Standard Specifications for Casting Tolerances- Linear Dimensions

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ABSTRACT

This standard provides guidance for casting dimension tolerances where no other requirements exist for form, fit or function (general tolerances). The general tolerances presented in this paper are based on international and US standards for general manufactured component tolerances and cast component tolerances. These tolerances are established using the basic size of the specific feature referred to by the dimension and the tolerances are smaller for small dimensions and larger for large dimensions (e.g. 2.5 ± 0.1, 75.5 ± 0.3) unlike traditional decimal place tolerances where the tolerance is established by the number of digits to the right of the decimal place (e.g. 10.0 ± 0.1, 1.000 ± 0.005). This paper does not address measurement method, measurement error, statistical uncertainty, statistical sampling, process capability, fit class, preferred numbers or drafting standards which should be specified separately and may be based on other international, US or company standards.

SCOPE

This specification provides general tolerance guidance for lost-wax investment castings based on the basic size of the specific feature referred to by the dimension.

This specification is not intended to address dimensional tolerances for features subject to specific form, fit or function requirements.

Values in mm or inches that have been converted from inches or mm using 25.4mm/inch are noted.

REFERENCED DOCUMENTS

1. ISO 8062-3:2007 Geometrical product specifications (GPS)- Dimensional and geometrical tolerances for moulded parts- Part 3: General dimensional and geometrical and machining allowances for castings, hereinafter **ISO 8062:2007.**
2. ISO 8062:1994 Castings -- System of dimensional tolerances and machining allowances, hereinafter **ISO 8062:1994**.
3. Steel Castings Handbook, Supplement 3, 2003 Dimensional Capabilities of Steel Castings, Steel Founders' Society of America, hereinafter **SFSA 2003.**
4. Investment Casting Handbook, 1997, Investment Casting Institute, hereinafter **ICI 1997**.
5. ISO 286-2:1988 ISO system of limits and fits - Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts, hereinafter **ISO 286-2**.
6. ANSI/ASME B4.1-1967 (R1999) Preferred Limits and Fits for Cylindrical Parts, hereinafter **ANSI B4.1.**
7. ISO 2768-1:1989(E) General Tolerances- Part 1: Tolerances for linear and angular dimensions without individual tolerance indications, hereinafter **ISO 2768-1**.

DEFINITIONS

Basic Dimension: The theoretical exact size, shape or location of a feature without tolerance. The basic dimension is used for establishing the dimension tolerance for the feature and not the actual dimension. For example, a feature with a specified width of 30mm has a tolerance per ISO 286-2 JS-14 of ± 0.26mm. During measurement the actual dimension is found to be 30.30mm. Per ISO 286-2 JS-14 a dimension of 30.30mm has a tolerance of ± 0.31mm. Because the theoretical exact size of the feature is 30mm the ± 0.26 tolerance must be used and the feature width is out-of-specification. If no dimensioned 2D drawing is provided, the basic dimension is the feature dimension from the 3D solid model.

Pattern Shrink: Pattern shrink is the difference in size and shape between the wax or plastic injection tool cavity as it is machined and the final wax or plastic pattern after the injected part has cooled. Pattern shrink is a function of the injection tool size, injection tool type, pattern material, injection parameters and the temperature of the measured part.

Casting Shrink: Casting shrink is the difference in size and shape between the pattern received by the casting supplier and casting following cooling, cleaning and finishing. Casting shrink is a function of the ceramic investment process, casting process, metal type, material lost during ceramic shell removal, material changes during surface defect removal and surface finishing and the temperature of the measured part.

Post-Processing Dimensional Changes: Post-processing of the cast part can increase or decrease feature dimensions. Shrinkage of the casting occurs due to hot isostatic pressing to remove sub-surface defects, heat treating to improve mechanical and chemical properties of the cast metal and surface cleaning (chemical milling, sand-blasting, etc.) to remove oxide and surface reaction layers. Surface hardening, plating and coating can increase feature size following casting and heat treatment.

