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An American National Standard

Standard Practice for Units of Measurement and Conversion Factors for Pulp, Paper, and Paperboard[1]

This standard is issued under the fixed designation D 4826; 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 practice covers the application of the International System of Units (abbreviated SI) within the field of pulp, paper, and paperboard. The SI units have been adopted by ISO, ASTM, and TAPPI as the preferred units for use in their standards and test methods.

1.2 Details of SI are given in various parts of ISO Standards 31 and 1000, and in ASTM Standard E 380. Application of this information is not always easy, as some properties cannot at this time be expressed in SI, some can be expressed in various units all within SI, and various multiples can be used. Such variation can lead to confusion in reporting test results and in quoting values for properties.

1.3 In order to overcome such problems within the pulp, paper, and paperboard field, ISO/TC6 has recommended appropriate units in ISO Standard 5651. These recommendations are reproduced in this practice, together with other information and recommendations.

2. Referenced Documents[2]

2.1 *ASTM Standards:*

IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System[3,4]

2.2 *ISO Standards:*

ISO 31 Quantities, Units and Symbols, Parts 0–13[4]

ISO 1000 SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units[4]

3. Summary of Practice

3.1 This practice covers the units recommended for use in expressing the properties of pulp, paper, and paperboard and other quantities found in the pulp, paper, and paperboard documents. It also provides the conversion factors for converting customary units to metric units or other recommended units, and marks with an asterisk (*) when the conversion factor is exact.

3.2 Units recommended in ISO 5651 are marked (+) or (#), with the latter indicating that the recommended unit for pulp, paper, and paperboard is not a preferred SI unit.

3.3 The international symbol for each unit is given in square brackets [ ] following the name of the unit.

4. Significance and Use

4.1 Uniformity in expressing the results of testing and in quoting property values is needed for improved communication in commerce and research.

4.2 The table of recommended units and symbols and the rules for using them provided in this practice will aid in achieving uniformity.

5. Procedure

5.1 In converting from the customary units to the recommended form, multiply the test value expressed in customary units by the conversion factor to obtain the test value in the recommended form. As an example, suppose that the property of interest is the thickness of a sheet of paper, and that this has been determined to be 5.3 mils. Examination of the table shows that in Section 1.2, Thickness, the conversion factor from mils to micrometres, is exactly 25.4. Multiplying 5.3 by 25.4, the test value in the recommended units is 134.62 µm. Generally, the converted value should be rounded to the same number of significant figures or one more than in the value in customary units, depending, respectively, on whether the first digit of the new value is more or less than that of the original value. Thus, in this case, the converted value would be 135 µm.

NOTE 1—The rounding rule given here is easy to remember and does not result in the loss of significant information. For more detailed information on rounding, see ASTM Practice E 380.

5.2 If the property of interest had been the thickness of corrugated board of, for example, 180 mils, the value would be converted to millimetres, not micrometres. The conversion factor is 0.0254 and the value in the recommended form is 4.57

[1] This practice is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

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[2] For the full titles of the standards and other documents listed in the table, see the ISO, ASTM, and TAPPI indexes.

[3] Availabe from ASTM International, www.astm.org (Excerpts in Related Material section of all ASTM volumes.)

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

or 4.6 mm, depending on whether the zero in the last digit of 180 is significant or simply holding the decimal place.

5.3 Generally, if the table allows a choice in the recommended form, choose that form that would have no more than three significant figures in front of the decimal point for most of the values and only one place after the decimal point. However, use, for example, 0.13 mm, not 130 µm, if the zero in 130 is not significant.

5.4 To minimize variety, it is recommended (and the table generally shows) that only prefixes representing 1000 raised to an integral power be used. Thus use:

10^9	giga-	G
10^6	mega-	M
10^3	kilo-	k
10^{-3}	milli-	m
10^{-6}	micro-	µ
10^{-9}	nano-	n

However, in expressing area or volume, the prefixes hecto-, deka-, deci-, and centi- may be needed, for example, cubic centimetres.

