MILITARY STANDARD

CASTINGS, INVESTMENT, TOLERANCES FOR

NO DELIVERABLE DATA DOCUMENT

AREA MECA

DEPARTMENT OF DEFENSE
Washington, DC 20301

CASTINGS, INVESTMENT, TOLERANCES FOR
MIL-STD-1897(AT)

1. This Military standard is approved for use by US Army Tank-Automotive Command, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Tank-Automotive Command, ATTN: DRSTA-GSS, Warren, MI 48090, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

This Military standard establishes the general as-cast tolerances for investment castings. Variations from tolerance bands shown can be controlled by the casting source.

CONTENTS

CONTENTS

TABLES

CONTENTS

CONTENTS

1. SCOPE

1.1 Purpose. The purpose of this standard is to provide design engineers with the tolerance capabilities of investment casting sources.

1.2 Scope. This standard covers general tolerances applicable to ferrous and nonferrous as-cast investment castings.

2. REFERENCED DOCUMENTS

2.1 Non-Government publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

ACOUSTICAL SOCIETY OF AMERICA (ASA)

B46.1	- Surface Texture Surface Roughness, Waviness and Lay.

(Copies of the above publication may be obtained from the Acoustical Society of America, 335 East 45th Street, New York, New York 10017.)

AMERICAN SOCIETY FOR METALS (ASM)

CASTING DESIGN HANDBOOK, 1962 EDITION

(Copies of the above publications may be obtained from the American Society for Metals, Metals Park, Ohio 44073.)

INVESTMENT CASTING INSTITUTE

INVESTMENT CASTING HANDBOOK

(Copies of the above publication may be obtained from the Investment Casting Institute, 8521 Clover Meadow Drive, Dallas, Texas 75243.

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. (SAE)

AMS 4640	- Aluminum Bronze.
SAE J448a	- Surface Texture.
SAE J449	- Surface Texture Control.

(Information as to the availability of the above standards may be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. DEFINITIONS

3.1 Definitions. Definitions relating to investment castings not shown here may be found in the reference documents.

3.1.1 Investment casting. Investment casting involves pouring metal into a mold produced by surrounding (investing) an expendable pattern with a refractory slurry that sets at room temperature. After this, the wax, plastic, or frozen mercury pattern is removed through the use of heat. This procedure is also known as precision casting or the lost wax process.

3.1.2 Gate (ingate). The portion of the runner in a mold through which molten metal enters the mold cavity. Sometimes the generic term is applied to the entire network of connecting channels which conduct metal into the mold cavity.

3.1.3 Draft. (1) The angle or taper on the surface of a die or the parts made with it which facilitates removal of the work. (2) Taper put on the surface of a pattern so that it can be successfully withdrawn from the mold.

3.1.4 Riser. A reservoir of molten metal connected to the casting to provide additional metal to the casting, required as a result of shrinkage before and during solidification.

3.1.5 Runner. (1) A channel through which molten metal flows from one receptacle to another. (2) The portion of the gate assembly that connects the downgate, sprue or riser with the casting. (3) Parts of patterns and finished castings corresponding to the described portion of the gate assembly.

3.1.6 Sprue (downsprue, downgate). (1) The channel that connects the pouring basin with the runner. (2) Sometimes used to mean all gates, risers, runners, and similar scrap.

3.1.7 Parting line. A plane on a pattern or a line on a casting corresponding to the separation between the two portions of a mold.

3.1.8 Pouring basin. A basin on top of a mold to receive the molten metal before it enters the sprue or downgate.

3.1.9 Runner box. A distribution box that divides the molten metal into several streams before it enters the mold cavity.

3.1.10 Investment compound. A mixture of a graded refractory filler, a binder and a liquid vehicle used to make molds for investment casting.

4. GENERAL REQUIREMENTS

4.1 Casting design.

4.1.1 Requirements.

a. Parts shall be designed so that parting lines, gates, and draft allowances do not interfere with any close tolerances that may be required for the use of the part.
b. Only essential casting tolerances shall be shown on the engineering drawing and they shall take precedence over tho referred to in this standard.

5. DETAIL REQUIREMENTS

5.1 Dimensional variations and tolerances. Unless otherwise specified, all dimensions and tolerances are in inches.

5.1.1 Variables affecting as-cast dimensional tolerances.

a. Contraction of the wax, plastic, or frozen mercury pattern material within the pattern mold cavity after injection.
b. Variation in the temperature and resulting expansion during heating of the investment mold just before the casting is poured.
c. Expansion and contraction of the ceramic mold as the hot metal is poured and begins to solidify.
d. Contraction of the cooling metal in the mold.

