioning, dimensions and testing parameters required by the materials specification shall take precedence over those required by this test method. Table 1 of

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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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 last approved version of this historical standard is referenced on www.astm.org.

*A Summary of Changes section appears at the end of this standard

Classification D4000 lists the ASTM materials standards that currently exist. If there is no material specification, then the requirements of this test method apply.

5.2 The pendulum impact test indicates the energy to break standard test specimens of specified size under stipulated conditions of specimen mounting, notching (stress concentration), and pendulum velocity at impact.

5.3 For this test method, the energy lost by the pendulum during the breakage of the specimen is the sum of the energies required to initiate fracture of the specimen; to propagate the fracture across the specimen; to throw the free ends of the broken specimen (toss energy); to bend the specimen; to produce vibration in the pendulum arm; to produce vibration or horizontal movement of the machine frame or base; to overcome friction in the pendulum bearing and in the indicating mechanism, and to overcome windage (pendulum air drag); to indent or deform, plastically, the specimen at the line of impact; and to overcome the friction caused by the rubbing of the striking nose over the face of the bent specimen.

NOTE 5—The toss energy, or the energy used to throw the free ends of the broken specimen, is suspected to represent a very large fraction of the total energy absorbed when testing relatively dense and brittle materials. No procedure has been established for estimating the toss energy for the Charpy method.

5.4 For tough, ductile, fiber-filled, or cloth-laminated materials, the fracture propagation energy is usually large compared to the fracture initiation energy. When testing these materials, energy losses due to fracture propagation, vibration, friction between the striking nose and the specimen has the potential to become quite significant, even when the specimen is accurately machined and positioned, and the machine is in good condition with adequate capacity (see Note 6). Significant energy losses due to bending and indentation when testing soft materials have also been observed.

NOTE 6—Although the frame and the base of the machine must be sufficiently rigid and massive to handle the energies of tough specimens without motion or excessive vibration, the pendulum arm cannot be made very massive because the greater part of its mass must be concentrated near its center of percussion at its striking nose. Locating the striking nose precisely at the center of percussion reduces the vibration of the pendulum arm when used with brittle specimens. Some losses due to pendulum arm vibration (the amount varying with the design of the pendulum) will occur with tough specimens even when the striking nose is properly positioned.

5.5 In a well-designed machine of sufficient rigidity and mass, the losses due to vibration and friction in the pendulum bearing and in the indicating mechanism will be very small. Vibrational losses are observed when wide specimens of tough materials are tested in machines of insufficient mass, or in machines that are not securely fastened to a heavy base.

5.6 Since this test method permits a variation in the width of the specimens and since the width dictates, for many materials, whether a brittle, low-energy break (as evidenced by little or no drawing down or necking and by a relatively low energy absorption) or a ductile, high-energy break (as evidenced by considerable drawing or necking down in the region behind the notch and by a relatively high energy absorption) will occur, it is necessary that the width be stated in the specification covering that material and that the width be stated along with the impact value.

5.7 This test method requires that the specimen break completely. Results obtained when testing materials with a pendulum that does not have sufficient energy to complete the breaking of the extreme fibers and toss the broken pieces shall be considered a departure from standard and shall not be reported as a standard result. Impact values cannot be directly compared for any two materials that experience different types of failure.

5.8 The value of this impact test method lies mainly in the areas of quality control and materials specification. If two groups of specimens of supposedly the same material show significantly different energy absorptions, critical widths, or critical temperatures, it is permitted to assume that they were made of different materials or were exposed to different processing or conditioning environments. The fact that a material shows twice the energy absorption of another under these conditions of test does not indicate that this same relationship will exist under another set of test conditions.

6. Apparatus

6.1 *Pendulum Impact Machine*—The machine shall consist of a massive base on which are mounted a pair of supports for holding the specimen and to which is connected, through a rigid frame and bearings, one of a number of pendulum-type hammers having an initial energy suitable for use with the particular specimen to be tested (or one basic pendulum designed to accept add-on weights), plus a pendulum holding and releasing mechanism and a mechanism for indicating the breaking energy of the specimen. The specimen anvil, pendulum, and frame shall be sufficiently rigid to maintain correct alignment of the striking edge and specimen, both at the moment of impact and during the propagation of the fracture, and to minimize energy losses due to vibration. The base shall be sufficiently massive so that the impact will not cause it to move. The machine shall be designed, constructed, and maintained so that energy losses due to pendulum air drag (windage), friction in the pendulum bearings, and friction and inertia in the indicating mechanism are held to a minimum.

6.1.1 *Pendulum*—The simple pendulum shall consist of a single or multi-membered arm with a bearing on one end and a head, containing the striking nose, on the other. Although a large proportion of the mass of the simple pendulum is concentrated in the head, the arm must be sufficiently rigid to maintain the proper clearances and geometric relationships between the machine parts and the specimen and to minimize vibrational energy losses, which are always included in the measured impact value. A machine with a simple pendulum design is illustrated in Fig. 1. Instruments with a compound-pendulum design also have been found to be acceptable for use. A compound-pendulum design is illustrated in Fig. 2.

6.1.1.1 The machine shall be provided with a basic pendulum capable of delivering an energy of 2.7 ± 0.14 J (2.0 ± 0.10 ft·lbf). This pendulum shall be used for specimens that extract less than 85 % of this energy when breaking a specimen. Heavier pendulums or additional weights designed to attach to the basic pendulum shall be provided for specimens

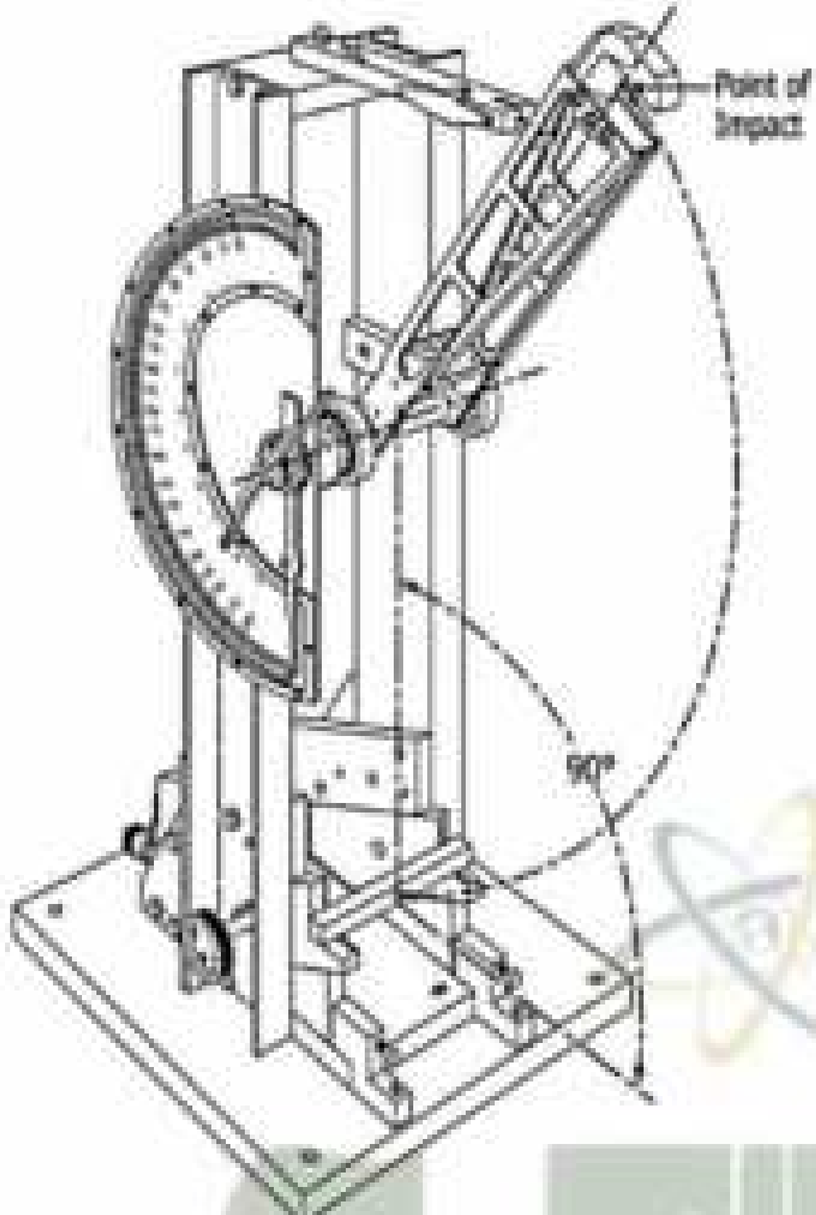


FIG. 1 Simple Beam (Charpy-Type) Impact Machine

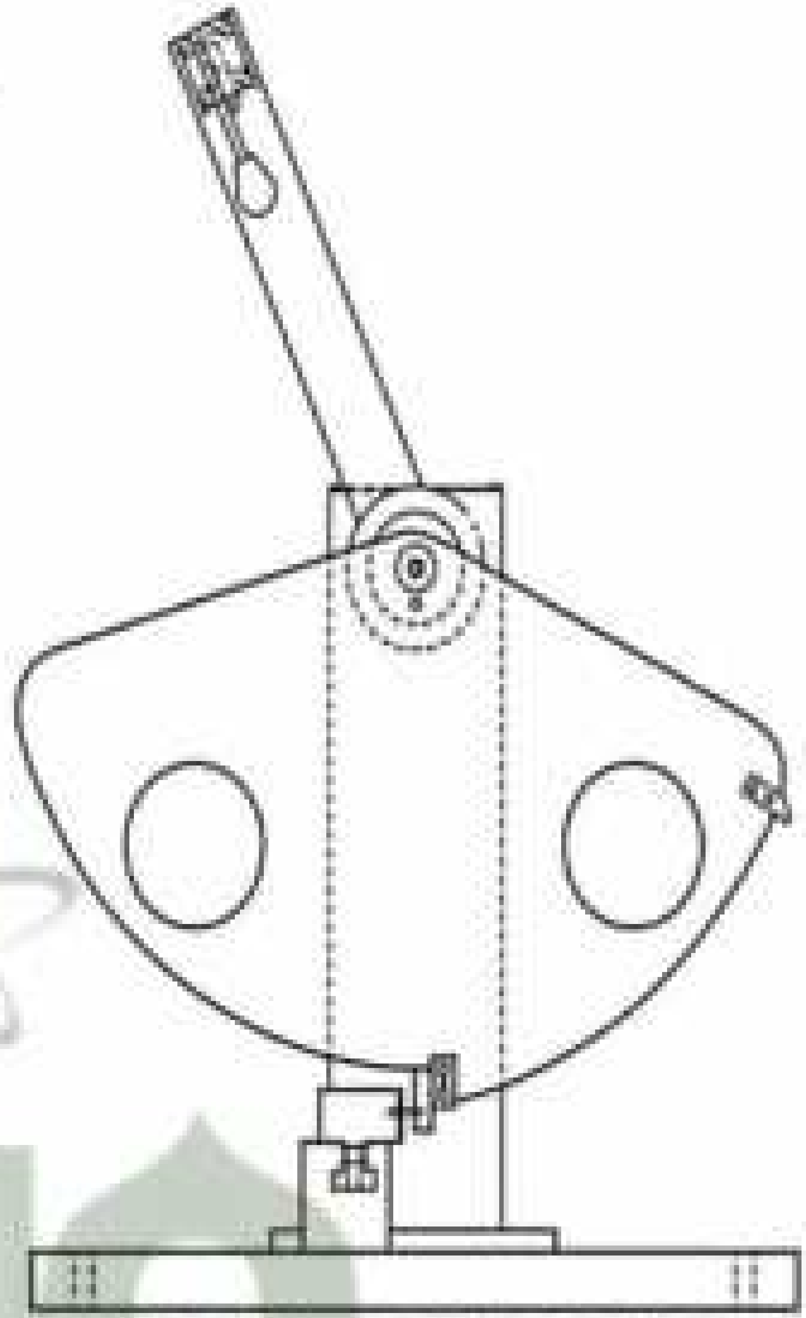


FIG. 2 Example of Compound-Pendulum-Type Machine

that require more energy to break. A series of pendulums such that each has twice the energy of the next lighter one has been found convenient.

