

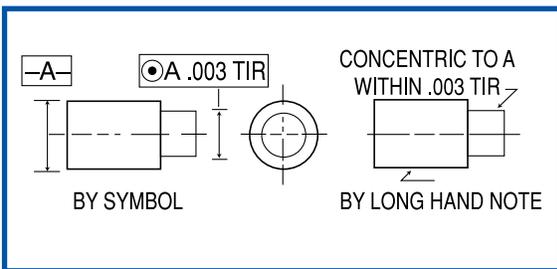
Section 10

ENGINEERING DATA

DEFINITIONS

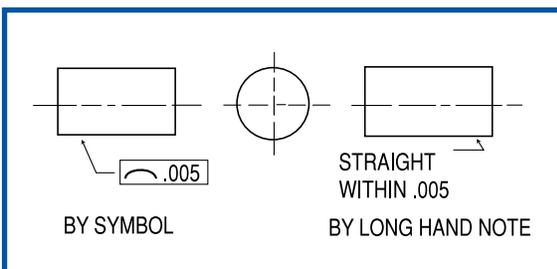
CONCENTRICITY . . . A measure of the lack of uniformity of the wall-thickness of the tube, this tolerance can be thought of as the degree to which the cylinders defined by the inner and outer surfaces of the tube parallel and overlap. Determined using an Indicating Gauge, this tolerance is reported as a deviation (\pm) or Total Indicator Reading (T.I.R.), i.e. the absolute variation in wall thickness at the ends of a tube rotated through 360°.

Method of specifying concentricity on drawings:



STRAIGHTNESS . . . Straightness of the elements of a precision bore tube is a condition which no element deviates from a straight line.

Method of specifying straightness of elements:



CAMBER . . . A measure of the lack of straightness of a tube, this tolerance is determined by gauging the deflection at the middle of a tube held at the ends and rotated through 360°. Recorded as a deviation (\pm) or Total Indicator Reading (T.I.R.).

TIR . . . This is the Total Indicator Reading...or the maximum dial variation from the datum or reference point when measurements of the I.D., O.D., wall thickness, camber, etc. of a precision bore tube are taken.

SPECIFICATIONS

TOLERANCES . . . Our guaranteed tolerance limits are your assurance that our precision bore glass tubing will perform satisfactorily in even the most demanding applications. I.D. tolerances vary somewhat depending on the I.D. of the tubing. However, depending on your particular requirements, we can supply PB tubing to the most demanding specifications. Nor is the I.D. the only tubing feature covered by our precise manufacturing procedure. We control straightness, length, I.D., O.D., concentricity, finish, etc. with the same precision.

NOTE: Should you require tolerances more stringent than those listed above, don't hesitate to call us.

WALL THICKNESS . . . The generally accepted method of referring to wall thickness in precision bore Tubing is by the terms Standard, Medium and Heavy. If it is important to your requirements that you know the actual dimensions of the wall thicknesses; our glass engineers will be happy to provide you with the necessary information.

LENGTHS . . . Although we have tooling for many lengths and sizes of PB tubing, it is important that we keep mentioning the need to order the shortest lengths available from the tooling on hand. The smaller lengths are easier to ship and we may be able to ship from stock.

MATERIALS . . . Generally our PB tubing is supplied in Pyrex Brand, Duran or KG-33 glass. However, we also work with various types of glasses. We also use synthetic or natural quartz, and can provide glass tubing for matched metal-to-glass seals.

ENGINEERING DATA

PRODUCT FINISH . . . Based on your requirements, we can modify our precision bore tubing in end finish or outside surface. We can cut the ends square or at any angle. End finishes include simple crack-off, wet wheel cut, fine ground, fire polished, belt or felt polished. External finishes include both rough and fine ground and varying degrees of polish. A surface profilometer is available for accurately quantifying surface finishes.

CONFIGURATIONS . . . Wilmad PB tubing is available in round, square, or rectangular shapes in standard, medium, or heavy walls. However, we can make it in practically any shape . . . oval, hexagonal, tapered, and fluted . . . or other special shapes which meet your requirements.

TUBING CLASSIFICATIONS

STANDARD TUBING . . . Standard tubing, as received from major manufacturers such as Corning, Kimble, Schott, and Kavalier has dimensional tolerances of $\pm 0.3\%$ depending on O.D. size. This type of tubing material is usually unsuited for precision parts but is used as the starting material for other classifications of tubing detailed in the links listed below.

REDRAWN TUBING . . . Redrawn tubing is produced by reheating standard or select material and re-extruding the softened material to rework the O.D., I.D., or shape to tighter tolerances. In many engineering applications, this material is sufficient and typically tolerances are from 5 to 10 times better than standard tubing.

PRECISION BORE TUBING . . . Precision bore (or PB) tubing, as Wilmad's principal product, is manufactured to our industry's strictest tolerances. The process of creating a piece of PB tubing involves the heating and softening of a standard tube over a precision mandrel. The glass is heated to the proper temperature and a vacuum is applied to the annular space between the tube and the mandrel. The final product is formed as the glass is softened and pulled over the mandrel. Each mandrel is carefully machined and polished to exact O.D. based on the difference in coefficient of expansion and contraction of the mandrel and the glass or quartz tubing utilized. Our stock of mandrels is extensive as listed in this catalog, and custom sized mandrels can be produced for virtually any I.D., shape or length.