5.1.2 Tolerances. Tolerances outlined in this standard are general for the investment casting industry. Some foundries, depending upon their practice, may be able to incorporate more restrictive tolerancing and as a result their unit cost would reflect this improvement.

5.1.2.1 Gates and risers.

a. Surfaces that require machining:

1. Flat or round surfaces, maximum protrusion 0.000 to 0.010 inch above adjacent surfaces in the same plane.
2. Irregular surfaces, maximum protrusion 0.000 to 0.030 inch above adjacent surfaces.
3. Intersection of planes, 0.25 inch fillet radius, maximum.

b. Unmachined surfaces. Maximum protrusion of 0.000 to 0.005 inch above surfaces in the same plane but not to exceed the drawing tolerance envelope.

5.1.2.2 Dimensional.

a. For all investment cast blades and vanes use table I.

TABLE I. Dimensional tolerances for investment cast blades and vanes.

Dimension	Tolerance
up to 0.999	± 0.005
1.000 to 1.999	± 0.010
2.000 to 3.999	± 0.015
4.000 to 5.999	± 0.020
6.000 to 11.999	± 0.030
12.000 and over	± 0.045

b. For all investment castings other than blades and vanes use Table II.

TABLE II. Dimensional tolerances for general category investment castings.

Dimension	Tolerance
up to 1.999	± 0.010
2.000 to 3.999	± 0.015
4.000 to 5.999	± 0.020
6.000 to 11.999	± 0.030
12.000 and over	± 0.045

5.1.2.3 Flatness (bow or dish). These tolerances apply regardless of feature size providing the form tolerance zone falls entirely within the tolerance zone for size. Each configuration must be evaluated in relation to alloy, total surface area, and volume of casting (see table III).

TABLE III. Flatness tolerances (bow or dish - plate) for investment castings.

Length	Tolerance
up to 0.999	± 0.005
1.000 to 1.999	± 0.008
2.000 to 3.999	± 0.012
4.000 to 6.000	± 0.015
6.001 and over	± 0.020

5.1.2.4 Shafts (solid).

5.1.2.4.1 Straightness. Straightness is the deviation of the cast axis from the true axis. The tolerances shown as table IV apply regardless of feature size.

TABLE IV. Straightness tolerances for investment castings.

Length	Tolerance
up to 1.999	± 0.010
2.000 to 5.999	± 0.020
6.000 and over	± 0.030

5.1.2.4.2 Roundness.

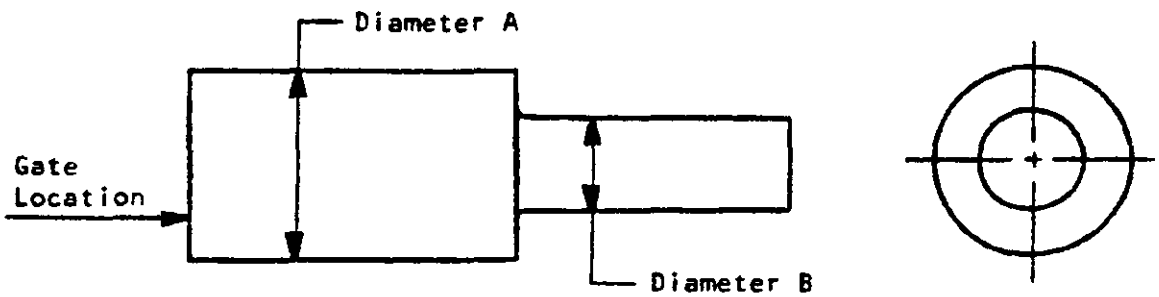
TABLE V. Out-of-roundness tolerances for solid shaft investment castings.

Diameter	TIR 1/
0.500	0.005
1.000	0.010
1.500	0.012
2.000	0.015

1/ Represents total indicator reading (TIR) and does not carry a plus (+) or minus (-) tolerance.

5.1.2.4.3 Concentricity. Limit is in relationship of diameters A and B. Gate location is a vital factor in maintaining concentricity (see table VI).

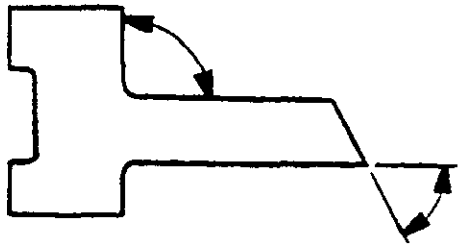
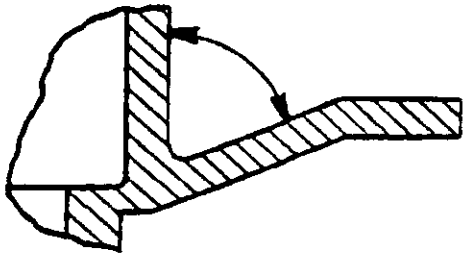
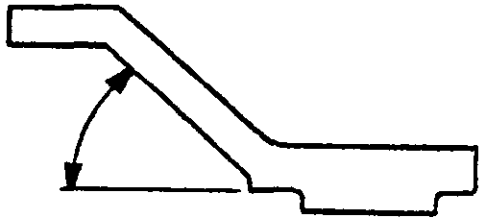
TABLE VI. Concentricity tolerances for solid shaft investment castings.