6. Notation

6.1 The quantities given in square brackets in the second and fourth columns are symbols, not abbreviations. Hence, do not use abbreviation marks. When two of these symbols are multiplied, as in Section 9.18, dynamic viscosity in pascal seconds, use a raised (center) dot between the symbols, thus Pa·s.

6.2 The same symbol is used for the plural, so adding an *s* for the plural is incorrect. Thus, write fifty-two grams as 52 g. Also the symbol for per is a slash (/), not the letter *p*, and scientific notation is used for squares, cubes, and higher powers. Thus, write fifty-two grams per square metre as 52 g/m^2, not gpsm nor gsm.

6.3 The symbols and the names of units are not mixed in the same expression. Therefore, g per square metre, grams/square metre, grams/m^2, g/sq m, and g per m^2 are all incorrect.

6.4 In the text, write out the name of the unit, except when preceded by a numerical value. Thus use “determine the mass in grams to the nearest 0.1 g.” However, expressions like “one gram’’ or “two to three grams” may be used when the value as well as the unit of measurement must be written out.

7. Keywords

7.1 conversion factors; paper; paperboard; pulp; units of measure

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
		Name [Symbol]	*exactly	Name [Symbol]
1.	**General Properties**			
1.1	Grammage (mass per unit area in g/m^2)	pounds per ream, 17 × 22 − 500 [lb/ream, 17× 22−500]	3.7597	+ grams per square metre [g/m^2]
	Basis weight (mass per unit area on ream basis)	pounds per ream, 24 × 36 − 500 [lb/ream, 24 × 36−500]	1.6275	grams per square metre [g/m^2]
		pounds per ream, 25 × 38 − 500 [lb/ream, 25 × 38−500]	1.4801	grams per square metre [g/m^2]
	ISO 536, 3039, 5270, 5638	pounds per ream, 25 × 40 − 500 [lb/ream, 25 × 40−500]	1.4061	grams per square metre [g/m^2]
	ASTM D 646	pounds per 1000 square feet [$lb/1000\ ft^2$]	4.8824	grams per square metre [g/m^2]
	TAPPI T 410	pounds per 3000 square feet [$lb/3000\ ft^2$]	1.6275	grams per square metre [g/m^2]
		pounds per 3300 square feet [$lb/3300\ ft^2$]	1.4795	grams per square metre [g/m^2]
1.2	Thickness (caliper)	mils (or points or thousandths of an inch)	*25.4	+ micrometres [µm]
	ISO 534, 3034 ASTM D 374, D 645 TAPPI T411	mils [mil or 0.001 in.]	*0.0254	+ [n] millimetres [mm] [n] for corrugated fiberboard
1.3	Apparent density	pounds per cubic foot [lb/ft^3]	16.01846	kilograms per cubic metre [kg/m^3]
	ISO 534, 5270	pounds per cubic foot [lb/ft^3]	27679.90	kilograms per cubic metre [kg/m^3]
	ASTM D 202	pounds per cubic inch [$lb/in.^3$]	27.67990	# [n] grams per cubic centimetre [g/cm^3]
	TAPPI T 258, T 694			[n] for paper and paperboard
1.4	Bulking thickness ISO 534 TAPPI T 220	mils [mil or 0.001 in.]	*25.4	+ micrometres [µm]
1.5	Book bulk ASTM D 2175 TAPPI T 500	mils [mil or 0.001 in.]	*0.0254	millimetres [mm]
1.6	Hygroexpansivity ISO 8226			+ percent [%] (by length)
1.7	Dimensional change after immersion in water ISO 5635			+ percent [%] (by length)
1.8	Drainability of pulp (freeness):			
1.8.1	Canadian standard freeness ISO 5267/2 TAPPI T 227			+ numerical value (CSF) [no. (CSF)]
1.8.2	Schopper-Riegler freeness ISO 5267/1			+ numerical value [SR number]
2.	**Strength Properties**			
2.1	Tensile strength ISO 1924, 3781, 5270	pounds-force per inch [lbf/in.] pounds-force per 15 millimetre width [lbf/15 mm]	0.1751268 0.29655	+ kilonewtons per metre [kN/m] kilonewtons per metre [kN/m]