6.1.1.2 The effective length of the pendulum shall be between 0.325 and 0.406 m (12.8 and 16.0 in.) so that the required elevation of the striking nose is obtained by raising the pendulum to an angle between 60 and 30° above the horizontal.

6.1.2 *Striking Edge*—The striking edge (nose) of the pendulum shall be made of hardened steel, tapered to have an included angle of 45 ± 2° and shall be rounded to a radius of 3.17 ± 0.12 mm (0.125 ± 0.005 in.). The pendulum shall be aligned in such a way that when it is in its free hanging position, the center of percussion of the pendulum shall lie within ±2.54 mm (0.10 in.) of the middle of the line of contact made by the striking nose upon the face of a standard specimen of square cross section. The distance from the axis of support to the center of percussion is determined experimentally from the period of motion of small amplitude oscillations of the pendulum by means of the following equation:

$$L = (g/4\pi^2)\,p^2 \quad (1)$$

where:

L = distance from the axis of support to the center of percussion, m,
g = local gravitational acceleration (known to an accuracy of one part in one thousand), m/s^2
π = 3.1416 ($4\pi^2$ = 39.48), and
p = period, in s, of a single complete swing (to and fro) determined from at least 20 consecutive and uninterrupted swings. The angle of swing shall be less than 5° each side of center.

6.1.3 *Pendulum Holding and Releasing Mechanism*—The mechanism shall be designed, constructed, and operated so that it will release the pendulum without imparting acceleration or vibration to the pendulum. The position of the pendulum holding and releasing mechanism shall be such that the vertical height of fall of the striking nose shall be 610 ± 2 mm (24.0 ± 0.005 in.). This will produce a velocity of the striking nose

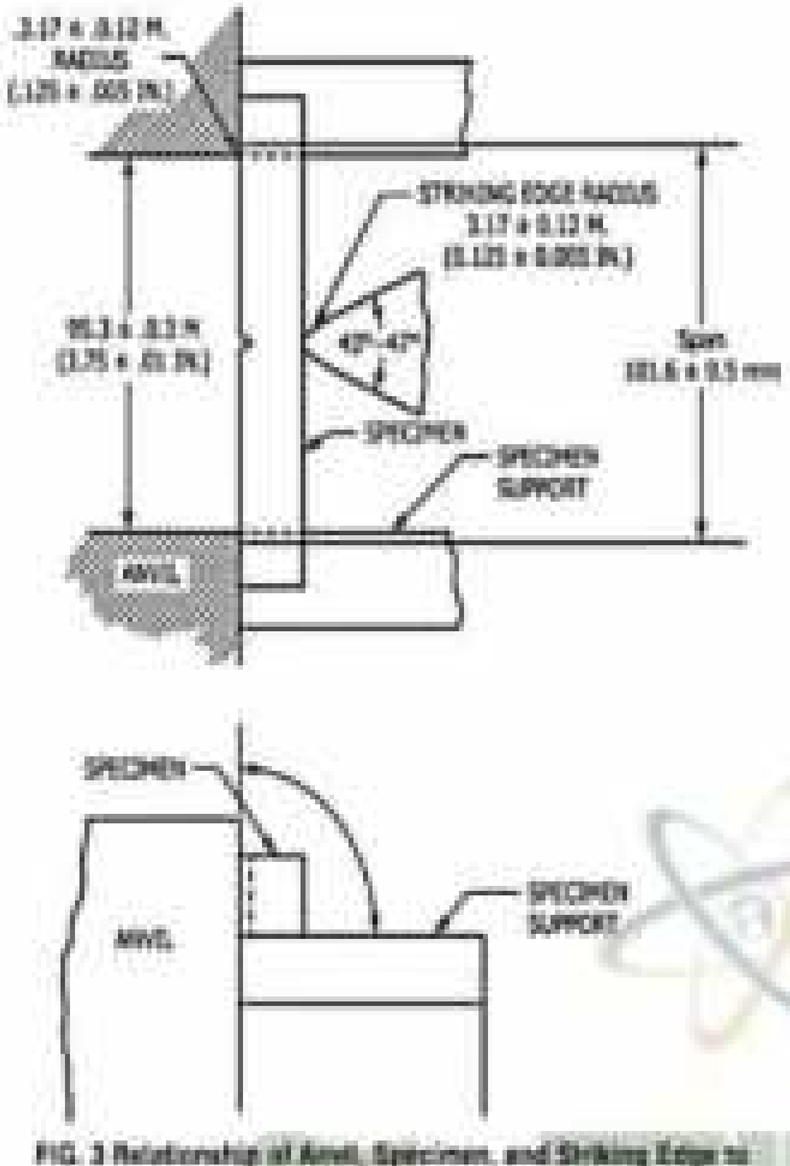


FIG. 3 Relationship of Anvil, Specimen, and Striking Edge to Each Other for Charpy Test Method

at the moment of impact of approximately 3.46 m (11.4 ft)/s as determined by the following equation:

$$v = \sqrt{2gh} \quad (2)$$

where:

v = velocity of the striking nose at the moment of impact,
g = local gravitational acceleration, and
h = vertical height of fall of the striking nose.

This assumes no windage or friction.

6.1.4 *Specimen Supports*—The test specimen shall be supported against two rigid anvils in such a position that its center of gravity and the center of the notch shall lie on tangent to the arc of travel of the center of percussion of the pendulum drawn at the position of impact. The edges of the anvils shall be rounded to a radius of 3.17 ± 0.12 mm (0.125 ± 0.005 in.) and the anvils' lines of contact (span) with the specimen shall be 101.6 ± 0.5 mm (4.0 ± 0.02 in.) apart (see Fig. 3). Some machine manufacturers supply a jig for positioning the specimen on the supports.

NOTE 7—Some machines currently in use employ a 100.0-mm span. Data obtained under these conditions are valid.[4]

6.1.5 *Indicator*—Means shall be provided for determining the energy expended by the pendulum in breaking the specimen. This is accomplished using either a pointer and dial mechanism or an electronic system consisting of a digital indicator and sensor (typically an encoder or resolver). In either case, the indicated breaking energy is determined by detecting the height of rise of the pendulum beyond the point of impact in terms of energy removed from that specific pendulum. The indicated remaining energy must be corrected for pendulum bearing friction, pointer friction, pointer inertia, and pendulum windage. Some equipment manufacturers provide graphs or tables to aid in the calculation of the correction for friction and windage. Instructions for making these corrections are found in Annex A1 and Annex A2. Many digital indicating systems automatically correct for windage and friction. Consult the equipment manufacturer for information on how this is performed.

6.1.6 Appendix X2 describes a calibration procedure for establishing the accuracy of the equipment. A check of the calibration of an impact machine is difficult to make under dynamic conditions. The basic parameters normally are checked under static conditions. If the machine passes the static tests, then it is assumed to be accurate. Appendix X2, however, also describes a dynamic test for checking certain features of the machine and specimen. For some machine designs, it might be necessary to change the recommended method of obtaining the required calibration measurements. Contact the machine manufacturer to determine if additional instructions for adjusting a particular machine are available. Other methods of performing the required checks are acceptable provided that they are proven to result in an equivalent accuracy.

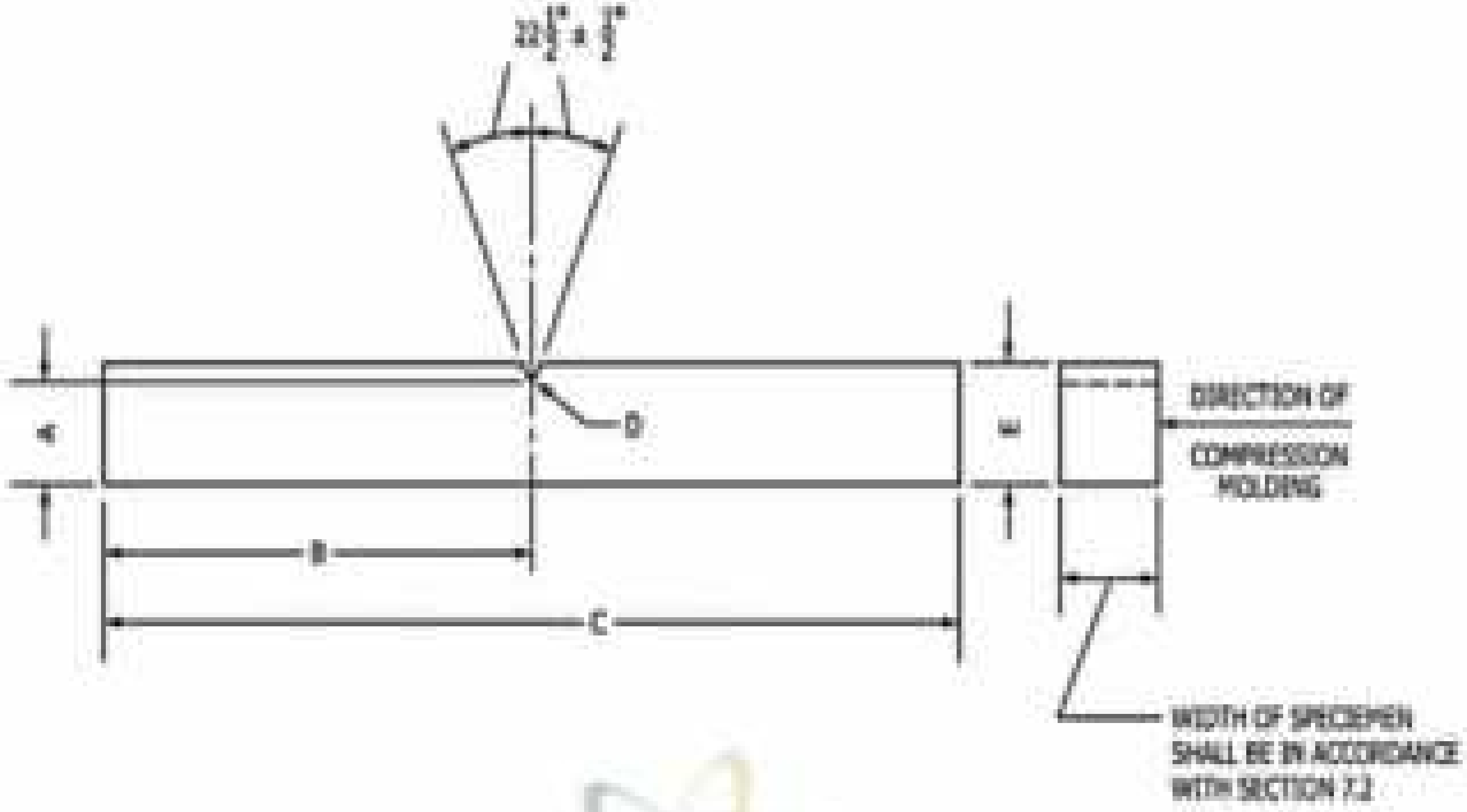
6.2 *Specimen Notching Machine*—Notching shall be done on a milling machine, engine lathe, or other suitable machine tool. A carbide-tipped or industrial diamond-tipped notching cutter is recommended. Both cutter speed and feed rate shall be controllable. Provision for cooling the specimen is recommended. Water and compressed air are suitable coolants for many plastics.