RESPONSIBILITY FOR ACHIEVING TOLERANCES

Responsibility for achieving dimensional tolerances of the finished casting for delivery to the buyer rests with the casting supplier if the casting supplier is responsible for providing the patterns and post-processing of the casting. If different parties, including the buyer and the casting supplier, share responsibility for providing the patterns, manufacturing the castings, heat treating the castings and post-processing operations, then one party must be responsible for ensuring the various suppliers deliver their product to dimensions and tolerances calculated to yield an acceptable finished casting.

Pattern Shrink: The lost-wax investment casting process uses one expendable pattern to create each casting. Patterns may be rapid prototypes, wax patterns created using a wax injection tool, plastic patterns created using a plastic injected tool, low melting point metal parts (zinc, magnesium, aluminum, etc.) fabricated by machining, die casting or silicon mold casting or machined plastic or low-melting point alloy metal parts. The size and shape of the castings are primarily established by the size and shape of the patterns used and primary responsibility for castings meeting specified dimensions and tolerances rests with the party responsible for the patterns. Typical ASTM specifications for investment castings, including ASTM A957/A957M-06, Standard Specifications for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use, do not specify dimensional tolerances and state "All castings shall be made in a workmanlike manner and shall conform to the dimensions on the drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser or is produced using a die supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern or die." Typical ISO Specifications including ISO 8062:1994 Castings - System Of Dimensional Tolerances And Machining Allowances state "The system specified applies when the foundry provides the pattern or die equipment or accepts responsibility for proving it."

Casting Shrink: The casting supplier is responsible for determining shrinkage during the investing, casting and finishing process and providing the shrinkage value to the pattern supplier.

Post-Processing Dimensional Changes: The party responsible for post-processing of the cast part is responsible for providing finished surface dimensional change values to the casting supplier and the pattern supplier. The casting supplier is typically responsible for hot isostatic pressing and heat treating and these shrinkage values can be added into the casting shrink values to provide a single shrinkage value for the heat treated casting relative to the pattern size.

PATTERN CHARACTERISTICS

The primary influence of pattern dimensions on the final casting dimensions has been described in Definitions and Responsibility for Achieving Tolerances. Different pattern types possess dimensional characteristics that strongly influence the final dimensions and dimensional variation of the finished castings. In addition, systematic improvements can be made to finished casting dimensions and dimensional variation by refining the pattern size for a subsequent cycle of casting after measuring finished castings from a previous cycle. Multiple development cycles consisting of pattern fabrication, casting, casting measurement and pattern adjustment can substantially reduce finished casting variation from basic dimensions.

Rapid Prototype patterns: Large feature tolerances are moderate due to the lack of volumetric shrinkage compared to wax and plastic injected patterns. Small feature tolerances may be large due to inaccuracies inherent in certain additive fabrication processes and surface finish which may be rougher than wax or plastic injected patterns.

Wax injected patterns: Large feature tolerances may be high due to volumetric shrinkage. Small feature tolerances may be high due to fill issues and shrinkage.

Plastic injected patterns: Large feature tolerances may be high due to volumetric shrinkage. Plastic patterns provide the best (lowest) small feature tolerances compared to rapid prototype and wax injected patterns.

Low melting point metal parts may be fabricated by machining, die casting or silicon mold casting and the tolerances are established by the production process employed. Machined or die cast low melting point metal parts are typically used when transitioning from a non-ferrous alloy part to a cast part with improved mechanical or corrosion resistant properties.

Machined plastic patterns are an excellent alternative to rapid prototype patterns for easy to machine designs and low volume applications. Surface finish and dimensional accuracy have a strong impact on machined pattern cost and schedule.

Fabricated patterns may be assembled from rapid prototypes, wax or plastic injected parts and machined plastic parts to create complex assemblies where the final assembly may be difficult or cost prohibitive to fabricate as a single piece.

TYPES OF TOLERANCE SYSTEMS

Three types of tolerance systems are used for castings:

Casting Tolerance Systems: The tolerance systems set forth in ISO 8062:2007, ISO 8062:1994, SFSA 2003 and ICI 1997 are specifically intended as general tolerances for investment castings. These systems include linear, angular and geometrical tolerances and may also include machining allowances, process capability recommendations and general tolerance guidelines for different types of casting.