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
	ASTM D 202, D 828	pounds-force per 15 millimetre width [lbf/15 mm]	0.67378	kilonewtons per metre [kN/m]
	TAPPI T 404, T 494, T456, T 220, T 813	kilograms-force per 25 millimetre width [kgf/25 mm]	0.39227	kilonewtons per metre [kN/m]
		kilograms-force per centimetre [kgf/cm]	*0.980665	kilonewtons per metre [kN/m]
		ounce-force per inch [ozf/in.]	10.945	*n* newtons per metre [N/m]
		grams-force per millimetre [gf/mm]	*9.80655	*n* newtons per metre [N/m]
		newtons per 15 millimetre width [N/15 mm]	66.66667	*n* newtons per metre [N/m] *n* for tissue towels
2.2	Tensile index ISO 1924, 5270	kilometres breaking length [km]	*9.80665	+ newton metres per gram [N·m/g]
2.3	Breaking length (to be replaced by tensile index) ISO 1924 TAPPI T 220, T 231, T 494	metres [m]	*0.001	+ kilometres [km]
2.4	Stretch at break (elongation) ISO 1924 ASTM D202 TAPPI T 220, T 404, T 494			+ percent [%] (by length)
2.5	Tensile energy absorption (TEA)	foot pounds-force per square foot [ft·lbf/ft^2]	14.59390	+ joules per square metre [J/m^2]
	ISO 1924	inch pounds-force per square inch [in·lbf/in.^{2}]	175.1268	joules per square metre [J/m^2]
	TAPPI T494	kilograms-force metres per square metre [kgf·m/m^2]	*9.80665	joules per square metre [J/m^2]
2.6	Tensile energy absorption index ISO 1924			#millijoules per gram [mJ/g]
2.7	Bursting strength	pounds force per square inch [psi] or points	6.894757	+ kilopascals [kPa]
	ISO 2758, 2759, 3689	kilograms-force per square centimetre [kgf/cm^2]	0.0980665	megapascals [MPa]
	ASTM D 774, D 2529, D 2738	kilonewtons per square metre [kN/m^2]	*1.000	kilopascals [kPa]
	TAPPI T 403, T 807, T 810			
2.8	Burst index (formerly burst factor)	Burst factor computed as: grams-force per square centimetre per (grams per square metre) [(gf/cm^2)/(g/m^2)]	*0.0980665	#kilopascal square metres per gram [kPa·m^2/g]
	ISO 2758, 2759, 3689, 5270 TAPPI T 220			
2.9	Tearing strength ISO 1974, 5270 ASTM D689 TAPPI T 414, T220, T496	grams-force [gf]	*9.80665	+ millinewtons [mN]
2.10	Tear index (replaces tear factor)	Tear factor computed as: 100 grams-force	*0.0980665	#millinewton square metres per gram [mN·m^2/g]
	ISO 1974, 5270 TAPPI T 220	per (gram per square metre) [100 gf/(g/m^2)]		
2.11	Puncture resistance	centimetre kilograms-force [cm·kgf]	*0.0980665	+ joules [J]
	ISO 3036	scale units (= 0.305 cm·kgf)	0.0299	joules [J]
	ASTM D 781	foot pounds-force [ft·lbf]	1.355818	joules [J]
	TAPPI T 803	inch pounds-force [in.·lbf]	0.1129848	joules [J]
		inch ounces-force [in.·ozf]	7.061552	millijoules [mJ]
2.12	Adhesion strength of glue bonds of corrugated fibreboard	pounds-force per inch [lbf/in.]	0.1751268	+ kilonewtons per metre [kN/m]
	TAPPI T 813	kilograms-force per millimetre [kgf/mm]	*9.80665	kilonewtons per metre [kN/m]
2.13	Z-direction tensile strength	pounds-force per square inch [lbf/in.^{2}]	6.894757	+ kilopascals [kPa]
	TAPPI T 506	kilograms-force per square centimetre [kgf/cm^2]	*98.0665	kilopascals [kPa]
2.14	Internal bond	foot pounds-force per square inch [ft·lbf/in.^{2}]	2101.5	joules per square metre [J/m^2]
2.15	Edge tearing resistance (Finch)	pounds-force [lbf]	4.44822	newtons (N)
	ASTM D 827	kilograms-force [kgf]	*9.80665	newtons (N)
	TAPPI T 470			
2.16	Tensile strength retention after immersion (or wet tensile strength) ISO 3781 ASTM D 829 TAPPI T 456			percent [%] (or see 2.1)
2.17	Bursting strength retention after immersion ISO 3689			percent [%]
3.	**Folding, Bending and Compression Properties**			
3.1	Static bending force	pounds-force [lbf]	4.448222	+ newtons [N]
	ISO 2493	grams-force [gf]	*9.80665	+ millinewtons [mN]
3.2	Bending stiffness	gram-force centimetres [gf·cm]	*98.0665	+ micronewton metres [µN·m]
	ISO 5629	gram-force centimetres [gf·cm]	*0.0980665	+ millinewton metres [mN·m]
	TAPPI T 489, T 535, T820	pound-force inches [lbf·in.]	0.1129848	+ newton metres [N·m]
3.3	Bending strength (modulus of rupture) TAPPI T 655, T 1003	pounds-force per square inch [lbf/in.^{2}]	6.894757	kilopascals [kPa]
3.4	Flat crush resistance of corrugated board	pounds-force per square inch [lbf/in.^{2}]	6.894757	+ kilopascals [kPa]
	ISO 3035	kilograms-force per square centimetre [kgf/cm^2]	*98.0665	kilopascals [kPa]
	ASTM D 1225 TAPPI T 808			

