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# SUPPLIER WORKMANSHIP STANDARDS MANUAL

**LQA 1800-0019 Rev. P**
**November 16, 2023**

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# Supplier Workmanship Standards Manual

## Table Of Contents

Table of Contents (continued)

# Supplier Workmanship Standards Manual

## 1.0 PURPOSE

1.1 The purpose of this workmanship standard is to provide a documented standard and the interpretations necessary to assure that the various suppliers of parts to Stellant Systems., (referred to as Williamsport facility or the company), Williamsport, PA, consistently apply high quality manufacturing and inspection practices.

1.2 Although our general objective is to give complete manufacturing instructions on each drawing, this is not always practical or possible due to limited space, much repetition, etc. In addition, there have been various changes through the years, especially in quality and drafting standards. For these reasons, it has become mandatory to supplement the drawings by use of this document, which answers most of the common questions relating to delineations, definitions, notes, references and general practices.

1.3 In general, the requirements in this standard cover areas where workmanship and inspection criteria are subject to interpretation or where required referenced documents may not be readily accessible.

## 2.0 SCOPE

2.1 The requirements of this standard apply when referenced on the purchase order, drawing, or other specifications required for the manufacture of supplies for the Williamsport facility.

2.2 This standard delineates manufacturing and inspection requirements which may not be specifically included on a drawing or specification. It shall be used in conjunction with, but does not alter or waive drawing or specification requirements.

2.3 The requirements stated herein are **mandatory** except when in conflict with applicable drawing or specification requirements. In all cases, the requirements of any drawing, specification, or purchase order requirement shall take precedence over this manual.

2.3.1 Order of precedence

2.3.1.1 The drawing, specification, or purchase order shall take precedence over this manual.

2.3.1.2 The order of precedence of specifications on drawings is dimensions, notes, and standards.

2.3.1.3 Dimensions on drawings may be supplemented by either notes or standards to establish requirements of specific features.

2.3.1.4 Notes are never superseded by standards.

2.3.1.5 If the drawing or specification does not contain requirements for certain geometric characteristic of the part, the requirements of section 14.0 of this standard and/or ASME Y14.5-2009 shall be met as a measure of good workmanship

2.3.1.6 If there is no standard referenced for drawing interpretation, the requirements of section 14.0 of this standard and/or ASME Y14.5-2009 shall be met.

2.4 If the contents of this document or other specified requirements are unclear or not understood, an error or problem is found with a requirement, or compliance with a requirement cannot be met, suppliers shall contact the cognizant Williamsport buyer for resolution prior to the start of fabrication. This is necessary to promote the understanding of, and solutions to mutual problems.

2.5 Upon completion of the purchase order/contract, procurement data and records, including manufacturing/inspection/test records, may be destroyed after 20 year retention.

2.6 Suppliers of products and services to the Williamsport facility have an awareness that:

- product or service conformity is required.
- ethical behavior is expected.
- product safety is paramount.

## 3.0 APPLICABLE DOCUMENTS

| | | |
|---|---|---|
| 3.1 | ASME Y14.5-2009 | Dimensioning and Tolerancing (Latest Rev.) |
| 3.2 | H28 | National Bureau of Standards Thread Handbook (Latest Rev.) |
| 3.3 | LQA 1800-155 | Supplier Deviation / Waiver Request |
| 3.4 | LQA 1800-109 | Government Property Control Procedure |
| 3.5 | PI-4020 | Purchase Specification for Ceramics |
| 3.6 | IPC-A-600 | Acceptability of Printed Circuit Boards |
| 3.7 | IPC-A-610 | Acceptability of Electronic Assemblies |
| 3.8 | IPC-A-620 | Requirements and Acceptance for Cable and Wire Harness Assemblies |

## 4.0 GENERAL INFORMATION APPLYING TO DRAWINGS, DIMENSIONS AND TOLERANCES

4.1 General

4.1.1 Unless otherwise specified, all dimensions are in inches.

4.1.2 Drawings are not to be scaled to obtain any missing dimensional information.

4.1.3 Interpretation of Drawings Utilizing Dash Numbers:

4.1.3.1 The part number for a drawing that uses the “Dash –000” is to be interpreted as the drawing number itself, i.e. the part number for item “535000-000” on the drawing would be interpreted as “535000”, **unless the procurement document specifies otherwise**. Dash numbers for items other than “-000” are to be interpreted as the drawing number plus the Dash Number, i.e. “535000-001 would be interpreted as “535000-001”.