Diameter A	Diameter B	TIR
0.500	0.250	0.005
1.000	0.500	0.008
2.000	1.000	0.012
2.500	1.250	0.015

5.1.2.5 Angles. Tolerances for angles, as-cast, depend upon the location of angles in the casting. The tolerance may range from ± 1/2 degree (°) for angles in well supported positions to ± 2° where inherent distortion could be expected (see table VII).

TABLE VII. Tolerances for angular surfaces of as-cast investment castings.

Angular surface	Tolerance
	± 1/2°
	± 1 1/2°
	± 2°

5.1.2.6 Squareness (angular part). Control of tolerance on flat, angular-type parts is difficult. Redesigning incorporating brace reinforcements or straightening, if feasible and permitted, are alternative solutions. The amount of straightening shall be a function of section thickness, variation, and support ribs. Where straightening is feasible and permitted, a tolerance of ± 1/2° shall be maintained.

5.1.2.7 Surface texture (finish). The height of roughness shall be expressed in microinches Arithmetic Average (μin. AA) as defined in SAE J448a, section 4.1. This value shall be used to describe surface texture of as-cast investment castings after cleaning in accordance with the engineering requirement, i.e., sand blast, and shall be in accordance with values specified in table VIII.

TABLE VIII. Surface texture for as-cast and sand blasted investment castings. 1/

Material/product	Roughness (µin. AA)	Material/product	Roughness (µin. AA)
Airfoil contours	63	Cobalt-chromium alloy	100
Aluminum alloy	100	Magnesium alloy	100
Aluminum bronze 2/	100	Nickel base superalloy	125
Beryllium copper	100	Stainless, 300 series	125
Carbon steel	125	Stainless, 400 series	125

1/ Method of measuring and controlling surface texture shall be in accordance with SAE J448 and SAE J449 respectively, or ASA B46.1.
2/ AMS 4640

5.1.2.8 Draft. Draft is normally not specified except in special applications on deep perpendicular draws or in long untapered cored holes. The amount of draft required will depend upon the pattern material used, length (depth of draw), and wall thickness. The need for draft shall be resolved between the casting source and engineering design. When required, draft shall be specified in degrees or in taper per inch. A taper of 1° is considered acceptable in most instances (see figure 1).

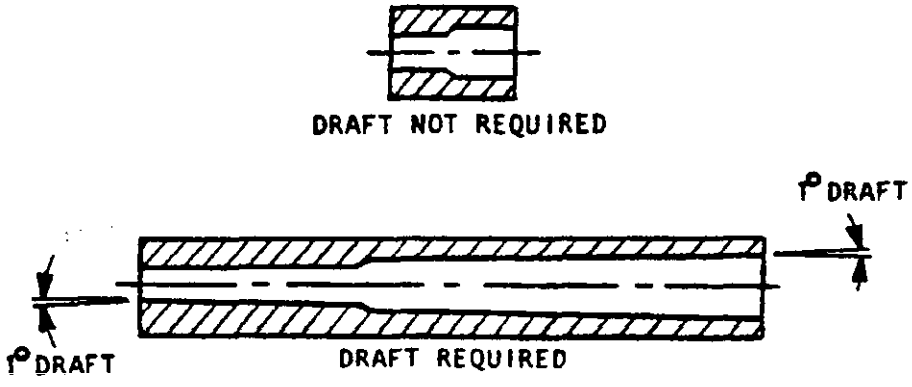
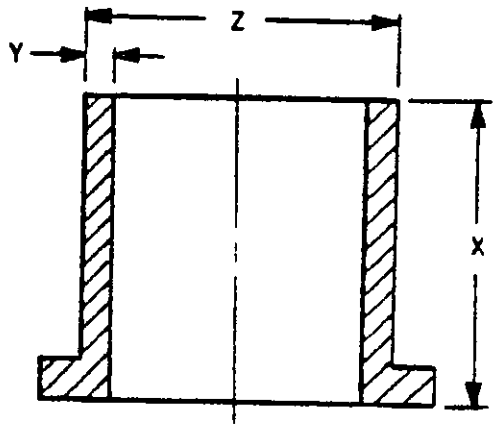


FIGURE 1. Examples of draft applications.