Fit Tolerance Systems: The tolerance systems set forth in ISO 286-2 Limit deviations for holes and shafts and ANSI B4.1-1967 are specifically intended for fits between two or more parts that must assemble or function together. These systems include tolerances for internal dimensions (holes) and external dimensions (shafts) that will result in locational fits, running and sliding fits and force fits.

General Tolerance Systems: Standards ISO 286-2 Standard Tolerances and ISO 2768-1 provide tolerance systems independent of fit requirements and may provide recommendations for tolerances based on processing method.

TOLERANCE CHARACTERISTICS

Tolerances for the referenced standards are summarized in Tables 1 (mm) and 2 (inches) and Charts 1 (mm) and 2 (inches). The tolerance groups set forth in the various standards have certain characteristics which can be important when selecting a standard for use, including:

ISO 8062:2007, ISO 8062:1994 and SFSA 2003: These tolerance systems are representative of current investment casting processes using conventional pattern fabrication techniques. There are sixteen tolerance grades ranging from 25 ± 0.11 mm to 25 ± 12 mm and the tolerances increase approximately 100% between 0 and 250mm: DCTG-4 10 ±0.26 mm to 250 ± 0.50mm. These standards offer a wide selection of grades however the tolerance range is small compared to all other standards and selecting a class with tight tolerances for the small feature basic dimensions may result in excessively tight tolerances for larger features.

ICI 1999: The ICI tolerance system provides a single set of tolerances with a 4x tolerance range between 0 and 250mm: 25± 0.25mm to 250 ± 0.94 mm. The ICI 1999 tolerances are very similar to ISO 286-2 Class JS-15.

ISO 286-2 Standard Tolerances, IT class: This system provides twenty tolerance grades with a 5x range of tolerances: IT14 3 ± 0.25 mm to 250 ± 1.15 mm. The number of grade choices and wide tolerance range provides options for balancing cast part accuracy and cost.

ISO 286-2 External Dimensions, JS class: This system is similar to the ISO 286-2 Standard Tolerances with two important exceptions, (1) the tolerance range varies, with the tighter JS-13 system having a tolerance range of 3.6x between 3 and 250 mm and the loose JS-15 system having a tolerance range of 4.6, and (2) this system provides relationships to a structured system of shaft and hole tolerance zones that can be used to specify tolerances for features with specific form, fit or function requirements.

ANSI B4.1: This system is similar to the ISO 286-2 Standard Tolerance, IT class system.

ISO 2768-1: This system provides four tolerance grades and the tolerance range varies from 4x for class f between 3 and 250 mm to 6x for class c. The basic dimension ranges are large compared to all the other standards described in this paper; eight ranges 0 to 4000 mm versus sixteen ranges 0 to 400 mm for ISO 8062 and SFSA 2003.

TOLERANCE RECOMMENDATIONS

As described in Responsibility for Achieving Tolerances, the pattern used in the lost-wax investment casting process is the primary determinant of the dimensions of the finished casting and the variation in feature dimensions. The method of pattern fabrication, quality of the pattern injection tooling and the quality of the pattern influence the pattern nominal feature dimensions and the variation in feature dimensions based on:

- Accuracy of the pattern fabrication process or the wax or plastic injection tooling fabrication process.
- Variation in surface finish due to rapid prototype stepping or injection tool finish.
- Variation in pattern thickness due to material flow during injection, pattern sink during cooling or material removal during pattern cleaning.

Recommendations for finished casting general tolerance selection based on typical pattern fabrication methods:

Rapid Prototype Patterns, fine resolution x:y:z

- ISO 8062:2007, ISO 8062:1994 and SFSA 2003 DCTG-6 or CT6
- ICI 1997
- ISO 286-2 IT14 (preferred)
- ISO 286-2 JS-15
- ANSI B4.1 Grade 13
- ISO 2768-1 c

Wax Injected Patterns, machined finish tooling

- ISO 8062:2007, ISO 8062:1994 and SFSA 2003 DCTG-5 or CT5
- ISO 286-2 IT13 (preferred)
- ISO 286-2 JS-14
- ANSI B4.1 Grade 12
- ISO 2768-1 m

Plastic Injected Patterns, EDM finish tooling

- ISO 8062:2007, ISO 8062:1994 and SFSA 2003 DCTG-4 or CT4
- ISO 286-2 IT11 (preferred)
- ISO 286-2 JS-13
- ANSI B4.1 Grade 11
- ISO 2768-1 f

The ISO 286-2 IT classes provide the best balance of tight tolerances for small features and large tolerances for larger features and are shown as preferred. ISO 8062:2007, ISO 8062:1994 or SFSA 2003 are recommended if tighter tolerances are desired for larger features.