4.2 Governing Tolerances

4.2.1 Dimensions and tolerances shall be as specified in the field of the drawing.

4.2.2 The tolerances to be used for untoleranced dimensions shall be those that are specified in notes or referenced specifications and/or standards. When no tolerance is shown or referenced, the pre-printed tolerance block on the drawing applies.

4.2.3 If there are no tolerances in the pre-printed tolerance block on the drawing form, or there is no tolerance block, the following tolerances shall apply for untoleranced dimensions or features.

| | |
|---|---|
| .X | +/-.06 |
| .XX | +/-.02 |
| .XXX | +/-.005 |
| .XXXX | +/-.0005 |
| Fraction | +/-1/64 |
| Angular | +/-1º |
| Surface Finish | 125 or Better |

4.2.4 Where only a tolerance of size is specified, the limits of size of an individual feature prescribe the extent to which variations in its geometric form, as well as size, are allowed.

4.2.5 A 90° angle is implied where center lines and lines depicting features are shown on a drawing at right angles and no angle is specified. When this occurs the angle shall be interpreted as 90° unless otherwise specified in notes or applicable specification.

4.3 Reference Dimensions

4.3.1 Dimensions marked Reference (Ref), and usually without tolerance, are for information purposes only and are intended as guides. They are considered as auxiliary information and do not govern production or inspection operations. Reference dimensions are usually a repeat of a dimension or derived from other values shown on the drawing or related documents.

4.4 Standard Temperature

4.4.1 All dimensions are intended to be measured at a standard temperature of 68°F. Proper compensation must be made in manufacturing when measurements are made at other temperatures.

4.5 Material Stock Tolerances

4.5.1 If the word STOCK (STK) is indicated on a dimension on a drawing, the tolerances shall conform to applicable tolerances for the standard raw material. The tolerance shall be as specified in the referenced Williamsport raw material purchase specification, or when a purchase specification is not referenced, the industrial standard (ASTM, etc.) for the material.

4.5.1.1 As the applicable thickness tolerances of sheet material usually vary with the width of the sheet, the thickness tolerance on the part shall conform to those of the widest standard width of sheet necessary for manufacturer of the part.

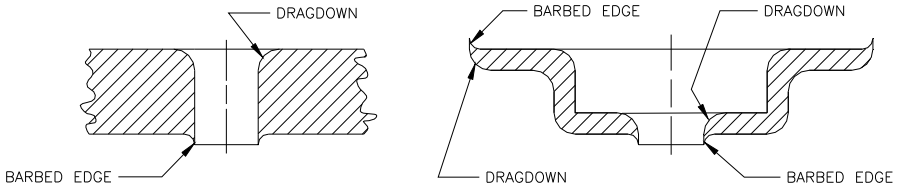
## 5.0 DEFINITIONS

5.1 ANNEALING – A process involving the controlled heating and relatively slow cooling of materials to induce softness, remove stresses, alter mechanical or physical properties, produce a definite microstructure or to remove gasses.

5.2 AXIS – A straight line, real or imaginary, about which parts of a body are symmetrically arranged. (Also see CENTERLINE)

5.2.1 The reference axis shall be defined as the actual axis of rotation of the reference diameter, or shall be defined as the axis of rotation formed by the intersection of planes which bisect the opposite sides of a square or rectangle shape.

5.3 BARBED EDGE – The material displaced in the direction of stock thickening which is caused by the flow of material into the clearance between the punch and die when punching parts.

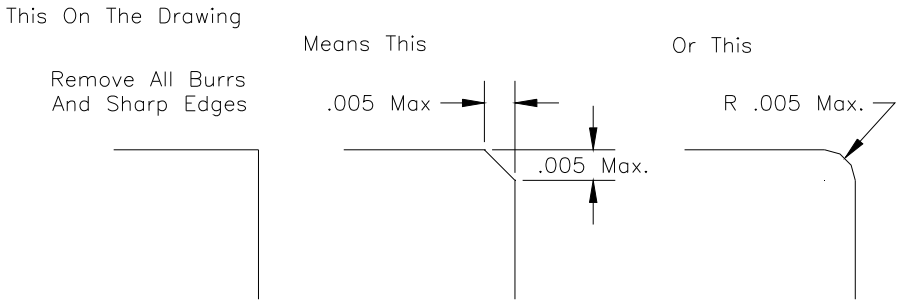



5.4 BASIC – Refers to a fundamental value or desired dimension used to describe the theoretically exact size, profile, orientation, or location. It may be modified by tolerance for practical manufacturing. When used in True Position Dimensioning it carries no tolerance, but it is the basis from which permissible variation is allowed as established by tolerances on other dimensions, in notes, or feature control frames.