5.1.2.9 Wall thickness. Designing for minimum wall thickness depends upon:

a. Fluidity of the alloy and its ability to flow in the mold, i.e. function of metal and mold temperature.
b. Solidification range of the alloy in relation to proper feeding of the section.
c. Surface area or exposed metal and feeding distance.

TABLE IX. Minimum wall thickness in relation to cored cavity for investment castings.



X	Z	Y - minimum
0.250	0.125	0.030
0.500	0.250	0.040
0.750	0.375	0.050
1.000	0.500	0.060
1.250	0.750	0.060
1.500	1.000	0.060
2.000	1.500	0.060
2.500	1.750	0.060

5.1.2.10 Radii and fillets. Sound casting design necessitates incorporating proper tolerancing of radii and fillets to minimize stress concentrations, tooling costs (internal coring), turbulence and wear, etc. Suggested minimum tolerance on all radii is ± 1/64 inch. Where smaller tolerances are absolutely necessary, see table X.

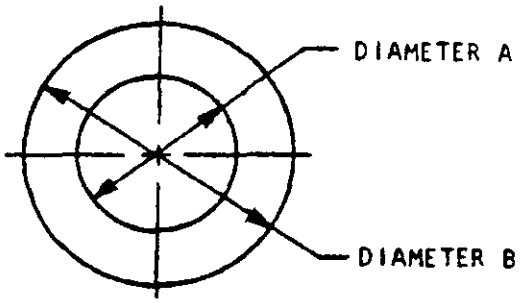
TABLE X. Radii and fillet tolerances for investment castings.

Radii	Minimum tolerance for fillet and external radii
0.031	± 0.004
0.062	± 0.004
0.125	± 0.004
0.250	± 0.004
0.500	± 0.005
1.000	± 0.005
over 1.000	± 0.005 inch/inch

5.1.2.11 Holes (cast or cored).

5.1.2.11.1 Concentricity. Limit in the relation of one diameter to another (see table XI).

TABLE XI. Concentricity tolerances for investment castings with holes.



Diameter A	Diameter B	TIR
0.250	0.750	0.005
0.500	1.000	0.005
0.750	1.500	0.010
1.000	2.000	0.010

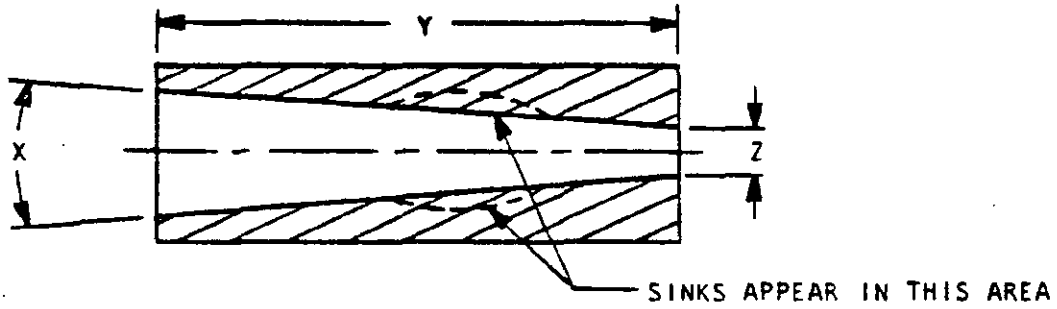
5.1.2.11.2 Roundness. Holes, depending upon casting stresses, may be cast "egg-shaped" as indicated in table XII.

TABLE XII. Out-of-roundness tolerances for investment castings with holes.

Diameter	TIR
0.500	0.005
1.000	0.010
1.500	0.012
2.000	0.050

5.1.2.11.3 Tapered holes. Castings with tapered holes may, depending upon size, exhibit some shrinkage (sink) (see table XIII).

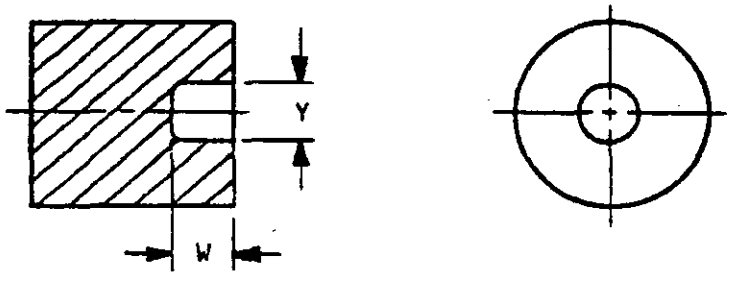
TABLE XIII. Angular tolerances for investment castings with tapered holes.