6.2.1 The profile of the cutting tooth or teeth shall be such as to produce a notch in the test specimen of the contour and depth specified in Fig. 4 and in the manner specified in Section 8.

6.2.2 A single-tooth cutter shall be used for notching the specimen, unless it is demonstrated that notches of an equivalent quality are produced with a multi-tooth cutter. Single-tooth cutters are preferred because of the ease of grinding the cutter to the specimen contour and because of the smoother cut on the specimen. The cutting edge shall be ground and honed carefully to ensure sharpness and freedom from nicks and burrs. Tools with no rake and a work relief angle of 15 to 20° have been found satisfactory.

6.3 *Micrometers*—Apparatus for measurement of the width of the specimen shall comply with the requirements of Test Methods D5947. Apparatus for the measurement of the depth of plastic material remaining in the specimen under the notch shall comply with requirements of Test Methods D5947, provided however that the one anvil or presser foot shall be a tapered blade conforming to the dimensions given in Fig. 5. The opposing anvil or presser foot shall be flat and conforming to Test Methods D5947.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1073.



	mm	in.
A	10.16 ± 0.05	0.400 ± 0.002
B	63.5 max	2.50 max
	61.0 min	2.40 min
C	127.0 max	5.00 max
	124.5 min	4.90 min
D	0.25R ± 0.05	0.010R ± 0.002
E	12.70 ± 0.15	0.500 ± 0.006

FIG. 4 Dimensions of Simple Beam, Charpy Type, Impact Test Specimen

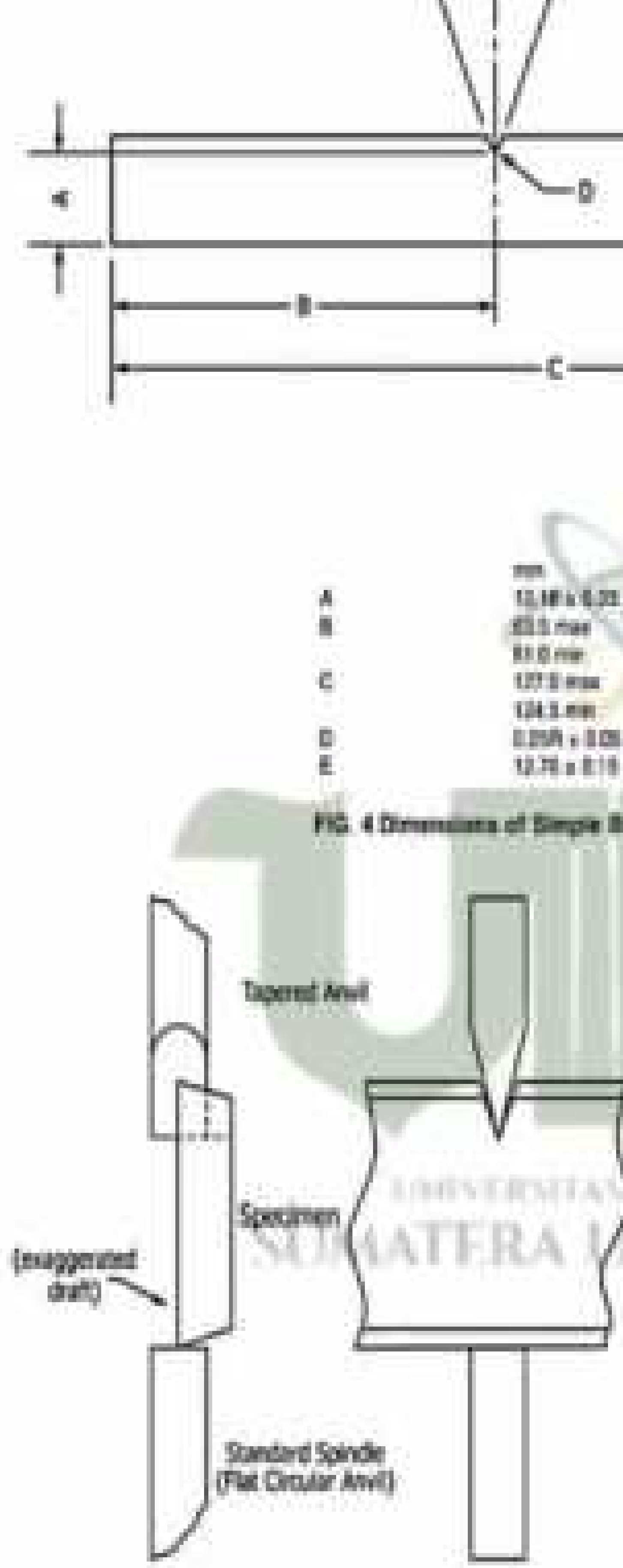


FIG. 5 Notch Depth Measurement on Test Specimens

7. Test Specimens

7.1 The test specimen shall conform to the dimensions and geometry of Fig. 4, except as modified in accordance with 7.2 – 7.5. To ensure the correct contour and conditions of the specified notch, all specimens shall be notched in accordance with Section 8.

7.2 Molded specimens shall have a width between 3.00 and 12.7 mm (0.118 and 0.500 in.). Use the specimen width as specified in the material specification or as agreed upon between the supplier and the customer.

7.2.1 The type of mold and molding machine used and the flow behavior in the mold cavity will influence the strength obtained. It is possible that results from a specimen taken from one end of a molded bar will give different results than a specimen taken from the other end. It is therefore important that cooperating laboratories agree on standard molds conforming to Practice D647, and upon a standard molding procedure for the material under investigation.

7.2.2 A critical investigation of the mechanics of impact testing has shown that tests made upon specimens under 6.35 mm (0.250 in.) in width absorb more energy due to crushing, bending, and twisting than do wider specimens. Specimens 6.35 mm (0.250 in.) or over in width are therefore recommended. The responsibility for determining the minimum specimen width shall be the investigator's, with due reference to the specification for that material.

7.2.3 The impact resistance of a plastic material will be different if the notch is perpendicular to, rather than parallel to, the direction of molding.

7.3 For sheet materials, the specimens shall be cut from the sheet in both the lengthwise and crosswise directions unless otherwise specified. The width of the specimen shall be the thickness of the sheet if the sheet thickness is between 3.00 and 12.7 mm (0.118 and 0.500 in.). Sheet material thicker than 12.7 mm (0.500 in.) shall be machined down to 12.7 mm (0.500 in.).

It is acceptable to test specimens with a 12.7-mm (0.500-in.) square cross section either edgewise or flatwise as cut from the sheet. When specimens are tested flatwise, the notch shall be made on the machined surface if the specimen is machined on one face only. When the specimen is cut from a thick sheet, notation shall be made of the portion of the thickness of the sheet from which the specimen was cut, for example, center, top, or bottom surface.

7.3.1 The impact resistance of a plastic material will be different if the notch is perpendicular to, rather than parallel to, the grain of an anisotropic bar cut from a sheet. Specimens cut from sheets that are suspected of being anisotropic shall be prepared and tested both lengthwise and crosswise to the direction of the anisotropy.

7.4 The practice of cementing, bolting, clamping, or otherwise combining specimens of substandard width to form a composite test specimen is not recommended since test results will be seriously affected by interface effects or effects of solvents and cements on energy absorption of composite test specimens, or both. If Charpy test data on such thin materials are required, however, and if possible sources of error are recognized and acceptable, the following technique of preparing composites ought to be utilized. The test specimens shall be a composite of individual thin specimens totaling 6.35 to 12.7 mm (0.125 to 0.500 in.) in width. Individual members of the composite shall be aligned accurately with each other and clamped, bolted, or cemented together. Care must be taken to select a solvent or adhesive that will not affect the impact resistance of the material under test. If solvents or solvent–containing adhesives are employed, a conditioning procedure shall be established to ensure complete removal of the solvent prior to test. The composite specimens shall be machined to proper dimensions and then notched. In all such cases, the use of composite specimens shall be noted in the report of test results.

7.5 Each specimen shall be free of twist and shall be bounded by mutually perpendicular pairs of plane, paralleled surfaces and free from scratches, pits, and sink marks. The specimens shall be checked for conformity with these requirements by visual observation against straight edges, squares or flat plates, and by measuring with micrometer calipers. Any specimen showing observable or measurable departure from one or more of these requirements shall be rejected or machined to the proper size and shape before testing. A specimen that has a slight twist to its notched face of 0.05 mm (0.002 in.) at the point of contact with the pendulum striking edge will be likely to have a characteristic fracture surface with considerable greater fracture area than for a normal break. In this case, the energy to break and toss the broken section will be considerably larger (20 to 30 %) than for a normal break.

8. Notching Test Specimens

NOTE 8—When testing a material for the first time, it is necessary to study the effect of all variations in the notching conditions, including cutter dimensions, notch depth, cutter speed, and feed rate. To establish that the notching parameters are suitable, it is advisable to notch several specimens of the material and inspect both the tool entrance and tool exit side of each notched specimen, in accordance with Appendix X1. Adjust the notching machine as required. The specimens used to determine notching conditions shall not be used to make determinations of impact resistance.

