ASME B5.50-2009

[Revision of ASME B5.50-1994 (R2003)]

7/24 Taper Tool to Spindle Connection for Automatic Tool Change

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME SETTING THE STANDARD

Date of Issuance: December 11, 2009

This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda or written interpretations of the requirements of this Standard issued to this edition.

Periodically, certain actions of the ASME B5 Committee may be published as Cases. Cases are published on the ASME Web site under the Committee Pages at http://cstools.asme.org as they are issued.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

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FOREWORD

The Aerospace Industries Association (AIA) developed, in cooperation with machine tool builders and users, standards of toolholder shanks and retention knobs for machining centers with automatic tool changers. AIA/NAS 970 was first published in 1964. The objective of this standardization effort was to reduce the large number of already existing tool shank configurations and to prevent the creation of new ones. The toolholder shanks made by different machine tool builders varied in the methods and in dimensional details of the gripping by the transfer mechanism and retention in the machine tool spindle. The resulting lack of interchangeability created problems of maintaining large toolholder inventories. The AIA standard covered a series of straight and tapered shank toolholders, but the standard never found wide acceptance; one of the reasons given for this was that standardization attempted too "early in the art" would have stifled innovation and development of better tool shanks for machining centers.

During the intervening years, almost every machine tool builder continued to develop their own, often proprietary and very ingenious, toolholder shank configurations for their machining centers. This resulted in an almost unbearable economic situation, where one user had to maintain no less than 28 noninterchangeable tool shank configurations to operate their machining centers, supplied by the various machine tool builders. These 28 different tool shank configurations should be multiplied by the number of basic sizes to get an understanding of the resulting tool inventory problem.

A major user of machining centers decided to end this situation and developed a tool shank for machining centers. Several major machine tool builders, toolholder manufacturers, and users of machining centers were approached to discuss and confirm the need and practicality of their proposed design, and consider it as a basis for an American National Standard. A technical committee (TC 45) of American National Standards Committee (ANSC) B5, Group C, was delegated to study the proposed tool shank and prepare drafts for an American National Standard.

A standard was developed and published in November of 1978, as ANSI B5.50-1978. The technical committee followed the policy to establish new standards in SI units, and it was hoped that ISO would adopt a common worldwide metric standard.

After a number of meetings and recommendations, the ISO put forward a recommendation that would create more than one standard, which would lead to confusion by the addition of a number of national metric standards.

TC 45 of ANSC B5, Group C therefore recommended that the 1978 edition of the standard be revised and replaced with a new inch standard to reflect usage in this country.

This Standard specifies the dimensions of toolholder shanks, retention knobs, and sockets, and useful related technical information for machine tool spindles having 7/24 tapers intended for automatic tool changing.

Dimension *M* (Table 1) has been revised to allow for greater manufacturing flexibility.

Prior to this Standard, there were no applicable standards specifying dimensions and tolerances for tool sockets to match the tool shanks in ASME B5.50-1994.

Suggestions for improvement of this Standard are welcome. They should be sent to The American Society of Mechanical Engineers, Secretary, B5 Standards Committee, Three Park Avenue, New York, NY 10016-5990.

This revision was approved as an American National Standard on March 31, 2009.

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Machine Tools — Components, Elements, Performance, and Equipment

(The following is the roster of the Committee at the time of approval of this Standard.)

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Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the standard, the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Request for Cases should also indicate the applicable edition(s) of the standard to which the proposed Case applies.

Attending Committee Meetings. The B5 Standards Committee regularly holds meetings, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the B5 Standards Committee.

7/24 TAPER TOOL TO SPINDLE CONNECTION FOR AUTOMATIC TOOL CHANGE

1 GENERAL

1.1 Scope

This Standard pertains to the standardization of basic toolholder shank, retention knob, and socket assemblies for numerically controlled machining centers with automatic tool changers. The requirements contained herein are intended to provide toolholder interchangeability between machining centers with automatic tool changers of various types. This Standard is the inch solution for basic toolholder shank, retention knob, and socket assemblies. This design specifies an interchangeable retention knob with a 45-deg clamping surface.

Section 2 of this Standard specifies the dimensions and tolerances of toolholder shanks having 7/24 tapers intended for automatic tool change. These are intended for use with the corresponding basic retention knob and spindle sockets specified in sections 3 and 4 (see Table 1).

Section 3 contains information for standardization of retention knobs for use with the 7/24 connection system described herein (see Table 2).

Section 4 specifies the dimensions and tolerances of spindle sockets, drive keys, and key seats for machine tool spindles having 7/24 tapers intended for automatic tool change (see Table 3 and Fig. 1). These are intended for use with the corresponding basic toolholder shank and retention knob specified in sections 2 and 3.

1.2 Noninterchangeability

Tool shanks conforming to ASME B5.18-1972 and ASME B5.40-1977 are not interchangeable with tool shanks established in this Standard. Tool shanks conforming to ISO 7388-1:1983 and retention knob ISO 7388-2:1984 types "A" and "B" are not interchangeable with this Standard. This also applies to additional shank and knob designs that are in the draft stages within the ISO standards development system. Accordingly, the reader should note the warning statement included with the retention knob specifications shown in Table 2.

Some incompatibility with existing automatic tool change arms may arise from dimension *M* (Table 1).

1.3 Classification

This Standard covers a basic toolholder shank with an "inch" threaded retention knob with 45-deg clamping surface that is applicable to general-purpose machining centers where loading and exchange of toolholders is accomplished by automatic means. The term *general purpose* is intended to differentiate between machine designs for unusually high accuracy requirements or designs intended to function with exceptionally high spindle rotational speeds coupled with higher axis feed rates, such as is normally found in high-speed machining. Tool shanks made to this Standard may be used with a variety of proprietary retention and/or flange locking systems.

1.4 Definitions

Terms relevant to this Standard and its application are as follows:

automatic tool changer (ATC): mechanism for the transfer of the toolholder between a storage feature and the spindle or nonrotating socket.

balance: when the mass centerline and rotational centerline of a rotor are coincident.

basic cone: geometrically ideal conical surface that is given by its geometrical dimensions. These are a basic cone diameter, the basic cone length, and the basic rate of taper, or the basic cone angle.

basic toolholder shank: unit that fits directly into the spindle or nonrotating socket of the machine and has provision for automatic tool change.

coolant hole: passage through the center of the retention knob that allows through-the-spindle coolant to pass. This hole also permits access to a tool set height adjustment screw if so equipped.

drive key: device intended to assist in delivery of the driving torque from the spindle nose to the tool.

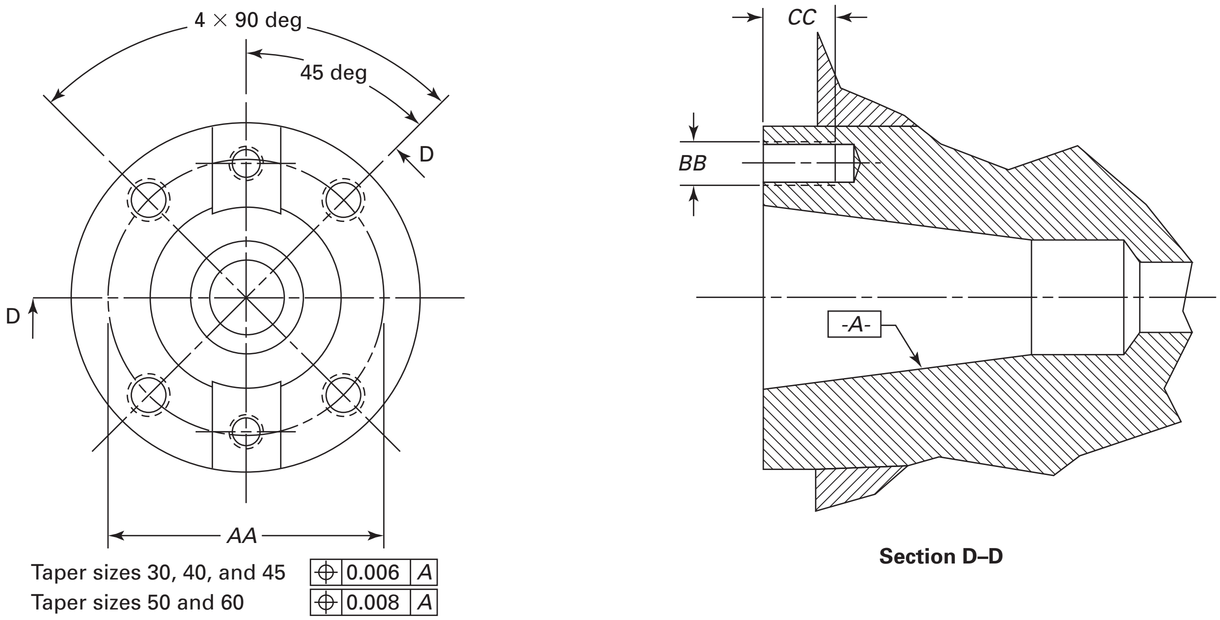
effective case: depth within a metal part, measured from the part's surface, where the minimum required hardness is present.

retention knob: member of the toolholder retention system that provides a coupling point between the toolholder taper and the spindle drawbar.

spindle: component assembly of the machine tool, the function of which is to accept the basic toolholder shank.

spindle nose: the part of a spindle into which the tool shank is accepted.