Z	Y	X	Tolerance for X
0.250	0.500	15°	± 0° 30'
0.500	0.750	30°	± 0° 30'
0.250	0.500	60°	± 0° 30'
0.500	0.750	90°	± 0° 45'
0.750	1.500	120°	± 1°

5.1.2.11.4 Blind holes. Blind holes are recommended for nonferrous alloys only. Blind holes can be cast in ferrous alloys, but no "rule of thumb" applies.

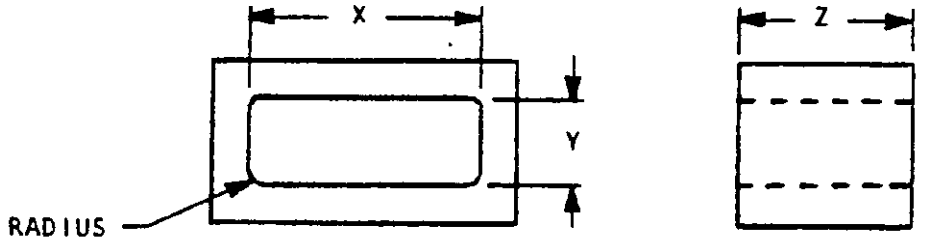
TABLE XIV. Blind hole limits for investment castings.



W - length	Y - minimum diameter	Draft
0.250	0.187	0°
0.500	0.250	0°
0.750	0.500	0°
1.000	0.625	0°
1.250	0.750	0° 15'
1.500	1.000	0° 15'
2.000	1.000	0° 15'
2.500	1.000	0° 15'

5.1.2.11.5 Rectangular holes.

TABLE XV. Tolerances for investment castings with rectangular holes.



Radius	Z	X	Tolerance for X	Y	Tolerance for Y
1/64	0.125	0.250	± 0.004	0.125	± 0.003
1/32	0.250	0.500	± 0.005	0.250	± 0.004
1/16	0.125	0.750	± 0.005	0.500	± 0.005
1/16	0.250	1.000	± 0.005	0.750	± 0.005
1/16	0.500	0.500	± 0.005	0.150	± 0.004
1/16	1.000	0.500	± 0.005	0.250	± 0.004
1/8	2.000	2.500	± 0.015	1.500	± 0.010

5.1.2.11.6 Curved holes. Size of opening and radius of curved passages take a different set of tolerances. Table XVI covers the tolerances for the radius of a curve. See table II for tolerances applicable to openings.

TABLE XVI. Tolerances for investment castings with curved holes.

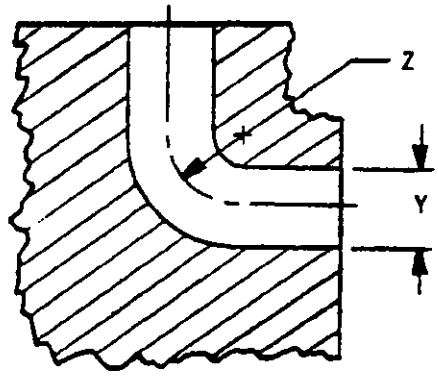
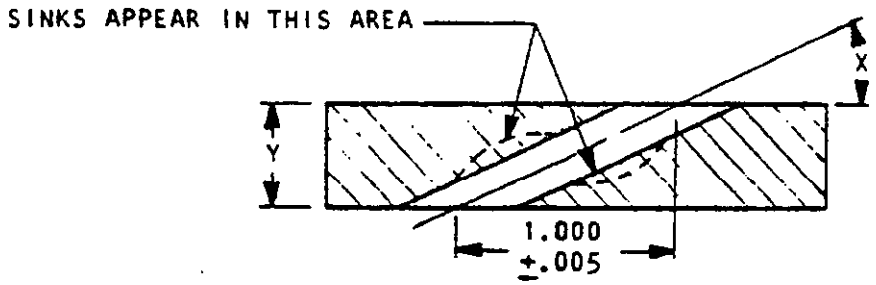


TABLE XVI. Tolerances for investment castings with curved holes - Continued.

Y	Z	Tolerance for Z
0.250	0.500	± 0.005
0.500	0.750	± 0.005
0.750	1.000	± 0.008
1.000	1.500	± 0.010
1.000	2.000	± 0.014
1.000	2.500	± 0.016
1.000	3.000	± 0.018

5.1.2.11.7 Angular cored holes.

TABLE XVII. Tolerances for investment castings with angular holes.



Y	X	Tolerance for X
0.250	15°	± 1°
0.500	30°	± 1°
1.000	45°	± 1°

5.1.2.11.8 Through-hole limits.

TABLE XVIII. Through-hole limits for investment castings.