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
3.5	Flat crush resistance of laboratory fluted corrugating medium (CMT method) ISO 7263 ASTM D 3806 TAPPI T 809	pounds-force (CMT) [lbf(CMT)]	4.448222	#newtons (CMT) [N(CMT)]
3.6	Edgewise crush resistance ISO 3037 TAPPI T 811	pounds-force per inch [lbf/in.] kilograms-force per inch [kgf/in.]	175.1268 0.38609	newtons/metre [N/m] + kilonewtons/metre [kN/m]
3.7	Ring crush ASTM D 1164 TAPPI T 818	*n* pounds-force (for a 6-inch length) [lbf/6 in.] *n* kilograms-force (for a 6-inch length) [kgf/6 in.] *n* usually expressed simply as "pounds'' or "kilograms''	0.02919 0.06435	+ kilonewtons per metre [kN/m] kilonewtons per metre [kN/m]
3.8	Fold number, double folds ISO 5270, 5626 ASTM D 643, D 2176 TAPPI T 423, T 511, T 220			+ numerical value (number of double folds)
3.9	Folding endurance ISO 5270, 5626 ASTM D 2176 TAPPI T 423, T 511	formerly equivalent to "fold number'' (see above), now "the log to the base 10 of the number of double folds''		+ $\log_{10}$(number of double folds)
4.	**Surface Properties**			
4.1	Roughness, Bendtsen ISO 2494, 8791			#millilitres per minute (Bendtsen) [mL/min (Bendtsen)]
4.2	Roughness, Sheffield ISO 2494 TAPPI T 538			#Sheffield units
4.3	Roughness, Print-surf ISO 8791	microns	*1.000	#micrometres (Print-surf) [µm(Print-surf)]
4.4	Smoothness, Bekk ISO 5627 TAPPI T 479			#seconds (Bekk) [s(Bekk)]
4.5	Coefficient of friction ASTM D 202, D 3247, D3248	Degrees of angle		numerical value numerical value = tangent of angle
4.6	Surface strength:			
4.6.1	Wax pick ASTM D 2482			Wax number
4.6.2	Picking velocity, IGT ISO 3782, 3783 TAPPI T 499	feet per minute [ft/min]	*5.080	+ millimetres per second [mm/s] + metres per second [m/s]
4.6.3	Viscosity-velocity-product (VVP), IGT TAPPI T 514	kilopoise centimetres per second [kP·cm/s] pascal-seconds metres-per-second [(Pa·s)(m/s)]	*1.000 *1.000	newtons per metre [N/m] newtons per metre [N/m]
4.7	Delamination velocity ISO 3782, 3783	feet per minute [ft/min]	*0.00508	+ metres per second [m/s]
4.8	Surface wettability Initial Rate ASTM D 724 TAPPI T 458			 degrees [°] degrees per second [°/s]
4.9	Specific external surface of pulp	square centimetres per gram [cm^2/g]	*0.100	square metres per kilogram [m^2/kg]
5.	**Permeability and Absorption Properties**			
5.1	Water vapor transmission rate ISO 2528 TAPPI T 448, T 464, T 523	grams per 100 square inches day [g/(100 $in.^2$·d)]	15.5	+ grams per square metre day [g/(m^2·d)]
5.2	Water absorbency—area basis ISO 535, 5637 ASTM D 3285, D 4250 TAPPI T441	grams per 100 square centimetres [g/100 cm^2]	*100.000	+ grams per square metre [g/m^2]
5.3	Water absorbency—mass basis ISO 5637 ASTM D 4250 TAPPI T 491			+ percent [%] (of initial mass)
5.4	Water absorbency—capillary rise ASTM D 202	inches [in.]	*25.4	+ millimetres [mm]
5.5	Ink absorbency, K and N			#"K and N'' units
5.6	Ink absorption of blotting paper ASTM D 2177 TAPPI T 431			seconds per millilitre [s/mL]
5.7	Saturating capacity of felt	millilitres per 100 grams [mL/100 g]	*1.000	Kerosine number