Fig. 1 Optional Face-Mount Holes, 7/24 Taper Spindle Socket



tool angular orientation: mechanical feature to position and retain the basic toolholder shank in a specific angular relationship to the spindle or nonrotating socket.

tool shank: the part of a tool which mates with the taper in the spindle nose.

1.5 References

1.5.1 The following is a list of publications referenced in this Standard.

ASME B5.18-1972, Spindle Noses and Tool Shanks for Milling Machines
ASME B5.40-1977, Spindle Noses and Tool Shanks for Horizontal Boring Machines
ASME Y14.5-2009, Dimensioning and Tolerancing
Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300 (www.asme.org)

ISO 1940-1:2003, Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances
ISO 1940-2:1997, Mechanical vibration — Balance quality requirements of rigid rotors — Part 2: Balance errors
ISO 1947:1973 (withdrawn), System of cone tolerances for conical workpieces from C = 1:3 to 1:500 and lengths from 6 to 630 mm
ISO 7388-1:2007, Tool shanks with 7/24 taper for automatic tool changers — Part 1: Dimensions and designation of shanks of forms A, AD, AF, U, UD and UF
ISO 7388-2:2007, Tool shanks with 7/24 taper for automatic tool changers — Part 2: Dimensions and designation of shanks of forms J, JD and JF
Publisher: International Organization for Standardization (ISO), 1 ch. de la Voie-Creuse, postale 56, CH-1211 Genève 20, Switzerland/Suisse (www.iso.org). Copies of ISO documents may be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036 (www.ansi.org).

1.5.2 The following documents are not referenced in this Standard but are relevant to the subject and may be of interest to the user of this Standard.

ASME B5.10-1994, Machine Tapers (Self Holding and Steep Taper Series)
ISO 9270:1992, 7/24 tapers for tool shanks for automatic changing — Tapers for spindle noses

2 ESSENTIAL DIMENSIONS FOR 7/24 TAPER TOOLHOLDER SHANK

See Table 1.

3 ESSENTIAL DIMENSIONS FOR RETENTION KNOBS

See Table 2.

4 ESSENTIAL DIMENSIONS FOR 7/24 TAPER SPINDLE SOCKETS

4.1 Dimensions

See Table 3.

4.2 Optional Face-Mount Holes

See Table 3 and Fig. 1.

Table 1 Essential Dimensions of Basic Toolholder Shanks for Machining Centers With Automatic Tool Changers

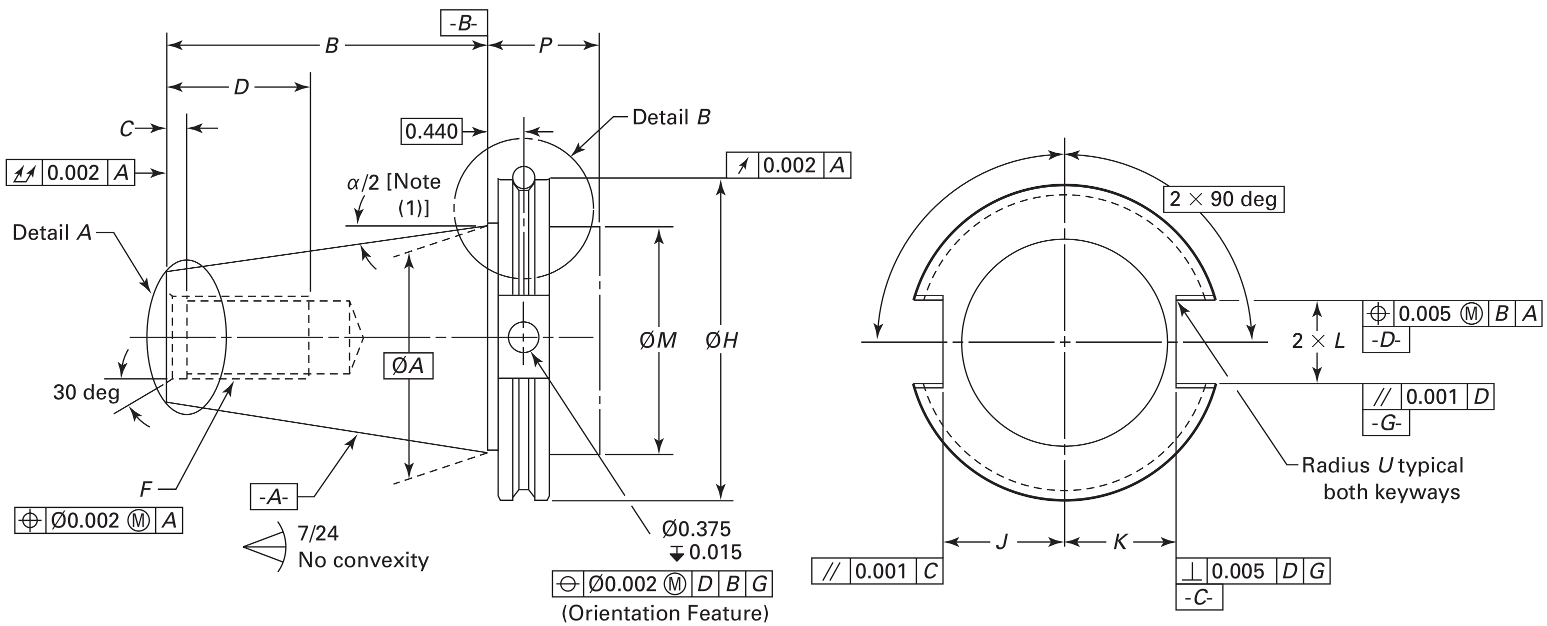
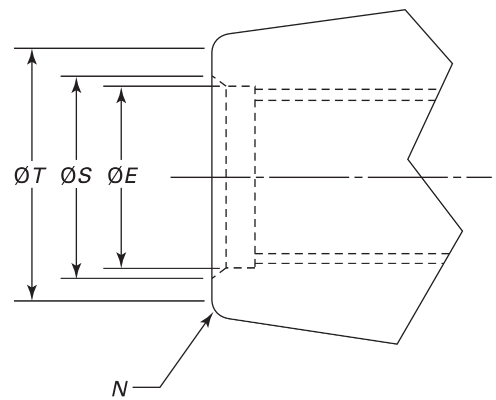
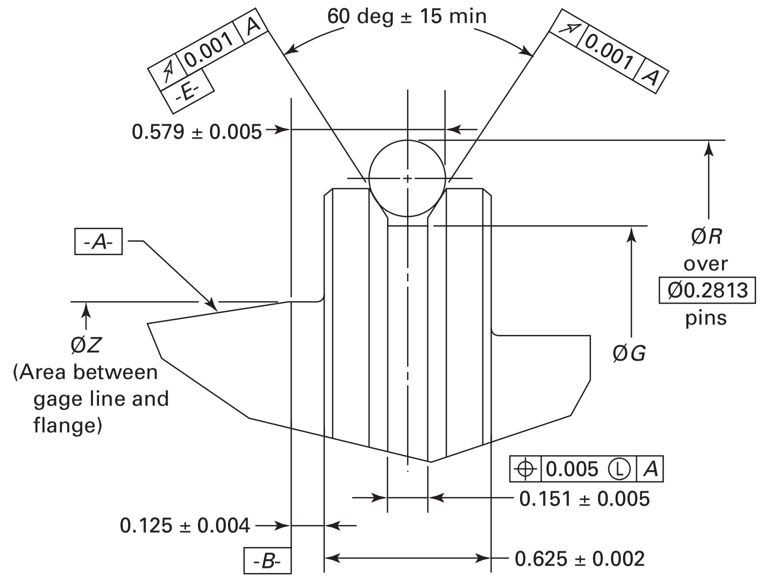