8.1 *Notch Dimensions*—The included angle of the notch shall be 45 ± 1° with a radius of curvature at the apex of 0.25 ± 0.05 mm (0.010 ± 0.002 in.). The plane bisecting the notch angle shall be perpendicular to the face of the test specimen within 2°.

8.1.1 The notch is a critical factor of this test. It is extremely important, therefore, that dimensions of the notch in the specimen are verified. There is evidence that the contour of notches cut in materials of widely differing physical properties by the same cutter will differ. It is sometimes necessary to alter the cutter dimensions in order to produce the required notch contour for certain materials.

8.1.2 A notching operation notches one or more specimens plus the "dummy bars". The specimen notch produced by each cutter will be examined after every 500 notching operations or less frequently if experience shows this to be acceptable. The specimen used to verify the notch shall be the same material that is being prepared for testing. Inspect and verify the notch in the specimen. If the angle or radius of the notch does not meet the requirements of 8.1, the cutter shall be replaced. One procedure for inspecting and verifying the notch is provided in Appendix X1.

NOTE 9—The contour of the notch made using multi-tooth cutters is checked by measuring the contour of the notch on a strip of soft metal that is inserted between two specimens during the notching process.

NOTE 10—When the same material is being tested on a repetitive basis, and it is demonstrated that the notch in the specimen takes the contour of the tip of the cutter and that the notch meets the contour requirements when checked in accordance with Appendix X1, then it is acceptable to check the contour of the tip of the cutter instead of the notch in the specimen.

8.2 *Notch Depth*—The depth of the plastic material remaining in the specimen under the notch shall be 10.16 ± 0.05 mm (0.400 ± 0.002 in.). This dimension shall be measured with apparatus in accordance with 6.3. The tapered blade will be fitted to the notch. The specimen will be approximately vertical between the anvils. Position the edge of the non-cavity (wider edge) surface centered on the micrometer's flat circular anvil.

8.3 *Cutter Speed and Feed Rate*—Select the cutter speed and feed speed based on the material being tested. The quality of the notch will be adversely affected by thermal deformations and stresses induced during the cutting operation if proper conditions are not selected.[5] The notching parameters used shall not alter the physical state of the material, such as by raising the temperature of a thermoplastic above its glass transition temperature.

8.3.1 In general, high cutter speeds, slow feed rates, and lack of coolant induce more thermal damage than a slow cutter speed, fast feed speed, and the use of a coolant. Too high a feed speed/cutter speed ratio, however, has been shown to cause impacting and cracking of the specimen. The range of cutter speed/feed ratios possible to produce acceptable notches has been shown to be extended by the use of a suitable coolant.

8.3.1.1 For some thermoplastics, suitable notches have been produced using cutter speeds from 54 to 150 m/min and a feed rate of 89 to 160 mm/min without a water coolant. Satisfactory

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1066.

notches also have been produced using the same cutter speeds at feed speeds of from 36 to 160 mm/min with water coolant.

8.3.1.2 Embedded thermocouples have been used to determine the temperature rise in the material near the apex of the notch during machining. Thermal stresses induced during the notching operation have been observed in transparent materials by viewing the specimen at low magnification between crossed polars in monochromatic light. The specimens used to determine temperature rise shall not be used to make determinations of impact resistance.

8.3.2 The feed rate and the cutter speed shall remain constant throughout the notching operation.

8.4 It is acceptable to notch specimens individually or in a group. In either case, however, an unnotched backup or dummy bar shall be placed behind the last specimen in the sample holder to prevent distortion and chipping by the cutter as it exits from the last test specimen.

8.5 All specimens having one dimension less than 12.7 mm (0.500 in.) shall have the notch cut on the shorter side. Compression molded specimens shall be notched on the side parallel to the direction of application of molding pressure. The impact resistance of a plastic material will be different if the notch is perpendicular to rather than parallel to the direction of molding, as with or across the grain of an anisotropic bar cut from a plate.

9. Conditioning

9.1 Check the materials specification for the material that is being tested. If there are no conditioning requirements stated by the materials specification, the test specimens shall be conditioned at 23 ± 2°C (73 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 40 h after notching and prior to testing in accordance with Procedure A of Practice D618 unless documented (between supplier and customer) that shorter conditioning time is sufficient for a given material to reach equilibrium of impact resistance.

9.2 For hygroscopic materials, such as nylons, the material specifications (for example, Classification System D4066) call for testing dry-as-molded specimens. Such requirements take precedence over the above routine preconditioning to 50 % relative humidity. These specimens shall be sealed in water vapor-impermeable containers as soon as molded. When notching these specimens, minimize the exposure time during notching and return the specimens to a dry container after notching to allow for full cooling of the specimens prior to testing.

9.3 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73 ± 3.6°F) and 50 ± 10 % relative humidity, unless otherwise specified. In cases of disagreement, the tolerances shall be ±1°C and ±5 % relative humidity.

10. Procedure

10.1 *Specimen Preparation:*

10.1.1 Prepare the test specimens in accordance with the procedures in Section 7. At least five and preferably ten or more individual determinations of impact resistance shall be made to determine the average impact resistance for a particular sample. The specimens shall be of nominal width only.

10.1.2 Notch the specimens in accordance with the procedure in Section 8.

10.1.3 Condition the specimens in accordance with the materials specification for the material that is being tested. If there are no conditioning requirements detailed in the materials specification, follow the conditioning requirements in Section 9.

10.2 *Machine Preparation:*

10.2.1 Estimate the breaking energy for the sample and select a pendulum of suitable energy. Select the lightest standard pendulum that is expected to break all specimens in the group with an energy loss of not more than 85 % of its capacity (see 6.1). If the breaking energy cannot be estimated, select the correct pendulum by performing trial runs. Use caution to avoid damaging the pendulum by selecting a pendulum that is too light for a particular sample.

NOTE 11—Ideally, an impact test would be conducted at a constant test velocity. In a pendulum-type test, however, the velocity decreases as the fracture progresses. For specimens that have an impact energy approaching the capacity of the pendulum, there is insufficient energy to complete the break and toss. By avoiding the higher 15 % scale energy readings, the velocity of the pendulum will not be reduced below 1.33 m/s. On the other hand, the use of a pendulum that is too heavy would reduce the sensitivity of the reading.

10.2.2 After installing the selected pendulum on the machine, check the machine for conformity with the requirements of Section 6 before starting the tests.

10.2.3 When using a machine equipped with a pointer and dial mechanism or an electronic indicator that does not automatically correct for windage and friction, determine the windage and friction correction factors for the machine before testing specimens. Windage and friction correction factors shall be determined on a daily basis and shall be calculated each time weights are added to the pendulum or the pendulum is changed. Refer to Annex A1 for information on constructing windage and friction correction charts or refer to Annex A2 for a procedure to calculate the windage and friction correction. If excessive friction is indicated (see X2.12 and X2.13) the machine shall be adjusted before testing specimens. Follow the machine manufacturer's instructions to correct for excessive windage and friction.

NOTE 12—The actual correction factors for windage and friction will be smaller than these factors in an actual test because the energy absorbed by the specimen prevents the pendulum from making a full swing. The indicated breaking energy of the specimen, therefore, must be included in the calculation of the machine correction.

10.2.4 Some machines equipped with an electronic digital display or computer automatically compensate for windage and friction.

10.3 *Specimen Testing:*

10.3.1 Check all of the specimens in the sample group for conformity with the requirements of Sections 7 and 8 and 10.1.

10.3.2 Measure and record the width of each specimen after notching to the nearest 0.025 mm (0.001 in.). Measure the width in one location adjacent to the notch centered about the anticipated fracture plane.

10.3.3 Measure and record the depth of material remaining in the specimen under the notch of each specimen to the nearest 0.025 mm (0.001 in). The tapered blade will be fitted to the notch. The specimen will be approximately vertical between the anvils. Position the edge of the non-cavity (wider edge) surface so that it is centered on the micrometer's flat circular anvil. See Fig. 5.

10.3.4 Position a test specimen horizontally on the supports and against the anvils so that it will be impacted on the face opposite the notch (see Fig. 3). Center the notch between the anvils. A centering jig is useful for this purpose.

10.3.5 Raise and secure the pendulum in the release mechanism and reset the indicating mechanism.

10.3.6 Release the pendulum, allowing the striking edge of the pendulum to impact the specimen. Note the indicated breaking energy.

10.3.7 Calculate the net breaking energy (see 11.1). If the net breaking energy is greater than 85 % of the pendulum's nominal energy, the wrong pendulum was used. Discard the result. Select and install a pendulum with a greater available energy or add additional weight to the pendulum, determine the windage and friction correction factor, and repeat the test on a new specimen.

10.3.8 If the proper pendulum was used, test the remaining specimens as described in 10.3.1 – 10.3.6. Results from specimens that do not break shall be discarded. A specimen that does not break completely into two or more pieces is not considered to be broken.

10.3.9 After all of the specimens for the sample have been tested, calculate the impact resistance, in joules per metre, for each individual specimen (see 11.2).

10.3.10 Calculate the average impact resistance for the group of specimens (see 11.3). Values obtained from specimens that did not break completely shall not be included in the average.

10.3.11 Calculate the standard deviation for the group of specimens (see 11.4).

11. Calculation

11.1 *Net Breaking Energy*—Subtract the windage and friction loss energy from the indicated breaking energy.

11.2 *Impact Resistance*—Divide the net breaking energy by the measured width of each individual specimen.

11.3 Calculate the average impact resistance for a group of specimens by adding the individual impact resistance values for the group and dividing the sum by the total number of specimens in the group.

11.4 Calculate the standard deviation as follows and report it to two significant figures:

$$s = \sqrt{\left(\sum X^2 - n\ \bar{X}^2\right) / (n - 1)} \quad (3)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type source, manufacturer's code number, and previous history.

12.1.2 A statement of how the specimens were prepared, the testing conditions used, the number of hours the specimens were conditioned after notching, and for sheet materials, the direction of testing with respect to anisotropy, if any.

12.1.3 The capacity of the pendulum, J.

12.1.4 The span.

12.1.5 The width and depth under the notch of each specimen tested.

12.1.6 The total number of specimens tested per sample of material (that is five, ten, or more).

12.1.7 The average impact resistance, J/m. Impact resistance is not to be reported for other than complete breaks. Reporting results in kJ/m² is optional (see Appendix X4).