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
	ASTM D 727 TAPPI T 427			
5.8	Resistance to water penetration			+ minutes, hours, or days [min, h, or d]
	ISO 5633 ASTM D 779 TAPPI T 433			seconds [s]
5.9	Water resistance of corrugated fibreboard ISO 3038			hours [h]
5.10	Water absorption rate TAPPI T 432			[s/0.01 mL] tissue [s/0.1 mL] towel
5.11	Resistance to grease penetration			+ minutes, hours, or days [min, h, or d]
	ISO 5634 ASTM D 722 TAPPI T 454			seconds [s]
5.12	Printing ink penetration (Castor oil test) ASTM D 780 TAPPI T 462			seconds [s]
5.13	Air permeance, general ISO 5636/1 TAPPI T 251	cubic feet per minute square foot 0.5-inch water [$ft^3/(min \cdot ft^2 \cdot 0.5$ in. H_2O)]	40.83	+ micrometres per pascal second [µm/(Pa·s)]
5.14	Air permeance, Bendtsen ISO 5636/3	millilitres per minute (Bendtsen) [mL/min (Bendtsen)]	0.01134	micrometres per pascal second [µm/(Pa·s)]
5.15	Air permeance, Sheffield ISO 5636/4	millilitres per minute [mL/min] (Sheffield corrected) where A = test area in square millimetres	162/A	micrometres per pascal second [µm/(Pa·s)]
5.16	Air resistance, general			pascal seconds per metre [Pa·s/m]
5.17	Air resistance, Gurley ISO 3687, 5270, 5336/5 ASTM D 726 TAPPI T 460, T 536	seconds [s] sometimes expressed as seconds per 100 millilitres	*1.000	#seconds (Gurley) [s(Gurley)]
6.	**Optical Properties**			
6.1	Reflectance factor ISO 2469, 2470, 3688 ASTM D 985 TAPPI T 452, T 442, T 525, T 534, T 646			+ percent [%]
6.2	Opacity ISO 2469, 2471 ASTM D 589 TAPPI T 425, T519			+ percent [%]
6.3	Gloss, 75° ISO 8254/1 ASTM D 1223 TAPPI T 480, T 653			+ percent [%] or numerical value (gloss units)
6.4	Reflection (optical) density			+ numerical value
6.5	Transmission (optical) density			+ numerical value
6.6	Light absorbing power			+ numerical value
6.7	Light scattering power			+ numerical value
6.8	Light absorption coefficient	square centimetres per gram [cm^2/g]	*0.100	+ square metres per kilogram [m^2/kg]
6.9	Light scattering coefficient TAPPI T 220	square centimetres per gram [cm^2/g]	*0.100	+ square metres per kilogram [m^2/kg]
7.	**Electrical Properties**			
7.1	Conductivity of extracts ISO 6587 ASTM D202 TAPPI T252	micromhos per centimetre [$\mu\Omega^{-1}/cm$] microsiemens per centimetre [µS/cm]	*0.100 *0.100	+ millisiemens per metre [mS/m] millisiemens per metre [mS/m]
7.2	Surface resistivity			+ ohms [Ω]
7.3	Volume resistivity	ohm centimetres [Ω·cm]	*0.010	+ ohm metres [Ω·m]
7.4	Electrical strength	volts per mil [V/mil]	0.03937	+ kilovolts per millimetre [kV/mm]
8.	**Composition**			
8.1	Moisture content (or dry matter content) ISO 287, 638 ASTM D 644, D 2044 TAPPI T 264, T 208, T 220, T 258, T 412, T 671			+ percent [%] (of total mass)
8.2	Stock concentration ISO 4119 TAPPI T240			+ percent [%] (of total mass)