Table 1 Essential Dimensions of Basic Toolholder Shanks for Machining Centers With Automatic Tool Changers (Cont'd)



Detail A



Detail B

Size	ØA (Gage Dia.)	B, ±0.005	C, ±0.010	D, Min.	ØE, +0.015, −0.000	F, UNC-2B	ØG, ±0.010	ØH, ±0.002	J, +0.000, −0.015	K, +0.000, −0.015	L, ±0.010	ØM, Max.	N, ±0.010	P, Min.	ØR, ±0.002	ØS, ±0.010	ØT, Min.	U, ±0.010	ØZ, +0.000, −0.005
30	1.250	1.875	0.188	1.00	0.516	0.500-13	1.531	1.812	0.735	0.640	0.645	1.812	0.020	1.38	2.176	0.590	0.652	0.030	1.250
40	1.750	2.687	0.188	1.12	0.641	0.625-11	2.219	2.500	0.985	0.890	0.645	2.500	0.040	1.38	2.863	0.720	0.880	0.030	1.750
45	2.250	3.250	0.188	1.5	0.766	0.750-10	2.969	3.250	1.235	1.140	0.770	3.250	0.040	1.38	3.613	0.850	1.233	0.030	2.250
50	2.750	4.000	0.250	1.75	1.031	1.000-8	3.594	3.875	1.485	1.390	1.020	3.875	0.040	1.38	4.238	1.125	1.427	0.030	2.750
60	4.250	6.375	0.312	2.25	1.281	1.250-7	5.219	5.500	2.235	2.140	1.020	5.500	0.040	1.50	5.863	1.375	2.309	0.040	4.250

GENERAL NOTES:

(a) Taper cone tolerance is in accordance with Nonmandatory Appendix B.

(b) Geometric dimension symbols are in accordance with ASME Y14.5.

(c) Debur all sharp edges.

(d) All unspecified fillets and radii: *R* 0.03 ±0.010 or 0.03 ±0.010 × 45 deg.

(e) Modification of diameter *G*, diameter *M*, orientation feature, and surfaces on both sides of the flange is permissible to improve high speed operation or accommodate tool identification chip.

(f) Central through-hole permissible.

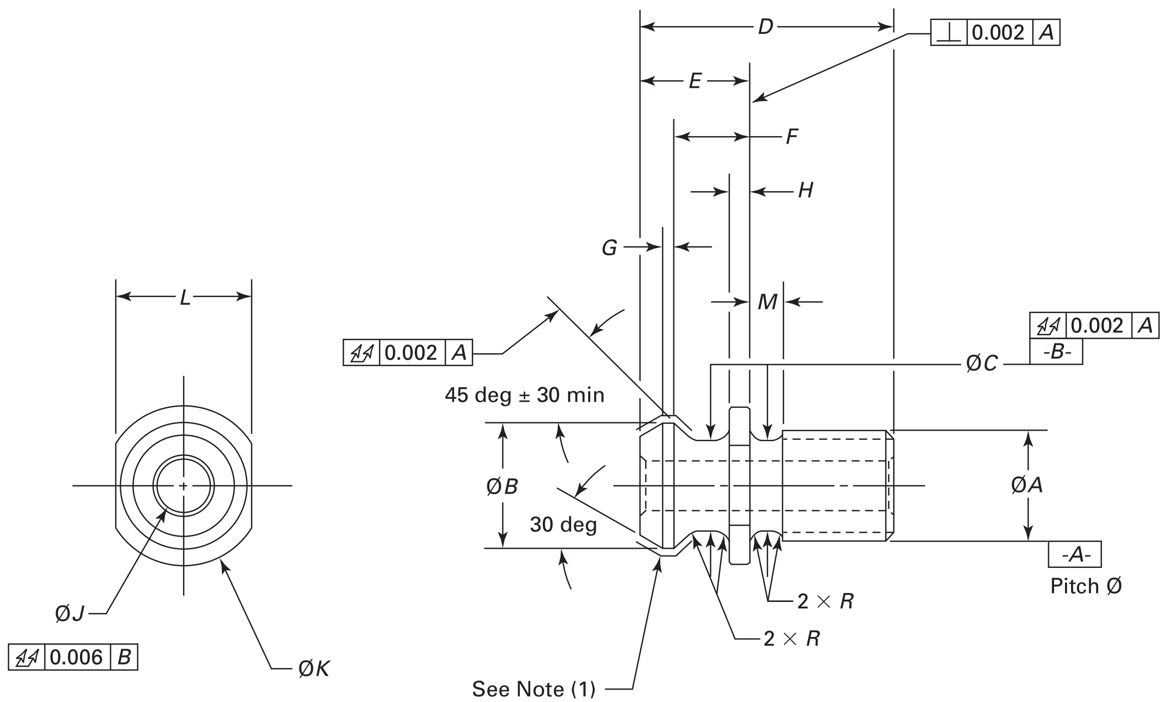
(g) For reference, see Table 1 illustration beginning on preceding page.

(h) See Nonmandatory Appendix B for general recommendations.

NOTE:

(1) The conicity tolerance shall conform with a minimum cone angle tolerance of grade AT_4 (see Nonmandatory Appendix B). These values shall be positive (increasing cone angle).

Table 2 Essential Dimensions of Retention Knobs



Size	ØA, UNC-2A	ØB, ±0.005	ØC, ±0.005	D, ±0.040	E, ±0.005	F, ±0.005	G, ±0.010	H, ±0.010	ØJ, ±0.010	ØK	L, +0.000, −0.010	M, ±0.040	R, +0.010, −0.005
30	0.500-13	0.520	0.385	1.10	0.460	0.320	0.04	0.10	0.187	0.64–0.65	0.53	0.19	0.094
40	0.625-11	0.740	0.490	1.50	0.640	0.440	0.06	0.12	0.281	0.92–0.94	0.75	0.22	0.094
45	0.750-10	0.940	0.605	1.80	0.820	0.580	0.08	0.16	0.375	1.18–1.20	1.00	0.22	0.094
50	1.000-8	1.140	0.820	2.30	1.000	0.700	0.10	0.20	0.468	1.42–1.44	1.25	0.25	0.125
60	1.250-7	1.460	1.045	3.20	1.500	1.080	0.14	0.30	0.500	2.06–2.14	1.5	0.31	0.125

Table 2 Essential Dimensions of Retention Knobs (Cont'd)

GENERAL NOTES:

(a) Material: low carbon alloy steel, tensile strength 116,000 psi minimum.
(b) Centers permissible.
(c) *J* hole shall not be case hardened.
(d) All unspecified fillets and radii: *R* 0.03 ±0.010 or 0.03 ±0.010 × 45 deg.
(e) *C* and *R* must be free of tool marks.
(f) Debur all sharp edges.
(g) Geometric dimension symbols are in accordance with ASME Y14.5.
(h) For reference, see Table 2 illustration on preceding page.

NOTE:

(1) Case harden 58 ±2 HRC on surfaces indicated, 0.016 to 0.028 effective case.

WARNING: Retention knobs are available in various styles and are not interchangeable. At all times, the proper retention knob and basic toolholder should be used per machine specifications. Failure to use the correct retention knob or failure to properly install and tighten the retention knob may result in the adapter coming loose. The result is a potential for personal injury and/or equipment damage.