Tolerances tighter than the recommendations provided above can be obtained after performing development cycles described in Pattern Characteristics.

SOLID MODEL TOLERANCES

Casting suppliers typically use a 3D solid model for pattern fabrication. General tolerances may be specified with the 3D solid model or general and specific tolerances can be provided on 2D drawings.

Tolerances embedded in a 3D solid model file as parametric dimensions, text callouts or notes must be brought to the attention of the casting supplier to ensure any solid model translation preserves and displays the tolerance information.

If 3D solid models and 2D drawings are supplied by the designer to the casting supplier, the solid model dimensions following translation will determine the pattern and finished casting size. Dimensions on 2D drawings derived from 3D solid models that are manually overridden will not be reflected in patterns or finished castings fabricated using the 3D solid model.

REJECTION OF CASTINGS

Unless otherwise required by contract, finished castings exceeding general tolerances should not be automatically rejected. General tolerances are established as a convenience for the designer and the casting supplier and castings should only be rejected if the feature dimensions not meeting the general tolerances impair the form, fit or function of the casting.

REFERENCES

ASTM A957/A957-06, Standard Specification for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use, ASTM International, West Conshohocken, PA
ANSI/ASME B4.1-1967 (R1999) Preferred Limits and Fits for Cylindrical Parts.

Basic tolerances and tolerance fields, extract from ISO 286-2, www.bossard.com, 2006.

Dr. Paul Jacobs and Tom Mueller, A Comparison of Quickcast and Thermojet Patterns for Investment Casting, Proceedings of the 53rd Annual Technical Conference and Expo, Investment Casting Institute, Dearborn, MI, 2005

H.T. Bidwell, Investment Casting Handbook, Investment Casting Institute, Dallas, TX, 1997. Used with permission of the Investment Casting Institute.

ISO 2768-1:1989(E) General Tolerances- Part 1: Tolerances for linear and angular dimensions without individual tolerance indications.*

ISO 286-2:1988 ISO system of limits and fits - Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 8062:1994 Castings -- System of dimensional tolerances and machining allowances.*
ISO 8062-3:2007 Geometrical product specifications (GPS)- Dimensional and geometrical tolerances for moulded parts- Part 3: General dimensional and geometrical and machining allowances for castings.**

Karthik, Chung, Ramani and Tomovic, Methodology for Metalcasting Process Selection,

Orberg, Jones, Horton and Ryffell, Machinery's Handbook, Twenty-Seventh Edition, Industrial Press, NY, NY, 2004

Standard ISO 2768-1, www.ams-prototipi.it, 2006.

Steel Castings Handbook, Supplement 3, 2003 Dimensional Capabilities of Steel Castings, Steel Founders' Society of America, www.sfsa.org, 2007. Used with permission of the Steel Founders' Society of America.

Terry Wohlers, Wohlers Report 2004, Rapid Prototyping, Tooling and Manufacturing State of the Industry, Annual Worldwide Progress Report, Wohlers Associates, Ft. Collins, CO, 2004

Tolerances and Fits, www.mitcalc.com, 2006.

* The ISO specifications indicated in this paper are used with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization (ISO). Copies of ISO standards can be purchased from ANSI at http://webstore.ansi.org/, info@ansi.org; 212.642.4980.

ABOUT THE AUTHOR A graduate of the University of California at Berkeley College of Engineering with BS degrees in Mechanical Engineering and Nuclear Engineering, KA Silva brings experience at two startups and twenty years experience at GE's Research and Development Center and Energy Systems businesses to RapidProtoCasting.