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
8.3	Ash ISO 1762, 2144, 2638 ASTM D 586 TAPPI T 413, T 211			+ percent [%] (of dry mass)
8.4	Other major constituents or coatings: Mass per unit area ASTM D2 423 TAPPI T 405, T 497, T 531, T 532 T 688, T 690, T 691	(See 1.1 for conversion factors)		+ grams per square metre [g/m^2]
8.5	Other major constituents: Relative mass ISO 624, 692, 699, 3260 ASTM D 202, D 549, D 984, D 1030, D 1224, D 548, D 588, D 590, D 591, D 921, D 982, D 1099, D 1160 TAPPI T 401, T 405 , T 406 , T 408 , T 41 8, T 419 , T 428, T 438, T 429, T 493, T 504, T 612, T 627, T 688, T 691 , T 203, T 204, T 207, T 212, T 222, T 235, T 249, T 250, T 255, T 256, T 261			+ percent [%] (of dry mass)
8.5.1	ASTM D590			percent [%] (of conditioned mass)
8.6	Dirt—area basis ASTM D 2019 TAPPI T 213, T437	parts per million [ppm] (by area)	*1.000	square millimetres per square metre [mm^2/ m^2]
8.7	Dirt and shives—mass basis ISO 5350 TAPPI T 246			square millimetres per kilogram [mm^2/kg] #100 times number of specks per kilogram [100(no. specks/kg)]
8.8	Other minor constituents ISO 776, 777, 778, 779, 1830, 9197, 9198 ASTM D 202 TAPPI T 241, T 242, T 243, T 244, T 245, T 247, T 434	parts per million [ppm] (by mass)	*1.000	+ milligrams per kilograms [mg/kg]
8.9	Saleable mass ISO 801 TAPPI T210			+ kg
8.10	Degree of delignification Kappa number; Chlorine consumption ISO 302, 3260 TAPPI T 236			+ percent [%] or numerical value
8.11	Copper number ASTM D9 19 TAPPI T 430			number (g copper/100 g fiber)
9.	**General Units Found in Pulp, Paper, and Paper-Board Testing Documents**			
9.1	Linear dimensions, including optical wavelength	angstroms [Å]	*0.100	nanometres [nm]
		microns	*1.000	micrometres [µm]
		mils [mil, or 0.001 in.]	*0.0254	millimetres [mm]
		inches [in.]	*25.4	millimetres [mm]
		feet [ft]	*0.3048	metres [m]
		miles [mi]	1.609	kilometres [km]
9.1.1	Fiber length TAPPI T 232, T 233			millimetres [mm]
9.2	Area			square millimetres [mm^2]
		square inches [in.^{2}]	*6.4516	square centimetres [cm^2]
		square feet [ft^2]	*0.09290304	square metres [m^2]
		square yards [yd^2]	*0.83612736	square metres [m^2]
		acres	4046.86	square metres [m^2]
		hectares [ha]	*0.0100	square kilometres [km^2]
		square miles [mi^2]	2.589988	square kilometres [km^2]
9.3	Volume	microlitres [µL]	*1.000	cubic millimetres [mm^3]
		cubic inches [in.^{3}]	16.38706	cubic centimetres [cm^3]
		cubic feet [ft^3]	28.316585	cubic decimetres [dm^3]
		cubic yards [yd^3]	0.7645549	cubic metres [m^3]
9.4	Volume of fluids (as above plus:)	fluid ounces (US) [fl oz (US)]	29.57353	millilitres [mL]
		fluid ounces (Imp) [fl oz (Imp)]	28.413	millilitres [mL]
		gallons (US) [gal(US)]	3.785412	litres [l or L] (L preferred, US)
		gallons (Imp) [gal(Imp)]	4.546092	litres [L]
9.5	Mass			micrograms [µg] milligrams [mg]
		ounces (avdp) [oz]	28.34952	grams [g]