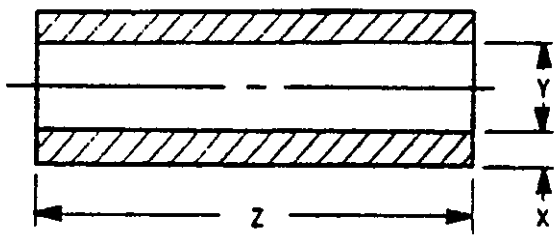
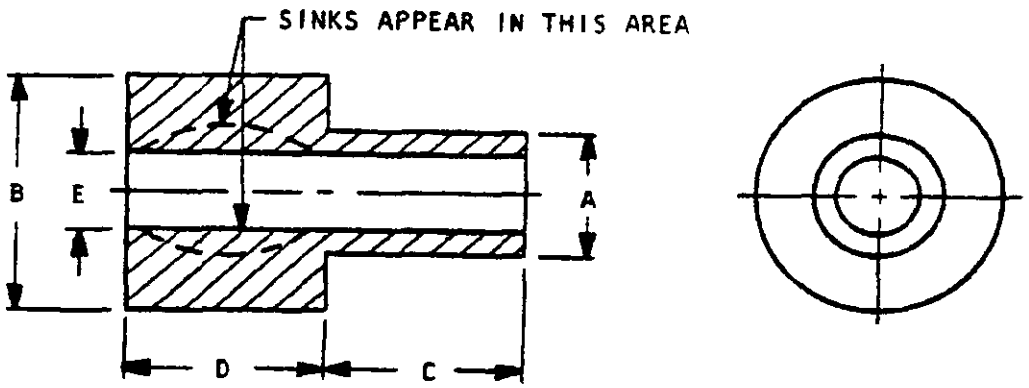


TABLE XVIII. Through-hole limits for investment castings - Continued.

X - minimum wall	Z - length	Y - minimum diameter	Draft
0.030	0.250	0.093	0°
0.040	0.500	0.125	0°
0.050	0.750	0.187	0°
0.060	1.000	0.250	0°
0.060	1.250	0.312	0°
0.060	1.500	0.437	0° 15'
0.060	2.000	0.500	0° 15'
0.060	2.500	0.625	0° 15'

5.1.2.11.9 Uneven wall sections.

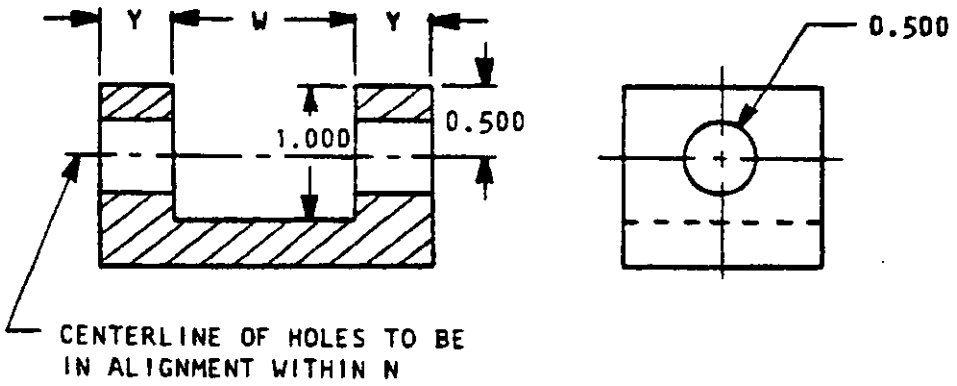
TABLE XIX. Tolerances for investment castings with uneven wall sections.



A	B	C	D	E	Tolerance for E
0.500	1.000	0.250	0.750	0.375	± 0.004
0.750	1.500	0.500	1.000	0.500	± 0.006
1.000	2.000	0.750	1.500	0.750	± 0.008
1.250	2.500	1.000	2.000	1.000	± 0.010

5.1.2.11.10 In-line holes. Centerline of holes shall be held to hole alignment tolerance as specified in table XX.

TABLE XX. Tolerances for investment castings with in-line holes.



W	Z	Y	Hole alignment tolerance
0.250	0.500	0.125	± 0.003
0.375	0.750	0.187	± 0.004
0.500	1.000	0.250	± 0.005
0.750	1.500	0.375	± 0.005
1.000	2.000	0.500	± 0.010
1.250	2.500	0.625	± 0.012
1.500	3.000	0.750	± 0.015

5.1.2.11.11 Finish stock in hole. Finish stock allowance of 0.010 to 0.015 inch per side is required for grinding or reaming a hole, provided that the section around the hole is uniform. For holes over 1 inch in diameter, sufficient stock should be allowed to maintain required tolerance and also guarantee "clean-up". If section around hole is not uniform, more finish stock will be required as heavier section tends to pull hole out of round (see figure 2).