Table 3 Essential Dimensions of 7/24 Taper Spindle Socket

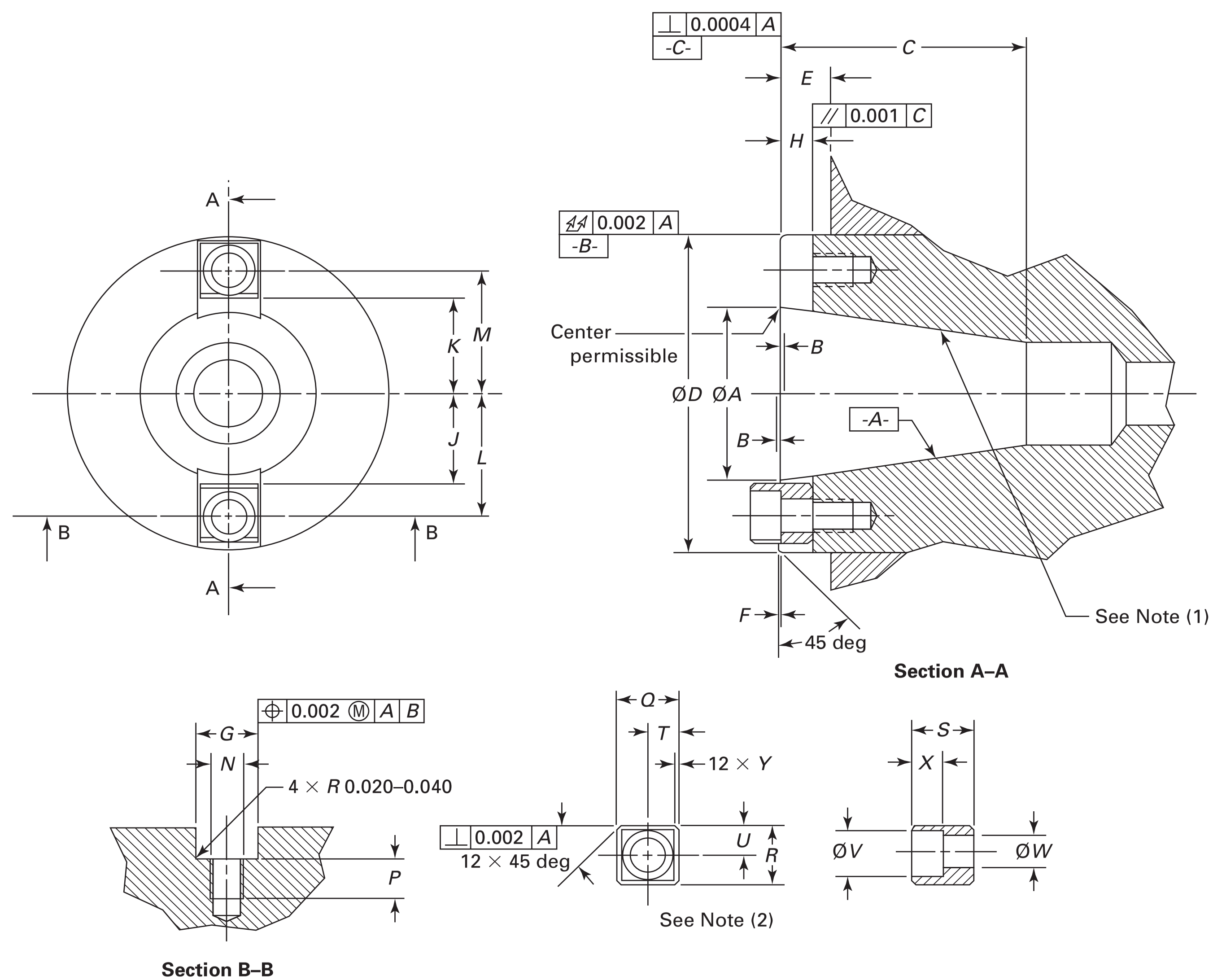


Table 3 Essential Dimensions of 7/24 Taper Spindle Socket (Cont'd)

	Taper Dimensions			Mounting Dimensions			Drive Key Seat Dimensions							
Taper	ØA (Basic)	B (Range)	C, ±0.008	ØD, +0.0000, −0.0005	E, Min.	F, ±0.008	G, +0.000, −0.001	H, Min.	J, +0.015, −0.000	K, +0.015, −0.000	L, ±0.005	M, ±0.005	N, UNC-2B	P, ±0.01
30	1.25	0.008	1.781	2.7493	0.50	0.040	0.625	0.313	0.670	0.765	0.999	0.999	0.312-18	0.44
40	1.75	0.008	2.552	3.4993	0.62	0.040	0.625	0.313	0.925	1.020	1.285	1.285	0.312-18	0.44
45	2.25	0.008	3.087	3.9993	0.62	0.040	0.750	0.375	1.180	1.275	1.572	1.572	0.375-16	0.53
50	2.75	0.008	3.800	5.0618	0.75	0.040	1.000	0.500	1.435	1.530	1.952	1.952	0.500-13	0.62
60	4.25	0.008	6.056	8.7180	1.50	0.040	1.000	0.500	2.185	2.280	2.733	2.733	0.500-13	0.62

	Drive Key Dimensions									Face Mount (See Fig. 1)		
Taper	Q, +0.000, −0.001	R, ±0.005	S, ±0.005	T, ±0.005	U, ±0.005	ØV, +0.005, −0.000	ØW, +0.005, −0.000	X, ±0.01	Y, Min.	AA	BB, UNC-2B	CC, ±0.01
30	0.6238	0.562	0.63	0.313	0.234	0.437	0.332	0.32	0.04	2.125	0.375-16	0.62
40	0.6238	0.625	0.63	0.313	0.265	0.437	0.332	0.32	0.04	2.625	0.500-13	0.81
45	0.7488	0.688	0.75	0.375	0.297	0.625	0.397	0.39	0.06	3.000	0.500-13	0.81
50	0.9988	0.938	1.00	0.500	0.422	0.781	0.531	0.51	0.06	4.000	0.625-11	1.00
60	0.9988	1.000	1.00	0.500	0.453	0.781	0.531	0.51	0.06	7.000	0.750-10	1.25

GENERAL NOTES:
(a) *A* is the basic diameter contained in the gage plane.
(b) Taper cone tolerance is in accordance with Nonmandatory Appendix A.
(c) Geometric dimension symbols are in accordance with ASME Y14.5.
(d) Debur all sharp edges.
(e) All unspecified fillets and radii: *R* 0.03 ±0.010 or 0.03 ±0.010 × 45 deg.
(f) For reference, see Table 3 illustration on preceding page.

NOTES:
(1) The conicity tolerance shall be AT_4 or better (see Nonmandatory Appendix A). These values shall be negative (decreasing cone angle).
(2) Drive key material shall be steel, case hardened, tensile strength 116,000 psi minimum, and case hardness of 58 ±2 HRC.

NONMANDATORY APPENDIX A
USEFUL TECHNICAL INFORMATION

A-1 GENERAL

This Nonmandatory Appendix is intended to provide informative content pertaining to the use of the 7/24 taper spindle-to-toolholder connection. These are general recommendations which if followed should maximize performance and minimize maintenance difficulties. Nominal operational values for 7/24 taper toolholder shanks are shown in Table A-1. All of this content is derived from decades of practical experience with the subject toolholder interface in aerospace, automotive, and general machine shop practice. Items to consider when specifying either the toolholder or spindle side of the interface are

(a) age, condition, and service requirements of the machine tool

(b) the ability to either maintain toolholder interface integrity or repair and replace worn-out equipment

(c) updated training for machinists and programmers

(d) the knowledge of your machine tool supplier on the subjects of machining dynamics, allowable machining forces, and maintenance of drawbar mechanisms

(e) the degree to which a given spindle taper can be reground without exceeding the depth of the hardened case

The cone tolerance system as historically described by ISO 1947 is presented to the extent that it pertains to this Standard (see Nonmandatory Appendix B).

A-2 DRAWBAR FORCES

7/24 taper tool to spindle connections require sufficient force pulling on the retention knob to achieve the following operational characteristics. These characteristics are directly affected by the amount of pulling force and, because of this, performance characteristics of the toolholder-to-spindle connection will change if drawbar force changes. At tool change, the drawbar pull force elastically deforms the mating tapers until enough surface area contact is made to distribute point contact forces and seat the taper. The performance characteristics affected by drawbar pull force are

(a) positional accuracy and stability of the machine tool

(b) resistance to torque-induced slippage at the toolholder–spindle interface

(c) resistance to pulling out (unseating the taper) during heavy cuts

(d) vibration characteristics of the machining system

(e) resistance to damage between mating tapers

NOTE: A poor taper fit will degrade any or all of the above performance characteristics regardless of drawbar pull force.

A-3 BALANCE REQUIREMENTS

Balance should not be pursued to unnecessarily high quality levels. For additional information, see ISO 1940-1 and ISO 1940-2.