5.5 BLEND OR BLENDED – The joining of radii or a radius such that the lines of demarcation are not distinguishable.

5.6 BREAK IN STOCK – A rough, torn, or broken surface which occurs near the end of the cut in a punching or shearing operation.

5.7 BURR – Any undesirable projection or displacement of metal (ridge, sliver, particle, or fragment of base metal) projecting above the surface, into holes or from any edge or corner, or which interrupts the normal symmetry of the part plane or surface.




Removing burrs and sharp edges by methods that create new burrs or sharp edges is not permissable.

A sharp edge is defined as an edge with a .002" or less radius/chamfer.

General notes on removing burrs and sharp edges do not apply to the crest of threads. Threads shall be made to thread specifications without burrs.

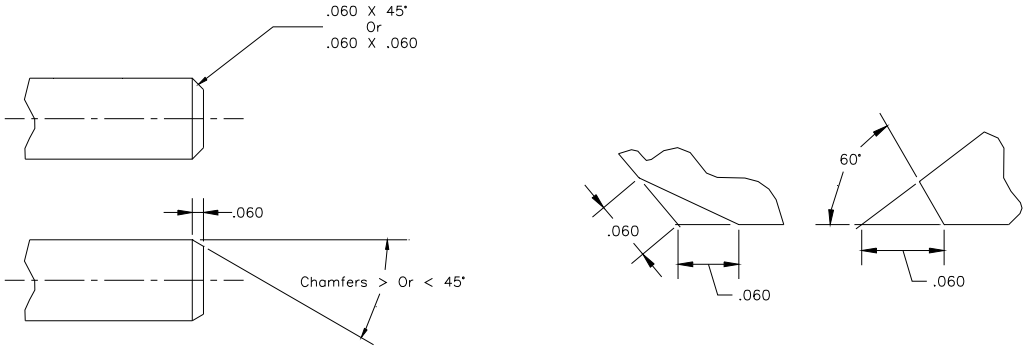
5.8 CENTER – A point, predetermined, about which dimensions are arranged.

5.9 CENTERED – To be located symmetrically about an axis, feature or reference plane.

5.10 CENTERED ON – The degree to which a feature is to be centered on a specified reference. The limit applied is the maximum distance (in either direction) from the specified reference that the feature may vary. The total indicated reading may be twice the applied tolerance when the feature varies from the reference to the extremes in either direction.

5.11 CENTERLINE – The line or lines of centers used as a base for layout of dimensions. (See AXIS).

5.12 CHAMFER – The surface formed by removal of the corner between two intersecting surfaces. The length dimension given is the length of the side opposite the specified angle.



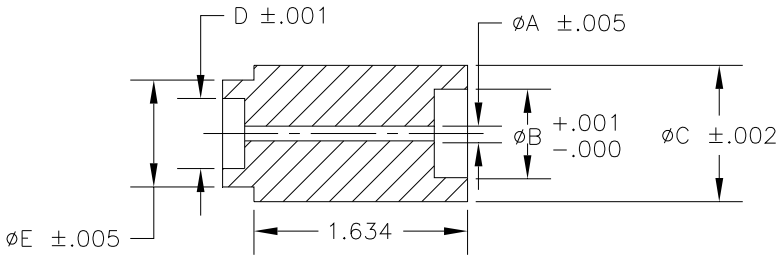

When a chamfer dimension is specified as maximum, the minimum dimension of the chamfer shall be one half the dimension given.

5.13 COINCIDE – To occupy the same place in space. (Not recommended for use)

5.14 CONCENTRIC – Having centers that coincide when projected to one plane.

5.15 CONCENTRICITY – The degree of coincidence of centers (See ECCENTRIC). Any feature designated as concentric with another feature shall have its center spaced no more than the limiting distance (in any direction) from the true center of the reference feature. Where straightness is a factor, its limits should be specified on the drawing.

5.15.1 If concentricity is not specified, any two diameters having a common centerline shall be concentric within a TIR of 1/2 (one-half) the arithmetic sum of the diameter tolerances. The diametrical surface having the smallest tolerance shall be the datum reference for all diameters.