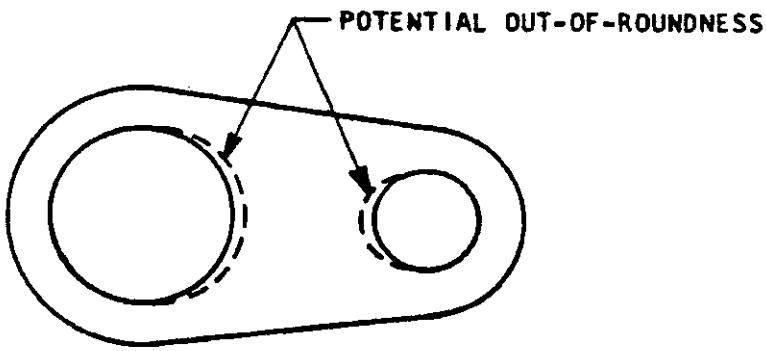
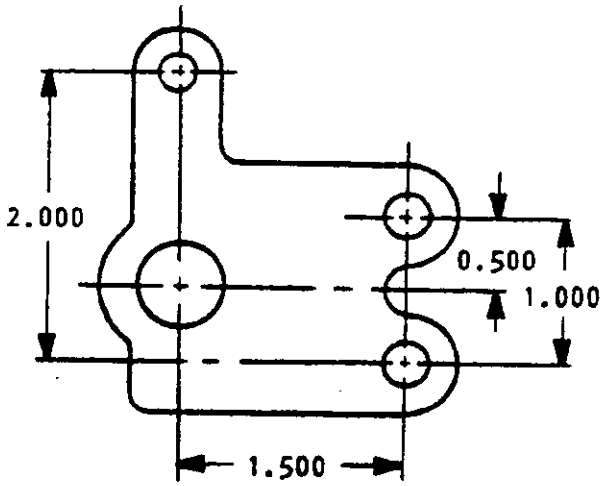


FIGURE 2. Potential out-of-roundness in an irregular mass.

5.1.2.11.12 Hole relationships.

5.1.2.11.12.1 Distance between holes.

TABLE XXI. Tolerances between holes in investment castings.



Distance between holes	Tolerance
0.500	± 0.004
1.000	± 0.005
1.500	± 0.008
2.000	± 0.010

5.1.2.11.12.2 Positioning. Holes (or bosses) shall be located within tolerances of true position on line BC as specified in table XXII.

TABLE XXII. Hole positioning tolerances for investment castings.

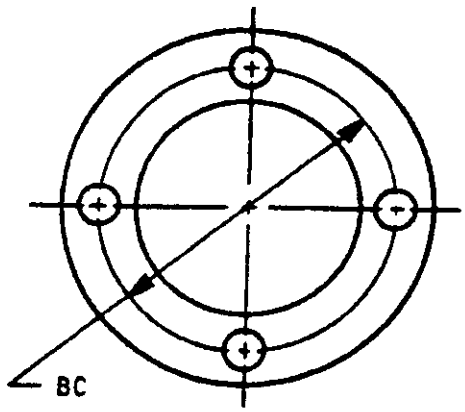
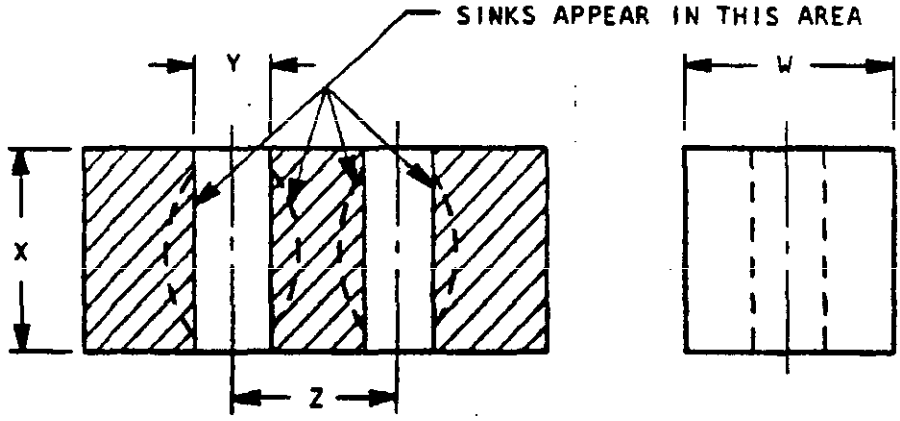


TABLE XXII. Hole positioning tolerances for investment castings - Continued.