TABLE *Continued*

	Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
		pounds [lb or lbm, lb preferred]	0.4535924	kilograms [kg]
		tons (= 2000 lb)	0.9071847	metric tons or tonne [t] (= 1000 kg)
9.6	Mass per unit length TAPPI T 234	milligrams per 100 metres [mg/100 m] or decigrex	*0.0100	milligrams per metre [mg/m]
9.7	Mass per unit area (also see 1.1, 8.4)	tons per 100 square feet [ton/100 ft^2]	0.092903	tonne per square metre [t/m^2]
9.8	Mass per unit volume, or Density (also see 1.3)	ounces per gallon [oz/gal]	7.489152	grams per litre [g/L]
		pounds per gallon [lb/gal]	0.1198264	kilograms per litre [kg/L]
		grams per litre [g/L]	*1.000	kilograms per cubic metre [kg/m^3]
		pounds per cubic inch [$lb/in.^3$]	27.67990	megagrams per cubic metre [Mg/m^3]
9.9	Time			microseconds [µs] milliseconds [ms] seconds [s] minutes [min] (= 60 seconds [s]) hours [h] (= 3.6 kiloseconds [ks]) days [d] (= 86.4 kiloseconds [ks])
9.10	Speed	feet per second [ft/s]	*0.30480	metres per second [m/s]
		feet per minute [ft/min or fpm]	*5.080	millimetres per second [mm/s]
9.11	Volume flow rate	gallons per minute [gal/min or GPM]	3.78541	litres per minute [L/min]
		cubic feet per second [ft^3/s]	0.02831685	cubic metres per second [m^3/s]
		cubic feet per minute [ft^3/min or cfm]	1.69901	cubic metres per hour [m^3/h]
9.12	Force	pounds-force [lbf] (factor exactly 4.448 221 615 260 5)	4.448222	newtons [N]
		ounces-force [ozf]	0.278014	newtons [N]
		kilograms-force [kgf]	*9.80665	newtons [N]
		dynes [dyn]	*0.0100	millinewtons [mN]
9.13	Force per unit length (linear load)	pounds-force per inch [lbf/in.]	0.1751268	kilonewtons per metre [kN/m]
	Surface tension TAPPI T 517	dynes per centimetre [dyn/cm]	*1.000	millinewtons per metre [mN/m]
9.14	Force per unit area	newtons per square metre [N/m^2]	*1.000	pascals [Pa]
	Pressure	grams-force per square centimetre [gf/cm^2]	*98.0665	pascals [Pa]
	Stress	pounds-force per square foot [lbf/ft^2]	47.88026	pascals [Pa]
		pounds-force per square inch [$lbf/in.^2$ or psi]	6.894757	kilopascals [kPa]
		millimetres of mercury (0°C) [mmHg]	0.133322	kilopascals [kPa]
		inches of water (60°F) [in.H_2O]	0.24884	kilopascals [kPa]