ABOUT RAPIDPROTOCASTING RapidProtoCasting provides quick delivery of precision castings in high-strength aerospace and medical alloys. RapidProtoCasting's process delivers finished castings in as little as next day from patterns and four days from solid model with tolerances to ± 0.001" (0,03 mm), thin walls to 0.012" (0,3 mm), surface finishes to Ra63 (0.8a) and 98% yield in copper, stainless steel, nickel, cobalt-chrome and titanium alloys.

Basic Dimension, mm		ISO 8062:2007, ISO 8062:1994 and SFSA 2003, mm							ICI mm*	ISO 286-2 Standard Tolerance, mm				ISO 286-2 External Dimension Tolerances, mm			ANSI B4.1-1967 (R1999) Standard Tolerances, mm*						ISO 2768-1, mm		
Over	Up to and including	DCTG-1 CT-1	DCTG-2 CT-2	DCTG-3 CT-3	DCTG-4 CT-4	DCTG-5 CT-5	DCTG-6 CT6	DCTG-7 CT7		IT11	IT12	IT13	IT14	JS-13	JS-14	JS-15	Gr.8	Gr.9	Gr.10	Gr.11	Gr.12	Gr.13	f	m	c
0	0.5	0.045	0.065	0.09	0.13	0.18	0.26	0.37	0.25	0.06	0.1	0.1	0.25	0.1	0.125	0.2	0.015	0.025	0.040	0.065	0.100	0.15			
0.5	3																						0.05	0.1	0.2
3	6									0.075	0.12	0.18	0.3	0.1	0.15	0.24	0.020	0.030	0.045	0.075	0.125	0.18	0.05	0.1	0.3
6	10									0.09	0.15	0.22	0.36	0.11	0.18	0.29	0.025	0.035	0.055	0.09	0.15	0.23	0.1	0.2	0.5
10	16	0.05	0.07	0.1	0.14	0.19	0.27	0.39		0.11	0.18	0.27	0.43	0.135	0.215	0.35	0.03	0.04	0.07	0.10	0.18	0.26			
16	18	0.055	0.075	0.11	0.15	0.21	0.29	0.41																	
18	25									0.13	0.21	0.33	0.52	0.165	0.26	0.37	0.03	0.05	0.09	0.13	0.21	0.31			
25	30	0.06	0.085	0.12	0.16	0.23	0.32	0.45	0.33																
30	40									0.16	0.25	0.39	0.62	0.195	0.31	0.5	0.04	0.07	0.10	0.15	0.26	0.41	0.15	0.3	0.8
40	50	0.065	0.09	0.13	0.18	0.25	0.35	0.5																	
50	63								0.41	0.19	0.3	0.46	0.74	0.23	0.37	0.6	0.05	0.08	0.12	0.18	0.31	0.46			
63	80	0.07	0.1	0.14	0.2	0.28	0.39	0.55																	
80	100								0.48	0.22	0.35	0.54	0.87	0.27	0.435	0.7	0.06	0.09	0.13	0.23	0.36	0.56			
100	120	0.075	0.11	0.15	0.22	0.31	0.44	0.6	0.56																
120	160								0.64	0.25	0.4	0.63	1	0.315	0.5	0.8	0.07	0.10	0.15	0.26	0.41	0.64	0.2	0.5	1.2
160	180		0.12	0.17	0.25	0.35	0.5	0.7	0.79																
180	250								0.94	0.29	0.46	0.72	1.15	0.36	0.575	0.925	0.07	0.12	0.18	0.31	0.46	0.71			