Example: All surfaces machined with øB as datum; therefore, the largest permissible deviation from concentricity to datum "B" will be:

Diameter A – .0055 TIR
Diameter C – .0025 TIR
Diameter D – .0015 TIR
Diameter E – .0055 TIR

5.16 COPLANAR – Lying in the same plane.

5.17 COPLANARITY – The degree of deviation from coplanar. The tolerance limit applied is the distance between two (2) parallel planes within which the specified surface must lie. The total indicated reading may not be more than the applied tolerance and the surface/surfaces must be within the specified limits of size.

5.18 CORNER SHAPE (RADIUS, FILLET, CHAMFER) – The equivalent corner radius shall be .005” Max. For the purpose of this definition, corner radius, fillet, and chamfer shall be considered as the corner shape.

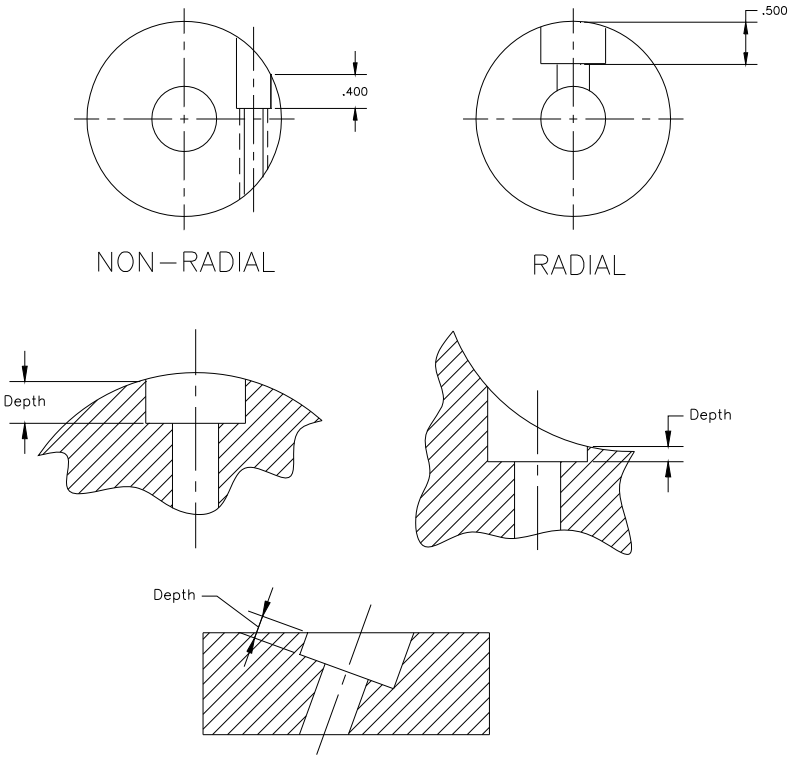
5.18.1 The corner shape should be such that it is equivalent to a maximum radius; i.e., an inside corner may have any shape between a sharp corner (radius=0) and a .005” radius. An outside corner may have any shape between a sharp corner (radius=0 and no burrs) and a 45° chamfer whose side is equal to a maximum of .005” (or a maximum .005” radius).