12.1.8 The standard deviation of the values of the impact resistance of the specimens in 10.3.11.

TABLE 1 Precision for Charpy Test

Values in ft·lbf/in. of Width

Material	Average	S_r [A]	S_R [B]	r [C]	R [D]	Number of Laboratories
Phenolic Reinforced	0.55	0.029	0.050	0.08	0.14	7
Nylon	1.88	0.060	0.143	0.16	0.40	7
Polycarbonate	3.83	0.065	0.422	0.23	1.18	8
Polypropylene	4.36	0.151	0.422	0.42	1.18	8
ABS	10.3	0.115	0.629	0.32	1.76	9

[A] S_r = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test result from all of the participating laboratories:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation:

$$S_R = [S_r^2 + S_L^2]^{1/2}$$

where S_L = standard deviation of laboratory means.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

13. Precision and Bias

13.1 Table 1 is based on a round robin[8] conducted in 1987 in accordance with Practice E691, involving five materials tested by nine laboratories. For each material, all samples were prepared at one source, but the individual specimens were notched and conditioned at the laboratories which tested them. Each laboratory tested an average of nine specimens for each material. (**Warning**—The explanations of r and R (13.2 – 13.2.3) are intended only to present a meaningful way of considering the approximate precision of this test method. The data presented in Table 1 are not to be applied to acceptance or rejection of materials, as these data apply only to the materials tested in the round robin and are unlikely to be rigorously representative of other lots, formulations, conditions, materials, or laboratories. Users of this test method are advised to apply

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1154.

the principles outlined in Practice E691 to generate data specific to their materials and laboratory, or between specific laboratories. The principles of 13.2 – 13.2.3 would then be valid for such data.)

13.2 *Concept of r and R in* Table 1 —If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from testing nine specimens for each test result, then:

13.2.1 *Repeatability—r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory. Two tests results shall be judged not equivalent if they differ by more than the *r* value for that material.

13.2.2 *Reproducibility—R* is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories, not necessarily on the same day. Two test results shall be judged not equivalent if they differ by more than the *R* value for that material.

13.2.3 Any judgement in accordance with 13.2.1 or 13.2.2 would have an approximate 95 % (0.95) probability of being correct.

13.3 There are no recognized standards by which to estimate bias of this test method.

14. Keywords

14.1 Charpy impact; impact resistance; notch sensitivity; notched specimen

ANNEXES

(Mandatory Information)

A1. INSTRUCTIONS FOR THE CONSTRUCTION OF A WINDAGE AND FRICTION CORRECTION CHART

A1.1 The construction and use of the chart herein described is based upon the assumption that the friction and windage losses are proportional to the angle through which these loss torques are applied to the pendulum. Fig. A1.1 shows the assumed energy loss versus the angle of the pendulum position during the pendulum swing. The correction chart to be described is principally the left half of Fig. A1.1. Some manufacturers supply windage and friction correction charts for their equipment. The energy losses designated as A or B are described in 10.3.

A1.2 Start the construction of the correction chart (Fig. A1.2) by laying off to some convenient linear scale on the abscissa of a graph the angle of pendulum position for the portion of the swing beyond the free hanging position. For convenience, place the free hanging reference point on the right end of the abscissa with the angular displacement increasing linearly to the left. The abscissa is referred to as Scale C. Although angular displacement is the quantity to be represented linearly on the abscissa, this displacement is more conveniently expressed in terms of indicated energy read from the machine dial. This yields a nonlinear Scale C with indicated pendulum energy increasing to the right.

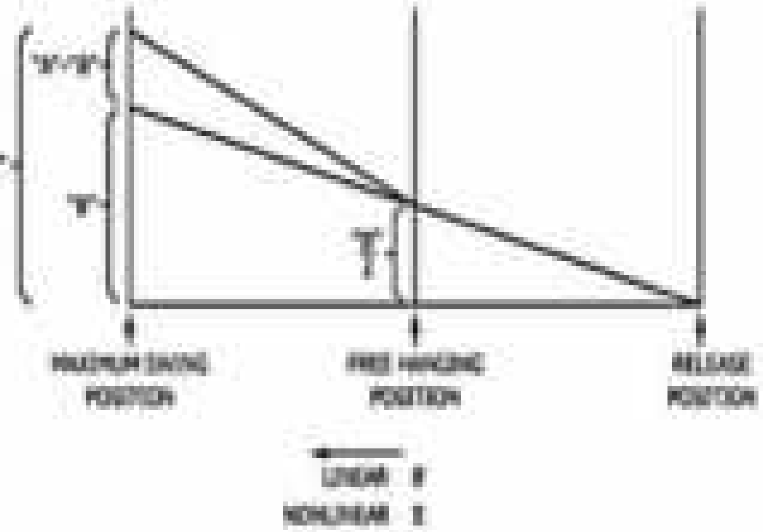


FIG. A1.1 Method of Construction of a Windage and Friction Correction Chart

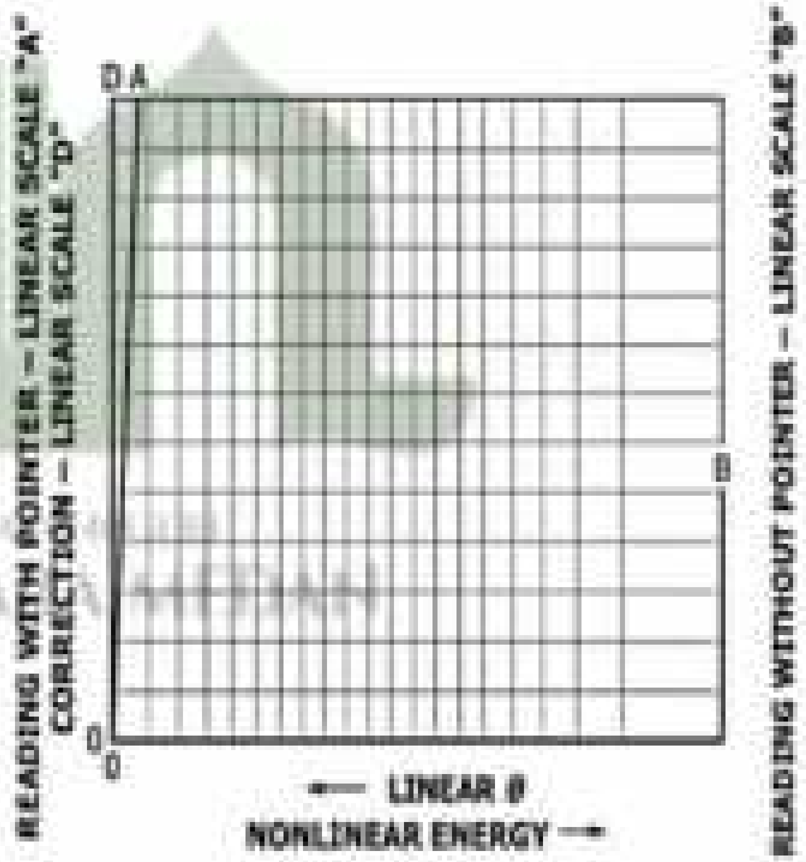


FIG. A1.2 Sample Windage and Friction Correction Chart

A1.3 On the right hand ordinate lay off a linear Scale B starting with zero at the bottom and stopping at the maximum expected pendulum friction and windage value at the top.

A1.4 On the left ordinate construct a linear Scale D ranging from zero at the bottom to 1.2 times the maximum ordinate value appearing on Scale B, but make the scale twice the scale used in the construction of Scale B.

A1.5 Adjoining Scale D draw a curve OA which is the locus of points whose coordinates have equal values of energy correction on Scale D and indicated energy on Scale C. This curve is referred to as Scale A and utilizes the same divisions and numbering system as the adjoining Scale D.

A1.6 *Instructions for Using Chart:*

A1.6.1 Locate and mark on Scale A the reading A obtained from the free swing of the pendulum with the pointer prepositioned in the free hanging or maximum indicated energy position on the dial.

A1.6.2 Locate and mark on Scale B the reading B obtained after several free swings with the pointer pushed up close to zero indicated energy position of the dial by the pendulum in accordance with instructions in 10.3.

A1.6.3 Connect the two points thus obtained by a straight line.

A1.6.4 From the indicated impact energy on Scale C project up to the constructed line and across to the left to obtain the correction for windage and friction from Scale D.

A1.6.5 Subtract this correction from the indicated impact reading to obtain the energy delivered to the specimen.

A2. PROCEDURE FOR THE CALCULATION OF WINDAGE AND FRICTION CORRECTION

A2.1 The procedure for the calculation of the windage and friction correction in this annex is based on the equations developed by derivation in Appendix X3. This procedure is acceptable as a substitute for the graphical procedure described in Annex A1 and is applicable to small electronic calculator and computer analysis.

A2.2 Calculate L, the distance from the axis of support to the center of percussion as indicated in 6.3. It is assumed here that the center of percussion is approximately the same as the center of strike.

A2.3 Measure the maximum height, h_M, of the center of percussion (center of strike) of the pendulum at the start of the test as indicated in X2.11.

A2.4 Measure and record the energy correction, E_A, for windage of the pendulum plus friction in the dial, as determined with the first swing of the pendulum with no specimen in the testing device. This correction must be read on the energy scale, E_M, appropriate for the pendulum used.

A2.5 Without resetting the position of the indicator obtained in A2.4, measure the energy correction, E_B, for pendulum windage after two additional releases of the pendulum with no specimen in the testing device.

A2.6 Calculate β_{max} as follows:

$$\beta_{max} = \cos^{-1}\{1 - [(h_M/L)(1 - E_A/E_M)]\} \quad (A2.1)$$

where:

E_A = energy correction for windage of pendulum plus friction in dial, J (ft·lbf),
E_M = full-scale reading for pendulum used, J (ft·lbf),
L = distance from fulcrum to center of strike of pendulum, m (ft),
h_M = maximum height of center of strike of pendulum at start of test, m (ft), and
β_{max} = maximum angle pendulum will travel with one swing of the pendulum.

A2.7 Measure specimen breaking energy, E_S, J (ft·lbf).

A2.8 Calculate β for specimen measurement E_S as:

$$\beta = \cos^{-1}\{1 - [(h_M/L)(1 - E_S/E_M)]\} \quad (A2.2)$$

where:

β = angle pendulum travels for a given specimen, and
E_S = dial reading breaking energy for a specimen, J (ft·lbf).

A2.9 Calculate total correction energy, E_{TC} as:

$$E_{TC} = (E_A - (E_B/2))(\beta/\beta_{max}) + (E_B/2) \quad (A2.3)$$

where:

E_{TC} = total correction energy for the breaking energy, E_S, of a specimen, J (ft·lbf), and
E_B = energy correction for windage of the pendulum, J (ft·lbf).

A2.10 Calculate the impact resistance using the following formula:

$$I_S = (E_S - E_{TC})/t \quad (A2.4)$$

where:

I_S = impact resistance of specimen, J/m (ft·lbf/in.) of width, and
t = width of specimen or width of notch, m (in.)