ORDERING INFORMATION

Wilmad PB Tubing is not priced in this catalog. Since every piece of Wilmad PB tubing and every assembly and subassembly made from it is custom manufactured to your specifications, it is not practical to prepare a price list in advance. Therefore, to receive a quotation, it is necessary to either write, e-mail, fax, or call customer service. Our glass engineers will review your needs and quote a price and delivery time. If your requirements are complex, please submit a drawing or sketch of the glassware you require showing all dimensions and tolerances.

Following are the web links for material specification and properties:

http://www.us.schott.com/epackaging/english/download/schott_techn_glaeser_us.pdf
<http://www.optics.heraeus-quartzglas.com/en/download/Downloads.aspx>

ENGINEERING DATA

CONVERSION FACTORS

To Convert	Multiply By	To Obtain
Atmospheres	760	Mercury (mm)
Centigrade	(°C X 9/5) + 32	Fahrenheit (degrees)
Centimeters	0.3937	Inches
Cubic Centimeters	0.06102	Cubic Inches
Fahrenheit (degrees)	(°F-32) X 5/9	Centigrade (degrees)
Feet	0.3048	Meters
Grams	0.03527	Ounces
Hertz	1.0	CPS
Inches	25.40	Millimeters
Inches	2.540	Centimeters
Kilograms	2.205	Pounds
Meters	39.37	Inches
Ounces	28.349	Grams
Pounds	453.6	Grams
Square Centimeters	0.1550	Square Inches
Square Inches	6.452	Square Centimeters
Torr	1.0	Mercury (mm)

WAVELENGTH CONVERSIONS

1 Angstrom	(A°)	=	10 Millimicrons
1 Angstrom	(A°)	=	.1 Nanometer
1 Angstrom	(A°)	=	3.937 X 10 ⁻⁹ Inches
1 Angstrom	(A°)	=	10 ⁻¹⁰ Meters
1 Angstrom	(A°)	=	10 ⁻⁸ Centimeters
1 Angstrom	(A°)	=	10 ⁻⁴ Microns
1 Micron	(μ)	=	10 ⁻⁴ Centimeters
1 Millimicron	(mμ)	=	10 ⁻³ Microns
1 Micron	(μ)	=	0.001 Millimeters
1 Nanometer	(nm)	=	1 Millimicron
1 Nanometer	(nm)	=	10 Angstroms
1 Wavelength (at 5500 A) λ	()	=	21.8 X 10 ⁻⁶ Inches

VOLUME

1 milliliter (ml.)	.....	0.03382 ounce (U.S. Liquid)
1 ounce (U.S. Liquid)	.....	29.573 milliliters
1 liter (L)	.....	1.05671 quarts (U.S. Liquid)
1 quart (U.S. Liquid)	.....	0.94633 liter
1 liter	.....	0.26418 gallon (U.S. Liquid)
1 gallon (U.S. Liquid)	.....	3.78533 liters
1 cubic centimeter (cc)	.....	0.001 liter (L)
1 cubic centimeter	.....	0.0610 cubic inch
1 cubic inch	.....	16.3872 centimeters
1 cubic meter (M)	.....	35.314 cubic feet
1 cubic foot	.....	0.02832 cubic meter

LENGTH

Inches	Inches	Millimeters (mm)
1/64	.015625	0.3969
1/32	.03125	0.7938
1/16	.0625	1.5875
1/8	.1250	3.1750
3/16	.1875	4.7625
1/4	.2500	6.3500
5/16	.3125	7.9375
3/8	.3750	9.5250
7/16	.4375	11.1125
1/2	.5000	12.7000
5/8	.6250	15.8750
3/4	.7500	19.0500
7/8	.8750	22.2250
1	1.0000	25.4000

1 millimeter (mm)	.....	0.1 centimeter (cm)
1 centimeter	.....	0.01 meter (M)
1 centimeter	.....	0.394 inch
1 inch	.....	2.540 centimeters
1 meter	.....	3.2808 feet
1 foot	.....	0.305 meter
1 millimeter (mm)	.....	0.03937 inches
2 millimeters (mm)	.....	0.07874 inches
3 millimeters (mm)	.....	0.11811 inches
4 millimeters (mm)	.....	0.15748 inches
5 millimeters (mm)	.....	0.19685 inches
6 millimeters (mm)	.....	0.23622 inches
7 millimeters (mm)	.....	0.27559 inches
8 millimeters (mm)	.....	0.41396 inches
9 millimeters (mm)	.....	0.35433 inches
10 millimeters (mm)	.....	0.39370 inches

TRANSMITTANCE VS. ABSORBANCE

Transmittance	Absorbance
(% T)	(A, Abs, AU)
100	0.0000
90	0.046
80	0.097
70	0.155
60	0.222
50	0.301
40	0.398
30	0.523
20	0.699
10	1.000
5	1.301
1	2.000
0.1	3.000
0	∞