A-4 REFERENCES AND INFORMATION

A-4.1 Care of the Tool-to-Spindle Connection

In order to guarantee the minimum runout error and a long spindle and toolholder life, special care must be taken to keep this area clean. The person loading and unloading tools from the machine should visually inspect each toolholder for wear and signs of corrosion.

Below is a description of each item involved in the process.

A-4.1.1 Spindle. The spindle nose must be kept clean and free from deposits of any kind. Depending on the application, the user must establish regular cleaning intervals. Occasionally, a special taper cleaner (commercially available from tool manufacturers) should be used to clean the seating surfaces. A high-resolution indicator can be used to measure the taper runout. If the runout is excessive, the spindle may need repair. A runout test arbor can be used to check the runout at a certain distance from the spindle nose.

A-4.1.2 Toolholder Care. Toolholders must be replaced when the taper starts to wear or when excessive corrosion is noted. Minor blemishes can be repaired with a stone or crocus cloth. Occasionally, the runout of the cutting tool seat should be checked with an indicator on the machine. Toolholders that will not be used for some time should be treated with a rust preventative.

Table A-1 Nominal Operational Values for 7/24 Taper Toolholder Shanks

Taper Standard	Retention Knob Installation Torque, ft-lb	Suggested Drawbar Pull Force, lb	Maximum Operational Bending Moment at Gage Line, in.-lb	Maximum Rotational Speed, rpm
30	8	1,200	1,800	14,000
40	30	2,300	3,450	10,000
45	50	4,000	6,000	8,000
50	75	5,000	7,500	6,000
60	120	13,000	19,500	3,600

GENERAL NOTE: Higher rotational speeds may be obtained by optimizing balance level and interface cone tolerances, and minimizing tool assembly projection.

A-4.1.3 Drawbar Care. The drawbar gripper position must be set according to the manufacturer's specifications, and should be checked frequently and adjusted if necessary. A pull-force gage can be used to determine the drawbar condition. A low pull force will cause excessive wear to toolholder and spindle nose and must be avoided. If low pull force is detected or suspected, the drawbar may require maintenance.

A-4.1.4 Tool Magazine. The tool magazine must be kept clean and free from chips. The magazine must be able to handle the toolholder and present it to the machine with sufficient accuracy that the holder will seat properly in the spindle after clamping. Grippers that allow excessive looseness/sag of the holder must be replaced or, alternatively, tools exceeding the magazine capacity must be loaded manually.

NONMANDATORY APPENDIX B EXCERPT FROM ISO 1947:1973, SYSTEM OF CONE TOLERANCES FOR CONICAL WORKPIECES FROM $C = 1{:}3$ TO 1:500 AND LENGTHS FROM 6 TO 630 mm

NOTE: This excerpt from ISO 1947:1973 and the standards referenced within are nonbinding to ASME B5.50. Content is shown to clarify the derivation of angular tolerance (AT) grades only. No tolerance system is endorsed nor encoded by inclusion herein. Portions of the original ISO 1947:1973 are omitted for clarity.

B-1 SCOPE AND FIELD OF APPLICATION

This international Standard specifies a cone tolerance system which applies to rigid conical workpieces for which the length of the generator can be considered as practically equal to the basic cone length; this applies in the case of cones having a rate of taper $C = 1{:}3$ to 1:500.[1]

For dimensioning and tolerancing cones on drawings, see ISO 3040, Technical drawings — Dimensions and tolerancing cones.[2]

For general information on tolerances of form and of position, see ISO/R 1101, Tolerances of form and of position — Part I: Generalities, symbols, indications on drawings.

B-2 BASIS OF THE SYSTEM

B-2.1 Types of Cone Tolerance

The following four types of tolerance provide the basis of the cone tolerance system:

(a) cone diameter tolerance, T_D, valid for all cone diameters within the cone length, L.

(b) cone angle tolerance, AT, given in angular or linear dimensions (AT_α or AT_D).

(c) cone form tolerance, T_F (tolerances for the straightness of the generator and for the roundness of the section).

(d) cone section diameter tolerance, T_{DS}, given for the cone diameter in a defined section. It is valid for the cone diameter of this section only.

B-2.2 Cone Diameter Tolerance, Cone Angle Tolerance, and Cone Form Tolerance

Normal cases will be handled by application of the cone diameter tolerance, T_D, only. It includes the two tolerances of the types in paras. B-2.1(b) and (c). This means that the deviations of these two types may, in principle, utilize the whole tolerance space given by the cone diameter tolerance, T_D (see Fig. B-1). In case of stronger requirements, the cone angle tolerance and the cone form tolerance may be reduced within the cone diameter tolerance, T_D, by means of supplementary instructions. In this case, likewise, no point on the conical surface is permitted to lie outside the limit cones' given T_D. In practice, all types of tolerance generally exist at the same time and, as far as normal cases are concerned, each tolerance may occupy a part of the cone diameter tolerance, T_D, only in such a way that no point on the conical surface lies outside the tolerance space. In other words, no point on the conical surface is permitted to lie outside the limit cones.

B-2.3 Cone Section Diameter Tolerance

If for functional reasons the cone diameter tolerance is required in a defined section, then the cone diameter tolerance, T_{DS} [para. B-2.1(d)], must be indicated. In this case, it is also necessary to indicate the cone angle tolerance. If general tolerances for the cone angle are specified, e.g., in an international document, and if it is referred to this tolerance, then it is not necessary to indicate special cone angle tolerances.

[1] For cones of 1:3 up to 1:500, the length of the generator and the cone length may be regarded as equal, since these lengths give differences in cone angle tolerances of less than 2%.

[2] At present at the stage of draft.

B-3 DEFINITIONS

B-3.1 Definitions Relating to Geometry of Cones

cone: a conical surface or a conical workpiece (see Fig. B-2), defined by its geometrical dimensions. In the absence of any indication concerning the geometrical form, cone is understood to mean a straight circular cone or truncated cone.

conical surface: a surface of revolution which is formed by rotating a straight line (generator) around an axis with the straight line intersecting this axis at the apex (see Fig. B-2). The parts of this infinite conical surface are also known as conical surfaces or cones. Similarly, "cone" is also the abbreviated designation of a truncated cone.

conical workpiece: a workpiece or portion of a workpiece, the main part of which is a conical surface (see Figs. B-3 and B-4).

external cone: a cone which limits the outside form of a conical feature of a workpiece (see Figs. B-3 and B-5).

internal cone: a cone which limits the inside form of a conical feature of a workpiece (see Figs. B-4 and B-5).

basic cone: the geometrically ideal conical surface which is given by its geometrical dimensions. These are either

(a) a basic cone diameter, the basic cone length, and the basic rate of taper or the basic cone angle, or

(b) two basic cone diameters and the basic cone length (see Fig. B-6)

actual cone: that cone the conical surface of which has been found by measurement (see Fig. B-7).

limit cones: the geometrically ideal coaxial surfaces, having the same basic cone angle, which result from the basic cone and the cone diameter tolerances. The difference between the largest and the smallest cone diameters is the same in all sections normal to the cone axis (see Fig. B-8). The surfaces of the limit cones may be made to coincide by axial displacement.

generator: the line of intersection of the conical surface with a section in the axial plane (see Figs. B-2 and B-5).

B-3.2 Definitions Relating to Sizes on Cones

cone diameter: the distance between two parallel lines tangent to the intersection of the circular conical surface with a plane normal to the cone axis.

basic cone diameters are as follows (see Fig. B-6):

(a) the largest cone diameter, D, or

(b) the smallest cone diameter, d, or

(c) the cone diameter, d, at a place determined by its position in the axial direction

actual cone diameter, d_a: the distance between two parallel lines tangent to the intersection of the surface of the actual cone with a defined plane normal to the cone axis (see Fig. B-7).

limit cone diameters: the diameters of the limit cones in each section in a plane normal to the axis (see Fig. B-8).

basic cone length, L: the distance in the axial direction between two limiting ends of a cone (see Figs. B-5 and B-6).

basic cone angle, α: the angle formed by the two generators of the basic cone in a section in the axial plane (see Fig. B-9).

limit cone angles: the largest and the smallest cone angles resulting from the basic cone angle, c_u, and the d position and magnitude of the cone angle tolerance (see Fig. B-10).

cone generating angle, $\alpha/2$: the angle contained between a generator and the cone axis (see Fig. B-9). The generating angle is equal to half the basic cone angle, α.

rate of taper, C: the ratio of the difference between the cone diameters, D and d, to the cone length, L

$$C = \frac{D - d}{L} = 2 \tan \frac{\alpha}{2}$$

The rate of taper is often indicated by the expressions $1{:}x$ or $1/x$ and "Cone $1{:}x$" for short. For example, $C = 1{:}20$ means that a diameter difference, $D - d$, of 1 mm occurs an axial distance, L, of 20 mm between the cone diameters, D and d.