5.18.2 Corner shapes shall blend with adjacent surfaces without a step being present.

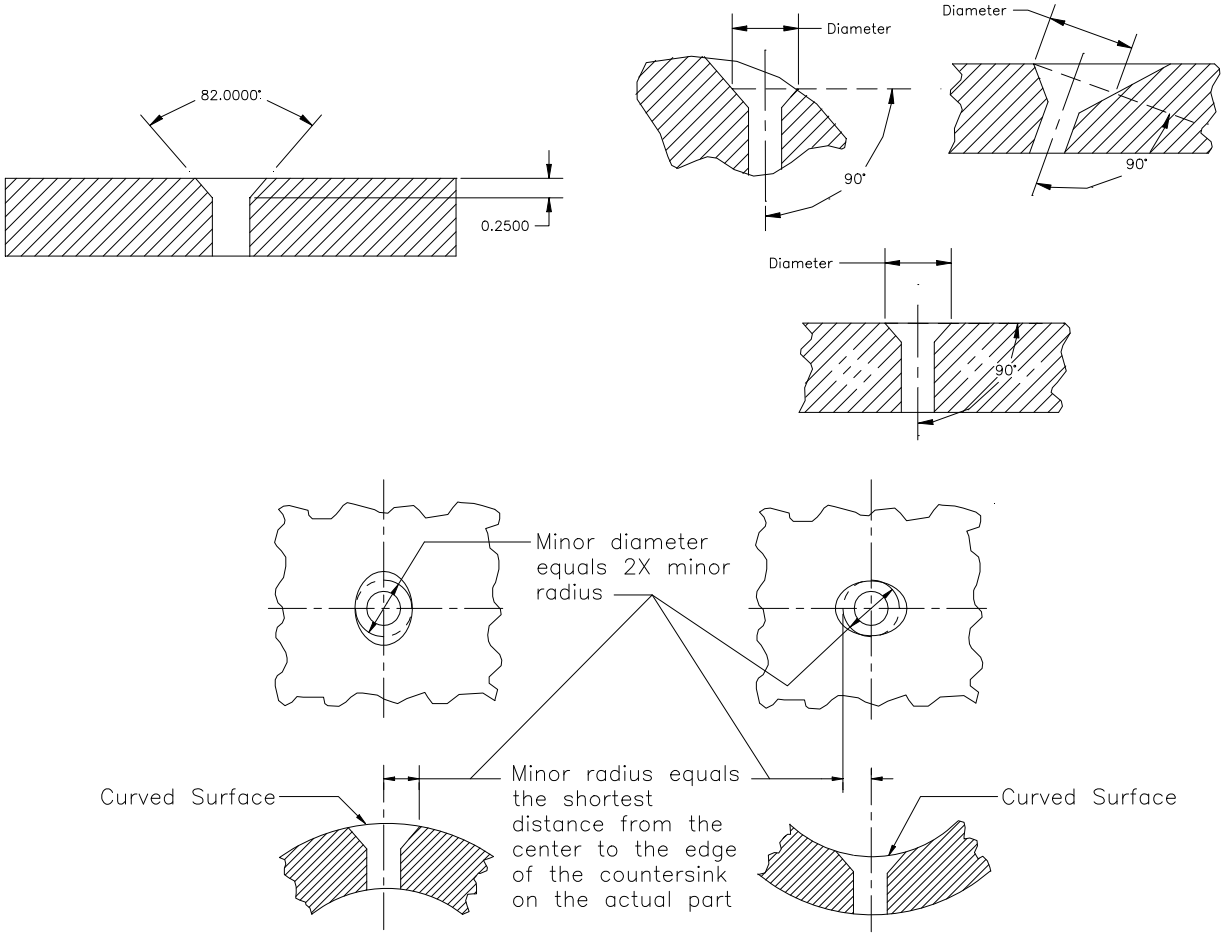
5.18.3 This definition does not apply to “as cast” or “as forged” surfaces or areas of castings or forgings.

5.19 COUNTERBORE – An enlargement of a hole for a portion of its length, usually made by subsequent machining. It is specified by a diameter to a specified depth or remaining thickness.

5.19.1 Unless otherwise specified, the depth dimension of a counterbore in a curved surface is measured at its shallowest point in non-radial applications. In radial applications the depth is measured from the top of curvature.



5.20 COUNTERSINK – A conical surface at the edge of a circular hole. The function of a countersink is for centering, removing sharp edges, providing clearance, or to receive the angular head of a screw, rivet or any such part. The angle is the included angle between opposite sides of the countersink, and the diameter is that of the outside of the countersunk hole.




5.21 CRACK –A separation or fissure in the material.

5.22 DATUM – A theoretically exact point, axis, or plane derived from the true geometric counterpart of a specified datum feature. A datum is the origin from which the location or geometric characteristics of features of a part are established.

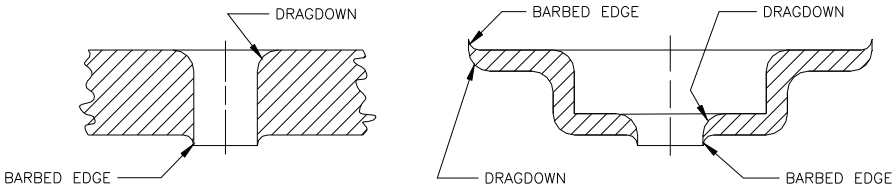
5.23 DENT – A gradual smooth edged depression.