* converted from inches at 25.4mm/inch

TABLE 1: Comparison of General Tolerance Systems, mm

Basic Dimension, inch		ISO 8062-1994 and SFSA 2003, inch*							ICI, inch	ISO 286-2 Standard Tolerance, inch*				ISO 286-2 External Dimension Tolerances, inch*			ANSI B4.1-1967 (R1999) Standard Tolerances, inch						ISO 2768-1, inch*		
	Up to and including	DCTG-1 CT-1	DCTG-2 CT-2	DCTG-3 CT-3	DCTG-4 CT-4	DCTG-5 CT-5	DCTG-6 CT6	DCTG-7 CT7		IT11	IT12	IT13	IT14	JS-13	JS-14	JS-15	Gr.8	Gr.9	Gr.10	Gr.11	Gr.12	Gr.13	f	m	c
0.00	0.02	0.002	0.003	0.004	0.005	0.007	0.01	0.015	0.010	0.002	0.004	0.004	0.01	0.004	0.005	0.008	0.0006	0.0010	0.0016	0.0025	0.0040	0.0060			
0.02	0.12																						0.002	0.004	0.008
0.12	0.24									0.003	0.005	0.007	0.012	0.004	0.006	0.009	0.0007	0.0012	0.0018	0.0030	0.0050	0.0070	0.002	0.004	0.012
0.24	0.40									0.004	0.006	0.009	0.014	0.004	0.007	0.011	0.0009	0.0014	0.0022	0.0035	0.0060	0.0090	0.004	0.008	0.02
0.40	0.63	0.002	0.003	0.004	0.006	0.007	0.011	0.015		0.004	0.007	0.011	0.017	0.005	0.008	0.014	0.0010	0.0016	0.0028	0.0040	0.0070	0.0100			
0.63	0.71	0.002	0.003	0.004	0.006	0.008	0.011	0.016																	
0.71	1.00									0.005	0.008	0.013	0.02	0.006	0.01	0.015	0.0012	0.0020	0.0035	0.0050	0.0080	0.0120			
1.00	1.19	0.002	0.003	0.005	0.006	0.009	0.013	0.018	0.013																
1.19	1.60									0.006	0.01	0.015	0.024	0.008	0.012	0.02	0.0016	0.0023	0.0040	0.0060	0.0100	0.0160	0.006	0.012	0.031
1.60	1.97	0.003	0.004	0.005	0.007	0.01	0.014	0.02																	
1.97	2.50								0.016	0.007	0.012	0.018	0.029	0.009	0.015	0.024	0.0018	0.0030	0.0045	0.0070	0.0120	0.0180			
2.50	3.15	0.003	0.004	0.006	0.008	0.011	0.015	0.022																	
3.15	4.00								0.019	0.009	0.014	0.021	0.034	0.011	0.017	0.028	0.0022	0.0035	0.0050	0.0090	0.0140	0.0220			
4.00	4.73	0.003	0.004	0.006	0.009	0.012	0.017	0.024	0.022																
4.73	6.30								0.025	0.01	0.016	0.025	0.039	0.012	0.02	0.031	0.0025	0.0040	0.0060	0.0100	0.0160	0.0250	0.008	0.02	0.047
6.30	7.09		0.005	0.007	0.01	0.014	0.02	0.028	0.037																
7.09	9.85								0.037	0.011	0.018	0.028	0.045	0.014	0.023	0.036	0.0028	0.0045	0.0070	0.0120	0.0180	0.0280			