B-3.3 Definitions Relating to Cone Tolerances

cone tolerance system: a system containing the cone diameter tolerances, the cone angle tolerances, and the tolerances on the cone form of the generator and the circumferential line of the section normal to the cone axis.

cone diameter tolerance, T_D: the difference between the largest and smallest permissible cone diameters in any section, i.e., between the limit cones (see Fig. B-8).

cone angle tolerance, AT:[3] the difference between the largest and smallest permissible cone angles (see Figs. B-10 and B-11).

cone form tolerances, T_F

tolerance on the straightness of the generator: the distance between two parallel, straight lines between which the actual generator must lie (see Fig. B-8). The actual value for the error on straightness is taken as the distance between two parallel straight lines touching the actual generator, and so placed that the distance between them is a minimum.

tolerance on the roundness of the section: the distance between two coplanar concentric circles in a section normal to the axis between which the actual cone section must be situated (see Fig. B-12). The actual value for the error on roundness is taken as the distance between two

[3] AT = angle tolerance.

coplanar concentric circles which touch the actual line of any section normal to the axis.

cone section diameter tolerance, T_{DS}: the difference between the largest and smallest permissible cone diameters in a defined section (see Fig. B-13).

B-3.4 Definitions Relating to Actual Cone Angles

actual cone angle: in any axial plane section, the angle between the two pairs of parallel straight lines that enclose the form errors of the two generators in such a way that the maximum distance between them is the least possible value (see Fig. B-14). For a given cone, there is not only one actual cone angle; for cones having deviations of roundness, the actual cone angle will be different in different axial planes (see α_1 and α_2 in Fig. B-14).

average actual cone angle: the arithmetical average value of the actual cone angle measured in accordance with the definition above in several equally distributed axial plane sections. Amongst the axial planes chosen, one at least shall cover the greatest deviation of roundness from the circle line of the cone diameter.

B-3.5 Definition Relating to Cone Tolerance Space

cone tolerance space: for the conical surface, the space between the two limit cones. Cone tolerance space includes all the tolerances referred to in para. B-3.3. It may be represented by tolerance zones in two plane sections (see Figs. B-8 and B-12).

B-3.6 Definitions Relating to Cone Tolerance Zones

cone diameter tolerance zone: in a graphic representation, that zone, lying in the plane section of the cone axis, which is limited by the limit cones. The total tolerances zone is represented in Figs. B-8 and B-12 by the hatched portions that also indicate the cone tolerance space. It includes the tolerances for the cone diameter, the cone angle, the roundness, and the straightness that can occupy the whole cone tolerance zone. In general, each of these particular deviations occupies a part of the cone diameter tolerance zone only.

tolerance zone for the cone angle: a fan-shaped zone within the limit cone angles. The inclination of the limit cones can be indicated by plus, minus, or plus/minus for the cone angle tolerances (see Fig. B-15). For the indication of plus/minus, the values can be different.

tolerance zone for the straightness of the generator: in a graphic representation, that zone (band), situated in any axial plane section and disposed on each side of the cone axis, which is determined by the form tolerance of the generators (see Fig. B-8). As this zone is smaller than that referred to in the above definition of cone diameter tolerance zone, it only applies if the tolerance on the straightness of the generator is reduced with respect to the cone diameter tolerance zone. The actual generator has to be situated anywhere within a tolerance zone given by the tolerance for the straightness.

tolerance zone for the roundness of the section: in a graphic representation, the zone lying in a section normal to the cone axis and formed by concentric circles (see Fig. B-12). As this zone is narrower than that referred to in the above definition of cone diameter tolerance zone, it only applies if the tolerance for the roundness of the section is reduced with respect to the cone diameter tolerance zone. The contour has to be situated anywhere within a tolerance zone given by the tolerance for the roundness of the section.

cone section diameter tolerance zone: the tolerance zone for the cone diameter in a defined section. It appears in that case if the cone diameter tolerance is indicated for a fixed diameter only.

B-4 CONE DIAMETER TOLERANCE, T_D

In general, the choice of the cone diameter tolerance, T_D, is based on the large cone diameter, D. It is selected from the ISO standard IT tolerances and applies over the whole of the cone length, L. If it is not required to indicate smaller tolerances of angle and form, a cone diameter tolerance, T_D, given on the drawing, applies also to the angle and form deviations. It should be borne in mind, however, that in this case all workpieces that conform to Figs. B-11 and B-16 must be accepted. The symbols of the ISO tolerances system shall be used to indicate the cone diameter tolerances referred to the corresponding cone diameter. If the conical surface of the conical workpiece concerned is not intended for a cone fit, the tolerance positions, J_S and j_s, should be chosen for preference, e.g., $40j_s10$.

B-5 CONE ANGLE TOLERANCE, *AT*

B-5.1 Cone Angle Tolerance Resulting From the Cone Diameter Tolerance, T_D

The actual cone angle lies within the cone diameter tolerance zone in case of absence of any special indication of cone angle tolerances. The cone angles, α_{max} and α_{min} (see Fig. B-11), are thus the limit cone angles resulting from the cone diameter tolerance, T_D. Consequently, in this case, the actual cone angle is permitted to be disposed with respect to the basic cone angle, α, from $+\Delta\alpha$ to $-\Delta\alpha$ (for values of $\Delta\alpha$, see Table B-1).

B-5.2 Fixed Cone Angle Tolerance

If the cone angle tolerance has to be smaller than that given by the cone diameter tolerance, it is necessary to establish the cone angle limits. For the cone angle tolerances, the deviations must be indicated by plus, minus, or plus/minus, e.g., $+AT$, $-AT$, $\pm AT/2$. For the indication of plus/minus, the values can be different.

B-6 CONE FORM TOLERANCES, T_F

Cone form tolerances comprise the tolerances on

(a) the straightness of the generator (see Fig. B-8)

(b) the roundness of the cone section (see Fig. B-12)

Cone form tolerances shall be especially indicated (in micrometers) if they must be smaller than half of the cone diameter tolerance.

B-7 CONE SECTION DIAMETER TOLERANCE, T_{DS}

If the cone diameter tolerance should be reduced locally and should be given for a defined section only, for functional or manufacturing reasons, the cone diameter tolerance must be indicated for this section only.

B-8 TABLE OF CONE ANGLE TOLERANCES

As the cone angle tolerances, AT, have different functions, they are stepped in grades represented by numbers, e.g., AT_5. They are expressed in microradians (μrad)[4] for AT_α, or in micrometers (μm) for AT_D, calculated from the constant AT value within a range of cone lengths. AT_D is valid normal to the axis[5] in the form of a diameter difference. It must be smaller with respect to the cone diameter tolerance, T_D. Taking account of the units (micrometers, microradians), the following relationship exists (see also Fig. B-17):

$$AT_D = AT_\alpha \times L$$

The grade numbers for IT (diameter) and AT (angle) tolerances are chosen in such a way that the same numbers correspond to approximately the same difficulties of manufacture. No direct relation is given, however, because the IT values are stepped in accordance with the diameter of cylindrical workpieces, whereas the AT values are stepped in accordance with the cone length, L.

The ratio for the cone angle tolerances from one AT grade to the next higher grade is 1.6. It is necessary to relate the cone angle tolerance, AT, to the cone length, L, because the longer the length of cone, the better the angle may be met. The cone lengths, L, from 6 mm to 630 mm are divided into ten ranges with a stepped ratio of 1.6.

The AT_α values decrease from one range of length to the next higher range by a step of 0.8, which corresponds to the experimental relationship

$$AT_\alpha \sim \frac{1}{\sqrt{L}}$$

As the AT_α values are held constant in a cone length range, it is the corresponding AT_D values that vary. They are given for the limits of the ranges of lengths and increase from one length range to the next with a ratio of 1.25.

Figure B-17 shows the largest and smallest values for AT_D resulting from the largest (L_{max}) and smallest (L_{min}) basic lengths of a length range at a constant AT_α value.