		feet of water (39.2°F) [ftH_2O]	2.98898	kilopascals [kPa]
		inches of mercury (60°F) [in.Hg]	3.37685	kilopascals [kPa]
		inches of mercury (32°F) [in.Hg]	3.38638	kilopascals [kPa]
		atmospheres [atm]	*0.101325	megapascals [MPa]
		bars [bar]	*100	kilopascals [kPa]
9.15	Torque, or bending moment (also see 3.2)	pound-force feet [lbf·ft]	.35582	newton metres [N·m]
		dyne centimetres [dyn·cm]	*0.1000	micronewton metres [µN·m]
9.16	Energy	metre newtons [m·N] = 10^7 ergs	*1.000	joules [J]
		foot-pounds force [ft·lbf]	1.35582	joules [J]
		metre kilograms-force [m·kgf]	*9.80665	joules [J]
		British thermal units, Int. [Btu]	1.055056	kilojoules [kJ]
		kilocalories, Int. Table [kcal]	*4.1868	kilojoules [kJ]
		horsepower hours [hp·h]	2.68452	megajoules [MJ]
		kilowatt hours [kW·h or kWh]	*3.600	megajoules [MJ]
9.17	Power	foot pounds-force per second [ft·lbf/s]	1.35582	watts [W]
		horsepower [hp] (= 550 foot-pounds force per second)	745.700	watts [W]
		metric horsepower	735.499	watts [W]
9.18	Dynamic viscosity	poise [P]	*0.100	pascal seconds [Pa·s]
	TAPPI T 630, T 634, T 652, T 662, T 675, T 814	centipoise [cP]	*1.000	millipascal seconds [mPa·s]
9.19	Kinematic viscosity	centistokes [cSt]	*1.000	square millimetres per second [mm^2/s]
9.20	Limiting viscosity number ISO 5351			#millilitres per gram [mL/g]
9.21	Illumination	footcandles [fc]	10.76391	lumens per square metre [lm/m^2]
		footcandles [fc]	10.76391	lux [lx]
9.22	Temperature	degrees Fahrenheit [°F] $T_C = (5/9)(T_F - 32)$		degrees Celsius [°C]
		degrees Celsius [°C] $T_K = T_C + 273.15$		kelvin [K]
9.23	Temperature change	Fahrenheit degrees change [ΔF]	0.555556	Celsius degrees change [ΔC]
		Celsius degrees change [ΔC]	*1.000	kelvin change [ΔK]
9.24	Color temperature			kelvin [K]
9.25	Frequency	cycles per second [s^{-1}]	*1.000	hertz [Hz]
9.26	Rotational frequency			revolutions per second [r/s or s^{-1}]
9.27	Plane angle			degrees [°] (decimal subdivisions)
9.28	pH ISO 6588			+ numerical value (pH units)

TABLE *Continued*

Property and ISO Standard	To Convert Values Expressed in Customary Units	Multiply by	To Obtain Values Expressed in Recommended Form
ASTM D7 78 TAPPI T 252, T 435, T 509, T529, T 667			