* converted from mm at 25.4mm/inch

TABLE 2: Comparison of General Tolerance Systems, inch

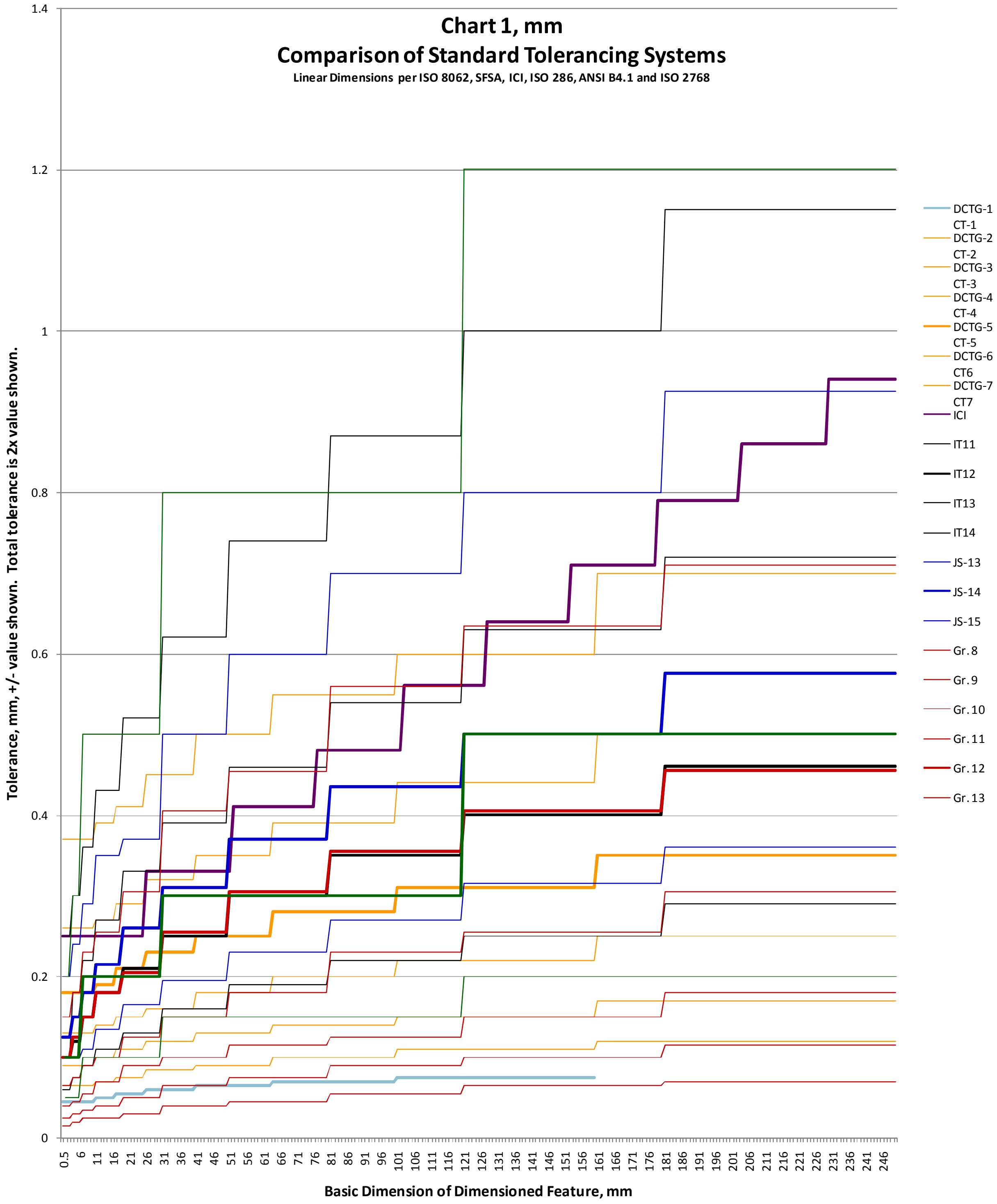
Chart 1, mm
Comparison of Standard Tolerancing Systems
Linear Dimensions per ISO 8062, SFSA, ICI, ISO 286, ANSI B4.1 and ISO 2768
Tolerance, mm, +/- value shown. Total tolerance is 2x value shown.
Basic Dimension of Dimensioned Feature, mm
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
141
146
151
156
161
166
171
176
181
186
191
196
201
206
211
216
221
226
231
236
241
246
DCTG-1 CT-1
DCTG-2 CT-2
DCTG-3 CT-3
DCTG-4 CT-4
DCTG-5 CT-5
DCTG-6 CT6
DCTG-7 CT7
ICI
IT11
IT12
IT13
IT14
JS-13
JS-14
JS-15
Gr. 8
Gr. 9
Gr. 10
Gr. 11
Gr. 12
Gr. 13