No relationship is provided for between the cone angle tolerance and the cone diameter because of lack of experience (see Fig. B-18). The introduction of such a relationship will be made in the future if sufficient experience is available. In the case of conical workpieces with large cone diameter, it is left to the user to select a higher AT grade than that used for conical workpieces of small diameter.

If finer or coarser angle tolerances are necessary, they shall be calculated by division or multiplication by 1.6 from the AT_1 and AT_{12} values, respectively. The finer AT grades shall be designated AT_0, AT_{01}.

[4] 1 μrad = an angle producing an arc of length 1 μm at a radial distance of 1 m. 5 μrad = 1 in. (1 sec); 300 μrad = 1 ft (1 min).

[5] The measurement normal to the cone axis is regarded as equivalent to the theoretical correct measurement normal to the generator, as the difference of the measured AT_0 values is only 2% even for a cone 1:3.

Fig. B-1 Cone Diameter Tolerance Space Formed by the Cone Diameter Tolerance

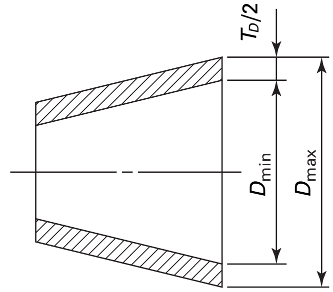


Fig. B-2 Cone

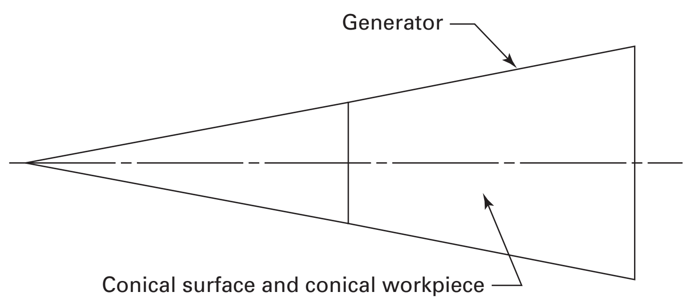


Fig. B-3 Conical Workpiece, External Cone

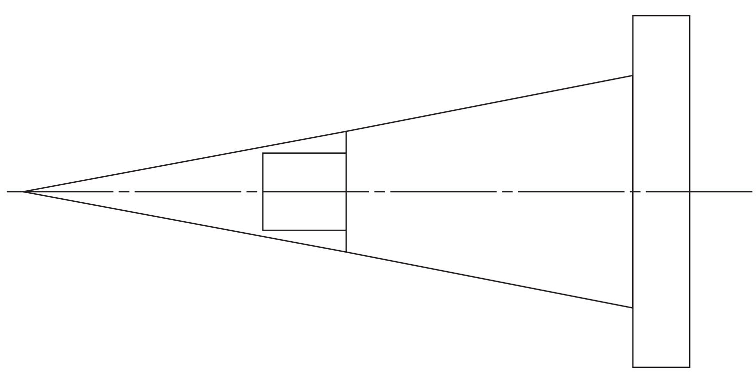


Fig. B-4 Conical Workpiece, Internal Cone

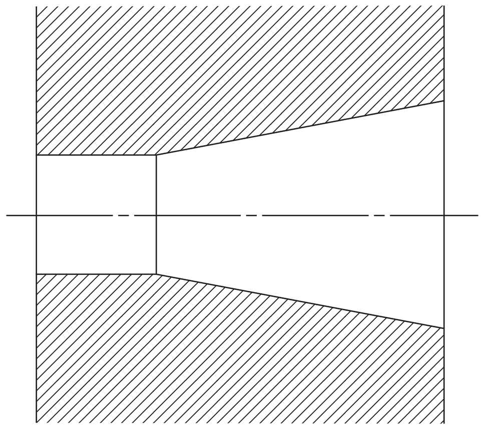


Fig. B-5 General Definitions

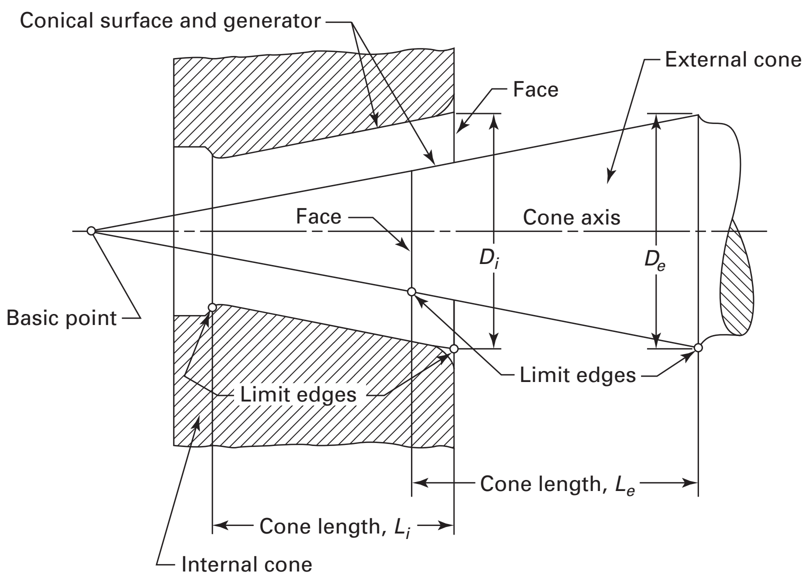


Fig. B-6 Basic Cone

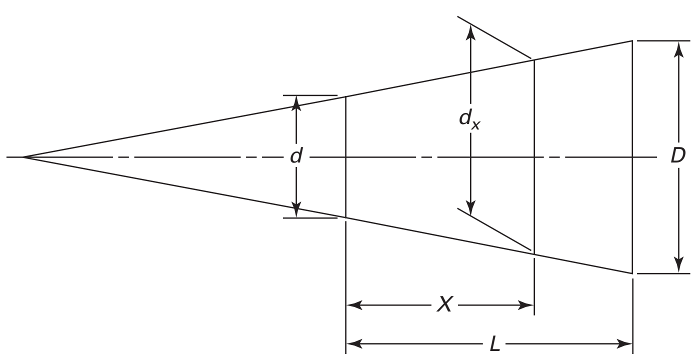


Fig. B-7 Actual Cone

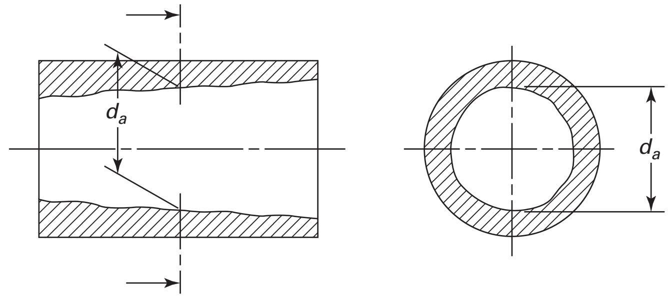


Fig. B-8 Limit Cones, Cone Diameter, Tolerance Zone, and Straightness of the Generator Tolerance Zone