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR THE INSPECTION AND VERIFICATION OF NOTCH

X1.1 The purpose of this procedure is to describe the microscopic method to be used for determining the radius and angle of the notch. These measurements could also be made using a comparator if available.

NOTE X1.1—The notch shall have a radius of 0.25 ± 0.05 mm (0.010 ± 0.002 in.) and an angle of 45 ± 1°.

X1.2 *Apparatus:*

X1.2.1 *Optical Device,* with minimum magnification of 60×, Filar glass scale and camera attachment.

X1.2.2 *Transparent Template,* that will be developed in this procedure.

X1.2.3 *Ruler.*

X1.2.4 *Compass.*

X1.2.5 *Plastic Drafting Set Squares (Triangles),* 45-45-90°.

X1.3 A transparent template must be developed for each magnification and for each microscope used. It is preferable that each laboratory standardize on one microscope and one magnification. It is not necessary for each laboratory to use the same magnification because each microscope and camera combination have somewhat different blowup ratios.

X1.3.1 Set the magnification of the optical device at a suitable magnification with a minimum magnification of 60×.

X1.3.2 Place the Filar glass slide on the microscope platform. Focus the microscope to the most distinct of the Filar scale is visible.

X1.3.3 Take a photograph of the Filar scale (see Fig. X1.1).

X1.3.4 Create a template similar to that shown in Fig. X1.2.

X1.3.4.1 Find the approximate center of the piece of paper.

X1.3.4.2 Draw a set of perpendicular coordinates through the center point.

X1.3.4.3 Draw a family of concentric circles that are spaced in accordance with the dimensions of the Filar scale. This task is accomplished by first setting a mechanical compass at a distance of 0.1 mm (0.004 in.) as referenced by the magnified photograph of the Filar eyepiece. Subsequent circles shall be spaced 0.02 mm apart (0.001 in.), as rings, with the outer ring being 0.4 mm (0.016 in.) from the center.

X1.3.5 Photocopy the paper with the concentric circles to make a transparent template of the concentric circles.

X1.3.6 Construct Fig. X1.3 by taking a second piece of paper, finding its approximate center, and marking this point. Draw one line through this center point. Label this line zero degree (0°). Draw a second line perpendicular to the first line through this center point. Label this line 90°. From the center draw a line that is 44° relative to the 0°. Label the line 44°. Draw another line at 46°. Label the line 46°.

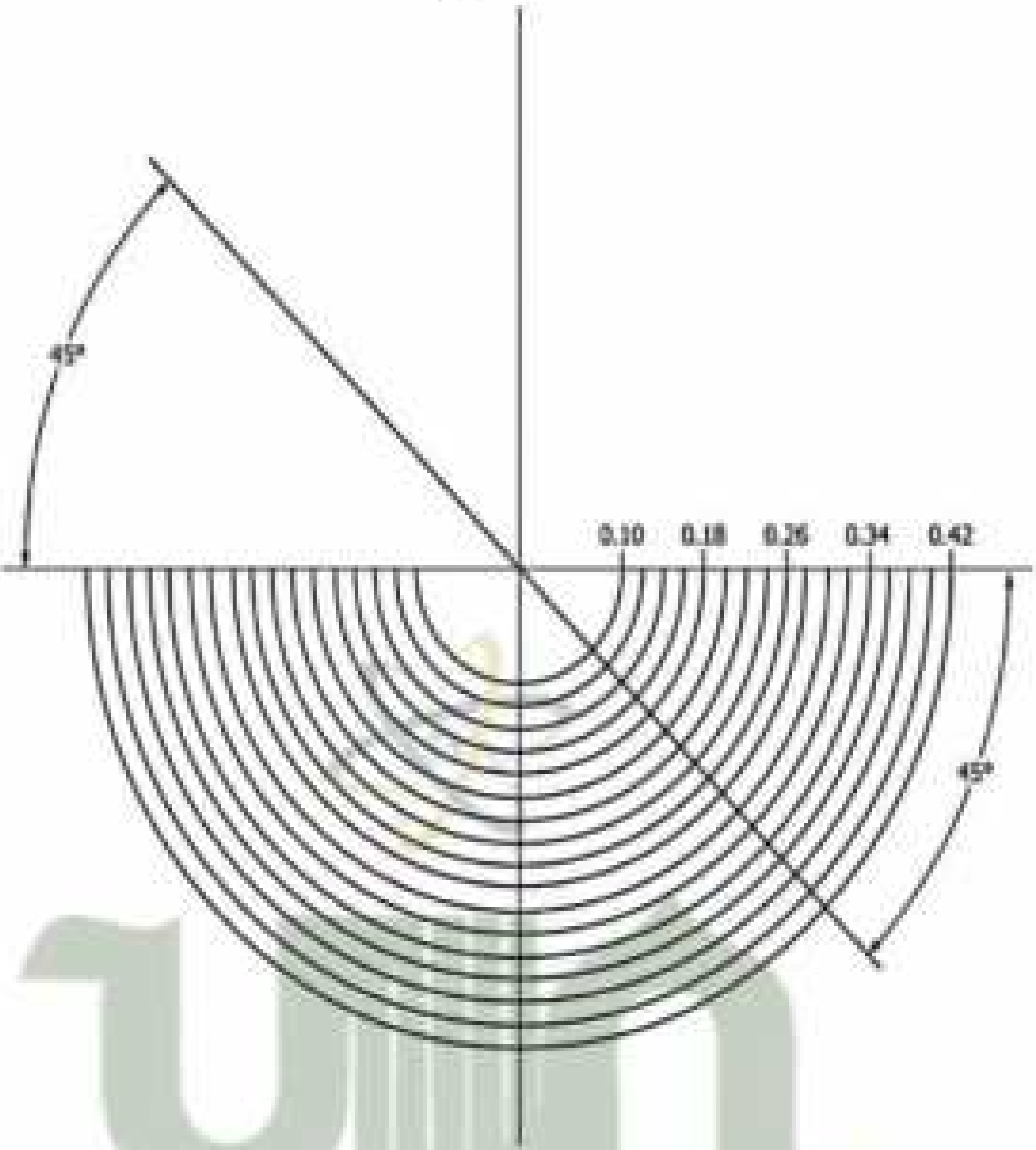
NOTE 1—100× Reference

NOTE 2—0.1 mm major scale; 0.01 mm minor scale

FIG. X1.1 Filar Scale

X1.4 Place a microscope glass slide on the microscope platform. Place the notched specimen on top of the slide. Focus the microscope. Move the specimen around using the platform adjusting knobs until the specimen's notch is centered and near the bottom of the viewing area. Take a picture of the notch.

X1.4.1 *Determination of Notching Radius* (Fig. X1.4):



NOTE 1—Magnification = 100×.

FIG. X1.2 Example of Transparent Template for Determining Radius of Notch

X1.4.1.1 Place the picture on a sheet of paper. Position the picture so that bottom of the notch in the picture faces downwards and is about 64 mm (2.5 in.) from the bottom of the paper. Tape the picture down to the paper.

X1.4.1.2 Draw two lines along the sides of the notch projecting down to a point where they intersect below the notch Point I (see Fig. X1.4B).

X1.4.1.3 Open the compass to about 51 mm (2 in.). Using Point I as a reference, draw two arcs intersecting both sides of the notch (see Fig. X1.4C). These intersections are called 1a and 1b.

X1.4.1.4 Close the compass to about 38 mm (1.5 in.). Using Point 1a as the reference point, draw an arc (2a) above the notch, draw a second arc (2b) that intersects with arc 2a at Point J. Draw a line between I and J. This establishes the centerline of the notch (see Fig. X1.4D).

X1.4.1.5 Place the transparent template on top of the picture and align the center of the concentric circles with the drawn centerline of the notch (see Fig. X1.4E).

X1.4.1.6 Slide the template down the centerline of the notch until one concentric circle touches both sides of the notch. Record the radius of the notch and compare it against the limits of 0.2 to 0.3 mm (0.008 to 0.012 in.).

X1.4.1.7 Examine the notch to ensure that there are no flat spots along the measured radius.

X1.4.2 *Determination of Notch Angle*—Place transparent template for determining notch angle (Fig. X1.3) on top of the photograph attached to the sheet of paper. Rotate the picture so that the notch tip is pointed towards you. Position the center point of the template on top of the Point I established in 0° axis of the template with the right side straight portion of the notch. Check the left side straight portion of the notch to ensure that this portion falls between the 44° and 46° lines. If not, replace the blade.

X1.5 A picture of a notch shall be taken at least every 500 notches or if a control sample gives a value outside its 3-sigma limits for that test.

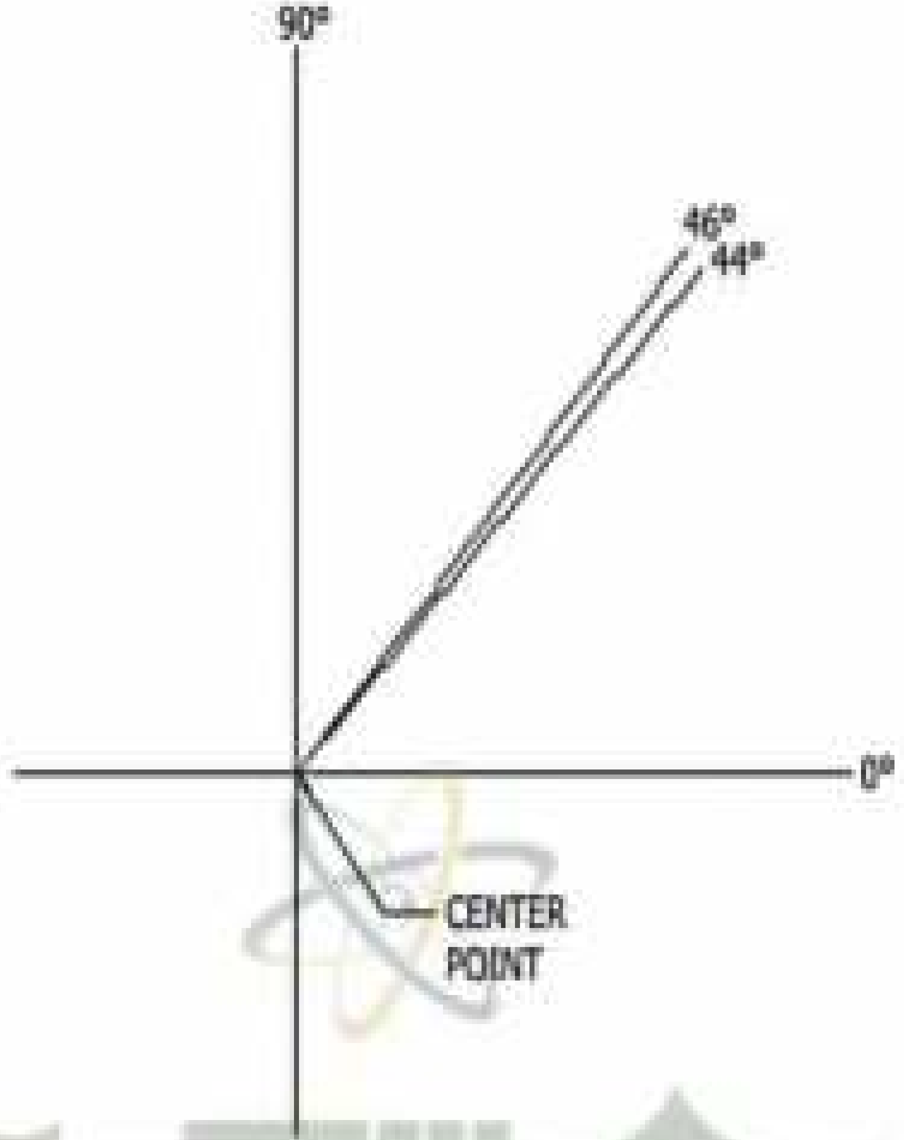


FIG. X1.3 Example of Transparent Template for Determining Angle of Notch

X1.6 If the notch in the control specimen is not within the requirements, take a picture of the notching blade and analyze it by the same procedure used for the specimen notch. If the notching blade does not meet ASTM requirements or shows damage, it shall be replaced with a new blade which has been checked for proper dimensions.