BC diameter	Tolerance
0.500	± 0.005
1.000	± 0.005
1.500	± 0.009
2.000	± 0.010
2.500	± 0.015
5.000	± 0.025
8.000	± 0.040
10.000	± 0.050

5.1.2.11.12.3 Parallelism. Centerlines of cored holes shall be held to parallelism tolerances as specified in table XXIII.

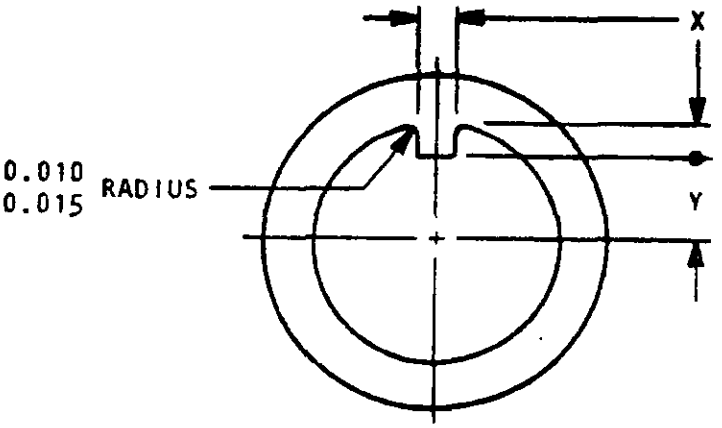
TABLE XXIII. Hole parallelism tolerances for investment castings.



W	X	Y	Z	Parallelism tolerance
0.375	0.250	0.125	0.500	± 0.003
0.500	0.500	0.250	0.750	± 0.005
0.625	0.750	0.375	1.000	± 0.005
0.875	1.000	0.500	1.250	± 0.008
1.000	1.250	0.625	1.500	± 0.008
1.250	1.500	0.750	1.750	± 0.010
1.375	2.000	0.875	2.000	± 0.010
1.500	2.500	1.000	2.250	± 0.015

5.1.2.12 Keyways.

TABLE XXIV. Keyway tolerances for investment castings.



X	Tolerance for X	Y	Tolerance for Y
0.031	± 0.003	0.500	± 0.005
0.046	± 0.003	0.750	± 0.005
0.062	± 0.003	1.000	± 0.005
0.125	± 0.003	1.500	± 0.008
0.250	± 0.003	2.000	± 0.010

5.1.2.13 Keyslots. Recommended for non-ferrous alloys only. A key slot can be cast in ferrous alloys, but no "rule of thumb" applies. When a closer tolerance is required, broaching stock and/or ream stock is allowed or keyslot is omitted entirely.

TABLE XXV. Keyslot tolerances for investment castings.

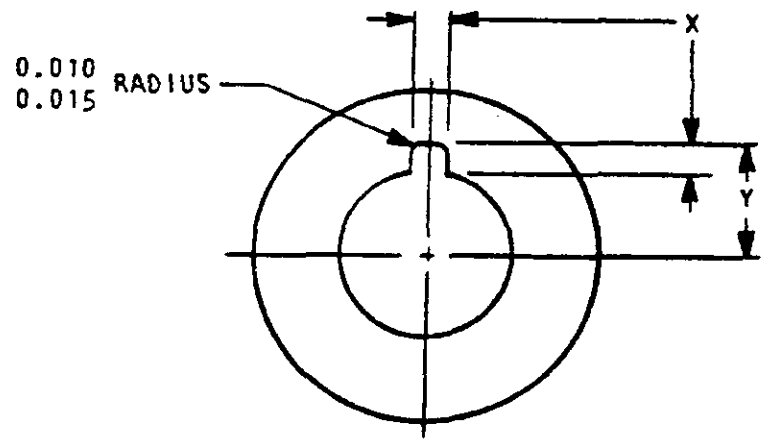


TABLE XXV. Keyslot tolerances for investment castings - Continued.

X	Tolerance for X	Y	Tolerance for Y
0.062	± 0.003	0.500	± 0.005
0.093	± 0.003	0.750	± 0.005
0.125	± 0.003	1.000	± 0.005
0.250	± 0.003	1.500	± 0.008
0.500	± 0.004	2.000	± 0.010

6. NOTES

6.1 Distortion. Problems involving distortion and the closely related casting defect, hot tearing, are conditions that can be eliminated or minimized by proper casting design. Distortion can result from:

a. Differences in solidification times.
b. Restraint imposed by the mold as the casting cools and contracts.
c. Stresses generated during heat treatment.
d. Differences in alloy composition.

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