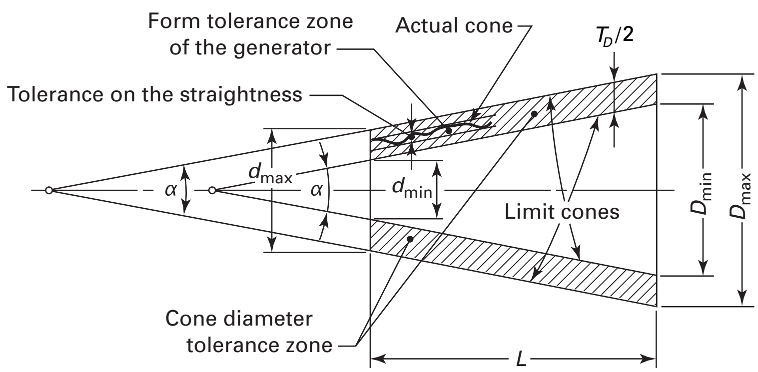


Fig. B-9 Angles on Cones

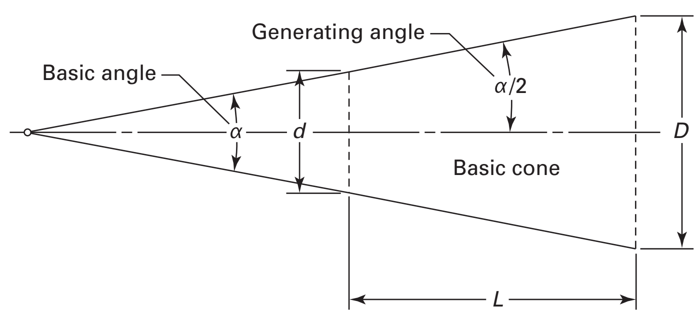


Fig. B-10 Limit Cone Angles

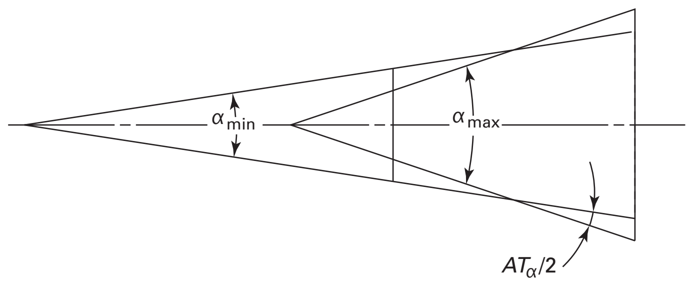


Fig. B-11 Admissible Limit Cone Angles Resulting From the Cone Diameter Tolerance

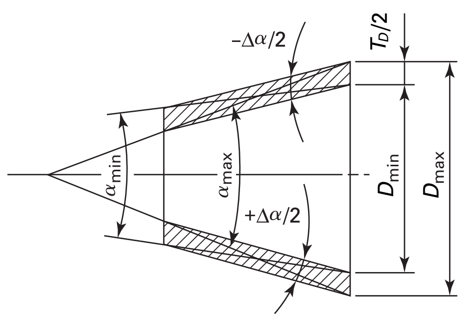


Fig. B-12 Cone Diameter Tolerance Zone and Roundness Tolerance Zone

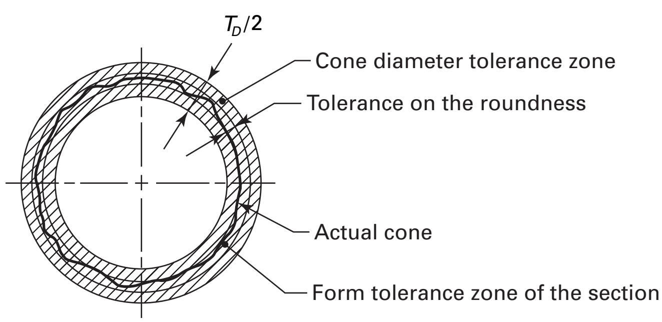
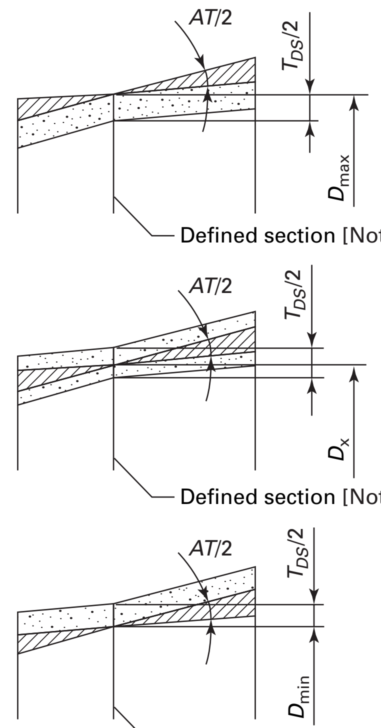


Fig. B-13 Cone Section Diameter Tolerance, T_{DS}, and Cone Angle Tolerance, *AT*



NOTES:
(1) The actual cone diameter in the defined section has the maximum permissible size of the cone diameter.
(2) The actual cone diameter in the defined section lies between the limit sizes of the cone diameter.
(3) The actual cone diameter in the defined section has the minimum size of the cone diameter.

Fig. B-14 Actual Cone Angles

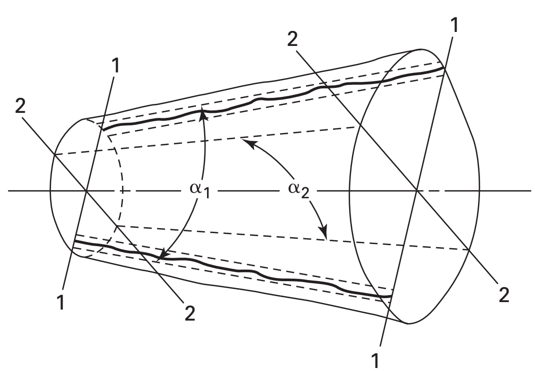


Fig. B-15 Position of the Cone Angle Within the Cone Diameter Tolerance Zone

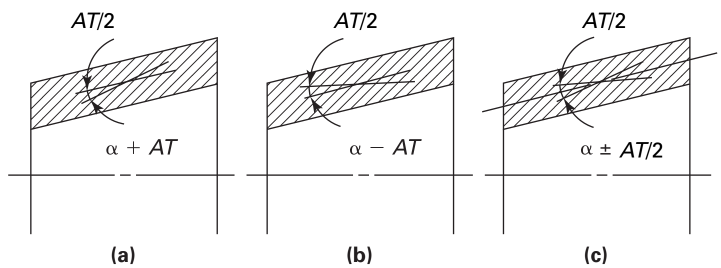


Fig. B-16 Admissible Cone Form Deviation Resulting From the Cone Diameter Tolerance

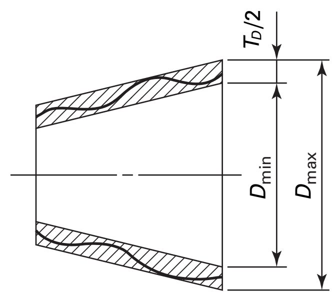


Fig. B-17 Variation of AT_D Within a Range of Cone Length With the Limits of the Length Range, L_1 and L_2

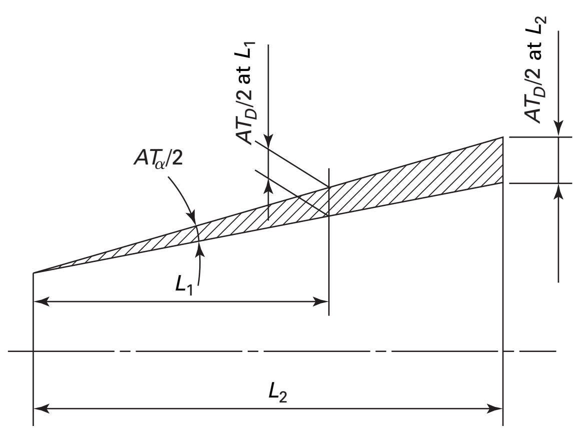


Fig. B-18 Cone Angle Tolerance, AT_α, of a Cone Defined by Its Measuring Diameter and the Longitudinal Dimensions of Which Are Defined Themselves From the Position of the Measuring Plane

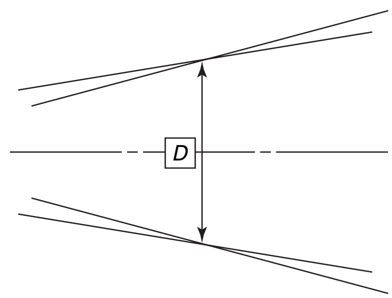


Table B-1 Table of Cone Angle Tolerances

Range of Cone Length, L, mm		AT_4			AT_3		
		AT_α			AT_α		
Over	Up to	µrad	sec	AT_D, µm	µrad	sec	AT_D, µm
6	10	200	41	1.3 to 2	125	26	0.8 to 01.3
10	16	160	33	1.6 to 2.5	100	21	1 to 1.6
16	25	125	26	2 to 3.2	80	16	1.3 to 2
25	40	100	21	2.5 to 4	63	13	1.6 to 2.5
40	63	80	16	3.2 to 5	50	10	2 to 3.2
63	100	63	13	4 to 6.3	40	8	2.5 to 4
100	160	50	10	5 to 8	31.5	6	3.2 to 5
160	250	40	8	6.3 to 10	25	5	4 to 6.3
250	400	31.5	6	8 to 12.5	20	4	5 to 8
400	630	25	5	10 to 16	16	3	6.3 to 10

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