X1.7 If a cutter has the correct dimensions, but does not cut the correct notch in the specimen, it will be necessary to evaluate other conditions (cutter and feed speeds) to obtain the correct notch dimensions for that material.

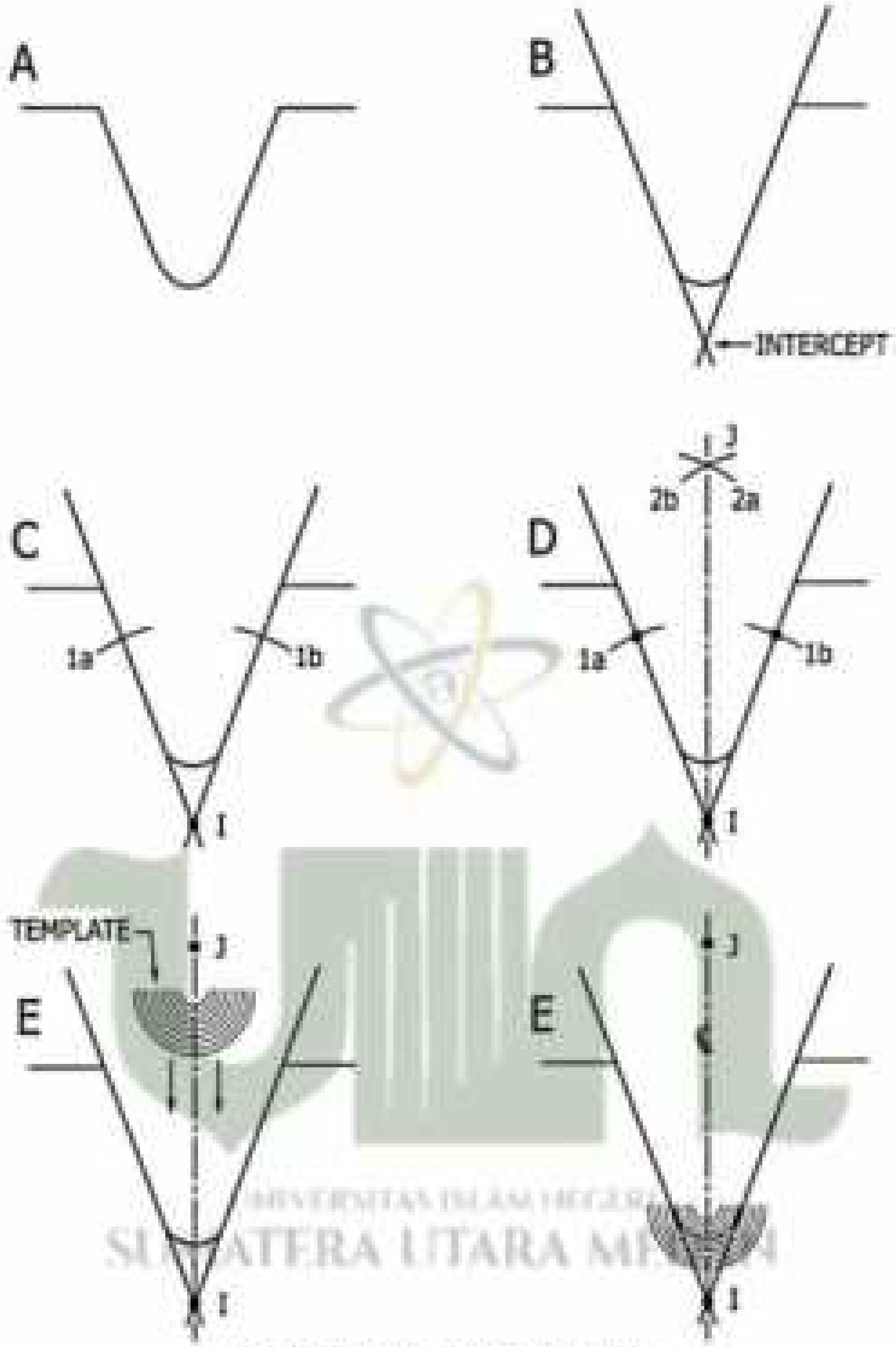


FIG. X1.4 Determination of Notching Radius

X2. CALIBRATION OF PENDULUM-TYPE HAMMER IMPACT MACHINES FOR USE WITH PLASTIC SPECIMENS

X2.1 This calibration procedure applies specifically to the Charpy impact machine.

X2.2 Locate the impact machine on a sturdy base. It shall not walk on the base and the base shall not vibrate appreciably. Loss of energy from vibrations will give high readings. It is recommended that the impact tester be bolted to a base having a mass of at least 23 kg if it is used at capacities higher than 2.7 J (2 ft·lbf).

X2.3 Check the level of the machine in both directions on the plane of the base with spirit levels mounted in the base, by a machinist's level if a satisfactory reference surface is available, or with a plumb bob. Level the machine to within $\tan^{-1}$ 0.001 in the plane of swing and to within $\tan^{-1}$ 0.002 in the place perpendicular to the swing.

X2.4 Contact the machine manufacturer for a procedure to ensure the striker radius is in tolerance (3.17 ± 0.12 mm) (see 6.1.2).

X2.5 Check the transverse location of the center of the pendulum striking edge that shall be within 0.40 mm (0.016 in.) of the center of the anvil. Readjust the shaft bearings or relocate the anvil or straighten the pendulum shaft as necessary to attain the proper relationship between the two centers.

X2.6 Check the pendulum arm for straightness within 1.2 mm (0.05 in.) with a straightedge or by sighting down the shaft. This arm is sometimes bent by allowing the pendulum to slam against the catch when high-capacity weights are on the pendulum.

X2.7 Center a notched 12.7-mm square metal bar having opposite sides parallel within 0.025 mm and 125 mm long on the Charpy anvils. Place a thin oil film, ink or dye on the striking edge of the pendulum and let the striking edge rest gently against the bar. If the striking edge is correctly making contact with the specimen, a thin line of oil, ink, or dye will be transferred across the entire width of the bar.

X2.8 When the pendulum is hanging free in its lowest position, the energy reading must be within 0.2 % of full scale.

X2.9 Swing the pendulum to a horizontal position, and support it by the striking edge in this position with a vertical bar. Allow the other end of this bar to rest at the center of a load pan on a balanced scale. Subtract the weight of the bar from the total weight to find the effective weight of the pendulum. The effective pendulum weight shall be within 0.4 % of the required weight for that pendulum capacity. If weight must be added or removed, take care to balance the added or removed weight without affecting the center of percussion relative to the striking edge. It is not advisable to add weight to the opposite side of the bearing axis from the striking edge to decrease the effective weight of the pendulum since the distributed mass has the potential to result in large energy losses from vibration of the pendulum.

X2.10 Calculate the effective length of the pendulum arm or the distance to the center of percussion from the axis of rotation by the procedure in 6.1.2. The effective length must be within the tolerance stated in 6.1.1.2.

X2.11 Determine the vertical distance of fall of the pendulum striking edge from its latched height to its lowest point. This distance shall be 610 ± 2 mm. This measurement is made with a half-width specimen positioned on the anvils. Place a thin oil film on the specimen and bring the striking edge against it. The upper end of the oil line on the striking edge is the center of strike. Measure the change in vertical height of the center of strike from the latched to the free hang position (the lowest point). This vertical fall distance is adjusted by varying the position of the pendulum latch.

X2.12 If a pointer and dial mechanism is used to indicate the energy, the pointer friction shall be adjusted so that the pointer will just maintain its position anywhere on the scale. The striking pin of the pointer shall be securely fastened to the pointer. Friction washers with glazed surfaces shall be replaced with new washers. Friction washers shall be on either side of the pointer collar. The last friction washer installed shall be backed by a heavy metal washer. Pressure on this metal washer is produced by a thin bent spring washer and locknuts. If the spring washer is placed next to the fiber friction washer, the pointer will tend to vibrate during impact.

X2.13 The free-swing reading of the pendulum (without specimen) from the latched height shall be less than 2.5 % of pendulum capacity on the first swing. If the reading is higher than this, the friction in the indicating mechanism is excessive or the bearings are dirty. To clean the bearings, dip them in grease solvent and spin dry in an air jet. Clean the bearings until they spin freely or replace them. Oil very lightly with instrument oil before replacing. A reproducible method of starting the pendulum from the proper height must be devised.

X2.14 The shaft about which the pendulum rotates shall have no detectable radial play, less than 0.05 mm (0.002 in.). An end play of 0.25 mm (0.010 in.) is permissible when a 9.8-N (2.2-lbf) axial force is applied in alternate directions.

X2.15 The machine shall not be used to indicate more than 85 % of the energy capacity of the pendulum. Extra weight added to the pendulum will increase available energy of the machine. This weight must be added so as to maintain the center of percussion within the tolerance stated in 6.1.2. Correct effective weight for any range is calculated as follows:

$$W = E_p / h \qquad (X2.1)$$

where:

W = the effective pendulum weight, N (lbf) (see X2.9),
E_p = potential or available energy of the machine, J (ft × lbf), and
h = the vertical distance of fall of the pendulum striking edge, m (ft) (see X2.11).

Each 4.5 N (1 lbf) of added effective weight increases the capacity of the machine by 2.7 J (2 ft × lbf).

NOTE X2.1—If the pendulum is designed for use with add-on weight, it is recommended that they be obtained through the equipment manufacturer.