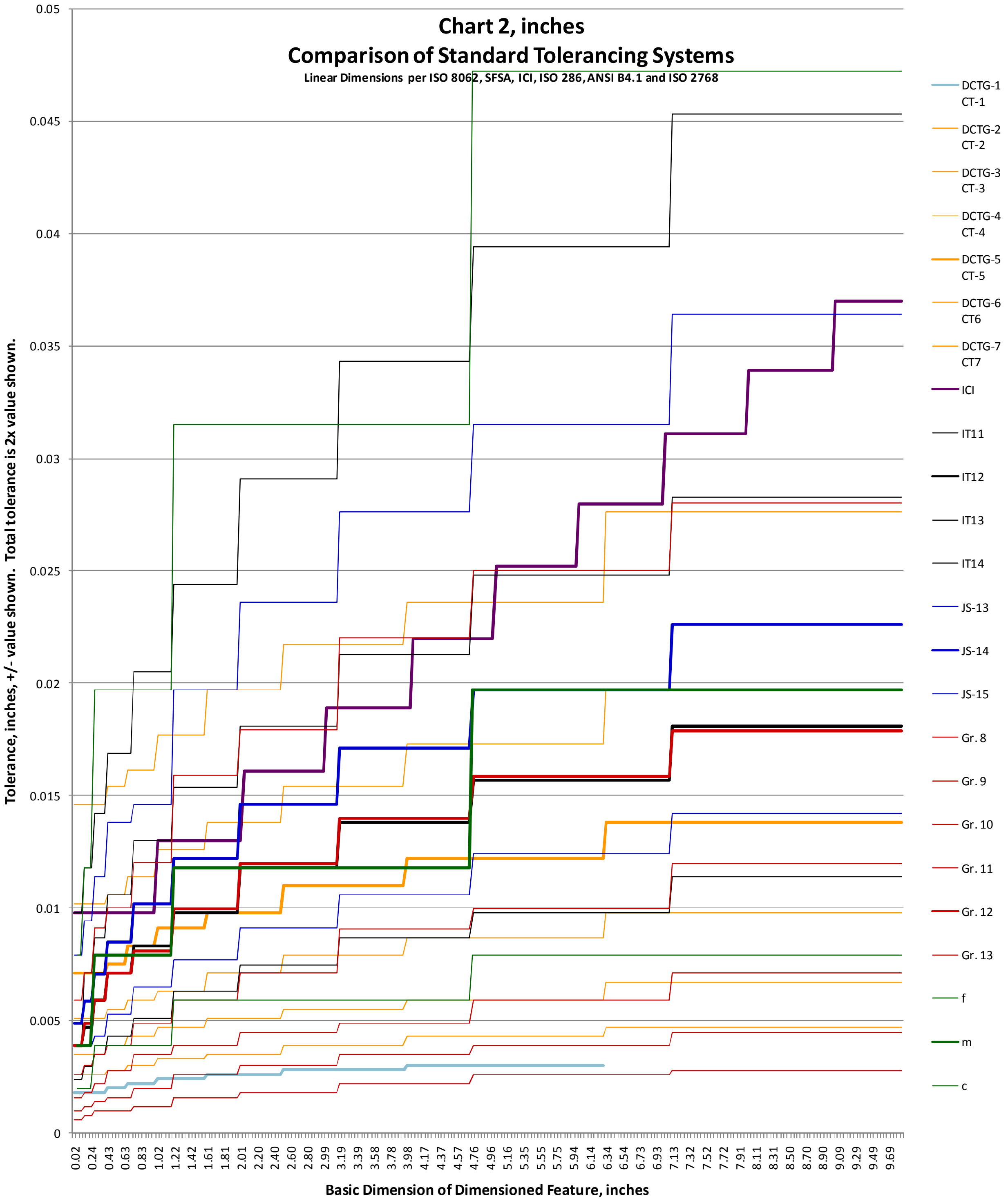
Chart 2, inches
Comparison of Standard Tolerancing Systems
Linear Dimensions per ISO 8062, SFSA, ICI, ISO 286, ANSI B4.1 and ISO 2768
Tolerance, inches, +/- value shown. Total tolerance is 2x value shown.
Basic Dimension of Dimensioned Feature, inches
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
DCTG-1 CT-1
DCTG-2 CT-2
DCTG-3 CT-3
DCTG-4 CT-4
DCTG-5 CT-5
DCTG-6 CT6
DCTG-7 CT7
ICI
IT11
IT12
IT13
IT14
JS-13
JS-14
JS-15
Gr. 8
Gr. 9
Gr. 10
Gr. 11
Gr. 12
Gr. 13
f
m
c