X3. DERIVATION OF PENDULUM IMPACT CORRECTION EQUATIONS

X3.1 From right triangle distances in Fig. X3.1:

$$L - h = L\cos\beta \quad (X3.1)$$

X3.2 The potential energy gain of pendulum, E_p, is:

$$E_p = hW_p g \quad (X3.2)$$

X3.3 Combining Eq X3.1 and Eq X3.2 gives the following:

$$L - E_p/W_p g = L\cos\beta \quad (X3.3)$$

X3.4 The maximum energy of the pendulum is the potential energy at the start of the test, E_M, or

$$E_M = h_M W_p g \quad (X3.4)$$

X3.5 The potential energy gained by the pendulum, E_p, is related to the absorption of energy of a specimen, E_s, by the following equation:

$$E_M - E_s = E_p \quad (X3.5)$$

X3.6 Combining Eq X3.3-X3.5 gives the following:

$$(E_M - E_s)/E_M = L/h_M(1 - \cos\beta) \quad (X3.6)$$

X3.7 Solving Eq X3.6 for β gives the following:

$$\beta = \cos^{-1}[1 - \{(h_M/L)(1 - E_s/E_M)\}] \quad (X3.7)$$

X3.8 From Fig. X3.2, the total energy correction, E_{TC}, is given as:

$$E_{TC} = m\beta + b \quad (X3.8)$$

X3.9 At the zero point of the pendulum the potential energy is:

$$E_A/2 = m(0) + b \quad (X3.9)$$

or

$$b = E_A/2$$

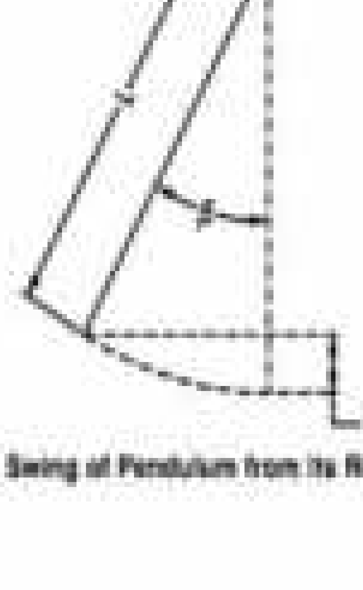


FIG. X3.1 Swing of Pendulum from Its Rest Position

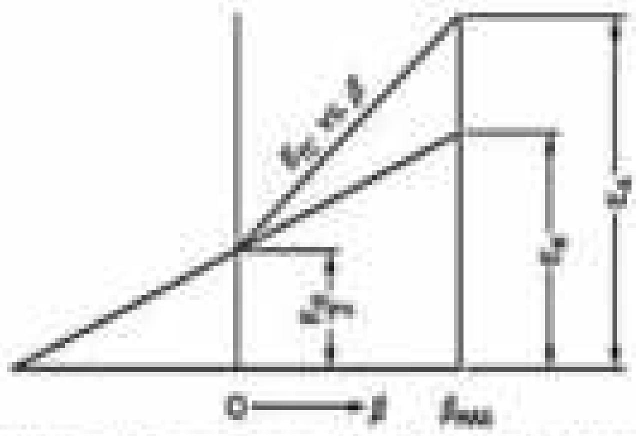


FIG. X3.2 Total Energy Correction for Pendulum Windage and Dial Friction as a Function of Pendulum Position

X3.10 The energy correction, E_A, on the first swing of the pendulum occurs at the maximum pendulum angle, β_{max}. Substituting in Eq X3.8 gives the following:

$$E_A = m\beta_{max} + (E_A/2) \quad (X3.10)$$

X3.11 Combining Eq X3.8 and Eq X3.11 gives the following:

$$E_{TC} = (E_A - (E_A/2))(\beta/\beta_{max}) + (E_A/2) \quad (X3.11)$$

X3.12 Nomenclature:

- b = intercept of total correction energy straight line,
- E_A = energy correction, including both pendulum windage plus dial friction, J,
- E_B = energy correction for pendulum windage only, J,
- E_M = maximum energy of the pendulum (at the start of test), J,
- E_p = potential energy gain of pendulum from the pendulum rest position, J,
- E_s = uncorrected breaking energy of specimen, J,
- E_{TC} = total energy correction for a given breaking energy, E_s, J,
- g = acceleration of gravity, m/s²,
- h = distance center of gravity of pendulum rises vertically from the rest position of the pendulum, m,
- h_M = maximum height of the center of gravity of the pendulum, m,
- m = slope of total correction energy straight line,
- L = distance from fulcrum to center of gravity of pendulum, m,
- W_p = weight of pendulum, as determined in X2.13, kg, and
- β = angle of pendulum position from the pendulum rest position.

X4. UNIT CONVERSIONS

X4.1 Joules per metre cannot be converted directly into kilojoules per square metre.

NOTE X4.1—If the optional units of kJ/m² (ft·lbf/in.²) are required the cross-sectional area under the notch must be reported.

X4.2 The following examples are approximations:

$$1\ \text{ft·lbf}/39.37\ \text{in.} = 1.356\ \text{J/m}$$
$$1\ \text{ft·lbf/in.} = (39.37)(1.356)\ \text{J/m}$$
$$1\ \text{ft·lbf/in.} = 53.4\ \text{J/m}$$
$$1\ \text{ft·lbf/in.} = 0.0534\ \text{kJ/m}$$

$$1\ \text{ft·lbf}/1550\ \text{in.}^2 = 1.356\ \text{J/m}^2$$
$$1\ \text{ft·lbf/in.}^2 = (1550)(1.356)\ \text{J/m}^2$$
$$1\ \text{ft·lbf/in.}^2 = 2101\ \text{J/m}^2$$
$$1\ \text{ft·lbf/in.}^2 = 2.1\ \text{kJ/m}^2$$

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D6110 - 08) that may impact the use of this standard. (April 1, 2010)

(1) Revised Section 9.

4. JIS 5905:2003 Fibreboards

JIS

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS A 5905 : 2003

Fibreboards

ICS 79.060.20
Reference number : JIS A 5905 : 2003 (E)

 19 S

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently **JIS A 5905** : 1994 is replaced with **JIS A 5905** : 2003.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

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In the event of any doubts arising as to the contents, the original JIS is to be the final authority.

Printed in Japan

Fibreboards

1 Scope This Japanese Industrial Standard specifies fibreboards which are formed mainly from vegetable fibres of woods or the like.

2 Normative references The standards indicated in Attached Table 1 contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards (including amendments) shall be applied.

3 Classification and symbols

3.1 Classification by density The fibreboards are classified by the density and the manufacturing method as shown in Table 1.

Table 1

Classification	Symbol	Density
Insulation fibreboard (hereafter referred to as "insulation board")(1)	IB	Under 0.35 g/cm³
Medium density fibreboard (hereafter referred to as "MDF")(2)	MDF	0.35 g/cm³ or over
Hard fibreboard (hereafter referred to as "hard board")	HB	0.80 g/cm³ or over

Notes (1) Among the insulation boards, the sheathing board which is treated with asphalt or the like in the manufacturing process or after manufacturing shall be under 0.40 g/cm³ in density.

(2) MDF is prepared by drying process.

3.2 Insulation boards The insulation boards shall be classified according to the use and incombustibility.

a) **Classification according to the use** The classification according to the use shall be as specified in Table 2.

Table 2 Classification according to the use

Classification	Symbol	Main use (informative)
Straw mat (TATAMI) board	T-IB	For straw mat (TATAMI) base
Class A insulation board	A-IB	For heat insulation
Sheathing board	S-IB	For sheathing of outside walls

b) **Classification by incombustibility** The classification by incombustibility shall be as specified in Table 3.

Table 18 Quality of decorative MDF

Moisture content %	In-plane tensile strength N/mm²	Impact resistance	Acid resistance	Alkali resistance	Stain resistance	Discoloration resistance		Scratch resistance
					Stain resistance for [illegible]	Appearance	Colour difference	
5 or more up to and incl. 13	0.4 or more	Free from radial cracks, fractures and separations. The diameter of the dent shall be 10 mm or under.	Not to be discoloured	Not to be discoloured	To be grade 4 of grey scale for staining or over.	To be free from defects such as cracks and swelling on the surface.	To be grade 4 of grey scale for discoloration or over, or to be not more than 3.0 of color difference.	To be free from noticeable scratches.

Remarks : The acid resistance, the alkali resistance, the stain resistance, the discoloration resistance and the scratch resistance shall not be applied to the veneer overlay nor after-coat.

Table 19 Quality of basic hard board

Classification			Density g/cm³	Moisture content %	Bending strength N/mm²	Water absorption %
Basic hard board	Standard board	S35	0.80 or more	5 or more up to and incl. 13	35.0 or more	35 (25) or under
		S25	0.80 or more	5 or more up to and incl. 13	25.0 or more	35 (30) or under
		S20	0.80 or more	5 or more up to and incl. 13	20.0 or more	40 (30) or under
	Tempered board	T45	0.90 or more	5 or more up to and incl. 13	45.0 or more	20 or under
		T35	0.80 or more	5 or more up to and incl. 13	35.0 or more	30 or under

Remarks: Figures in ( ) are applicable to the standard boards with thickness under 3.5 mm.

RIWAYAT HIDUP

Siti Aulia Hutauruk adalah nama penulis Skripsi ini, lahir di Pasar Sorkam tanggal 07 Juli 2002. Lahir dari keluarga Bapak Haslan Hutauruk dan Ibu Mayarni, merupakan anak keenam dari tujuh bersaudara. Penulis pertama kali menempuh pendidikan dimulai dari SDN 154510 Pasar Sorkam pada tahun 2008 dan lulus pada tahun 2014. Kemudian melanjutkan pendidikan di SMP Muhammadiyah 08 Medan dan lulus pada tahun 2017. Penulis kemudian melanjutkan pendidikan di SMA Negeri 14 Medan dan lulus pada tahun 2020. Pada tahun 2020 penulis terdaftar sebagai Mahasiswa di Program Studi Fisika Universitas Islam Negeri Sumatera Utara Medan untuk memperoleh gear Strata-1 (S1) dan lulus pada tahun 2024.

Atas Berkat Karunia Allah Azza Wa Zalla, dukungan, do'a, motivasi dari kedua orang tua, dan materi dari ueng dan uda, serta arahan dan bimbingan dari berbagai pihak sehingga penulis dapat menyelesaikan Skripsi. Semoga dengan adanya penulisan Skripsi ini mampu memberikan kontribusi lebih bagi dunia pendidikan terkhusus program studi Fisika.

Akhir kata penulis mengucapkan Hamdallah atas terselesaikannya Skripsi yang berjudul "Sintesis dan Karakterisasi Material Komposit Berbahan Serat Daun Nanas dengan Perekat Resin *Polyester*".