5.24 DIAMETER – The length of a chord which passes through the center of any circular shape.

5.25 DIAMETER, AVERAGE – The mean of the maximum and minimum diameters that can be measured in any one plane.

$$\frac{\textbf{maximum diameter} + \textbf{minimum diameter}}{\textbf{2}} = \textbf{average diameter}$$

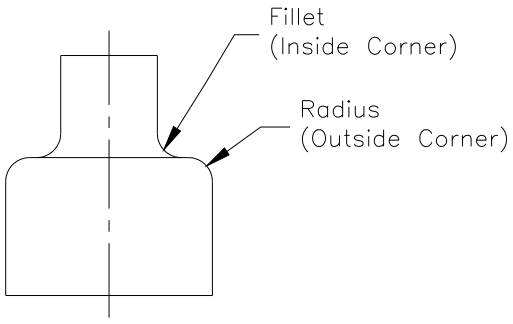
5.26 DRAGDOWN – The permanent deformation of metal in the direction of the stock thinning which occurs on the side opposite the barbed edge (or burr) on punched parts.



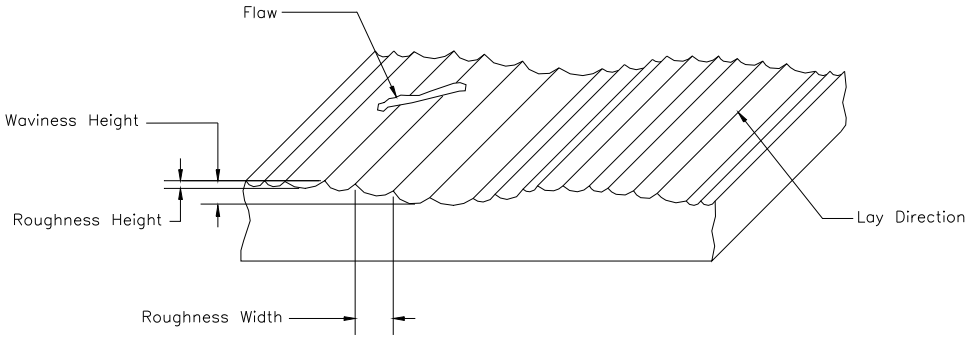

5.27 ECCENTRIC – Off center, located on centers that are not coincident. (See CONCENTRICITY for eccentricity allowed where features are intended to be concentric). Under these conditions eccentricity is the distance between the centers projected to one plane. (See para. 5.15)

5.28 FEATURE – The general term applied to a physical portion of a part, such as a surface, hole, or slot.

5.29 FILLET – A concave curve of uniform or blended compound radii, generally used at a change in section to avoid stress concentration in a corner (For convex curve see RADIUS).




5.30 FINISH - The nature of a surface resulting from small, complex irregularities characteristic of the process by which the surface was derived. This is not to be confused with the irregularities that are flaws which are caused by improper processing, defective material, or handling.



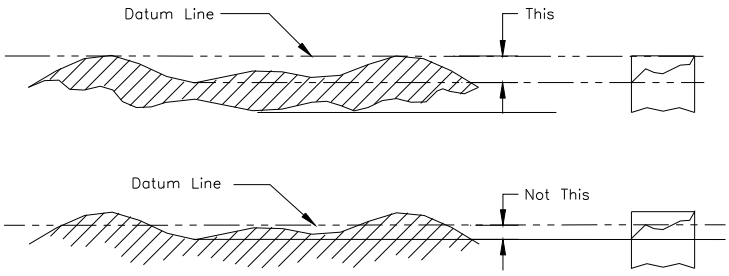
5.31 FINISH QUALITY – The magnitude of the irregularities of a given surface that result from the process by which the surface is derived.

5.32 FISSURE – A break or crack without complete separation of the material, or a hairline in the material surface.

5.33 FLASH – The excess material left by the entrance of material into a seam between mold or die parts.

5.34 FLAT – Any surface which has no radius or curvature in any direction.

5.35 FLATNESS – The permissible departure allowed from an absolutely flat surface. To determine that flatness limits are within specifications, measurements will be made between the plane of the high points of the surface and the low points. The flatness limit applied to the surface cannot be exceeded by the total indicator reading or the limit of size for the feature.




5.36 FLAWS – Irregularities, not characteristic of a given surface or manufacturing process, which occur at irregular and relatively infrequent intervals in the surface. Scratches, dents, cracks, peaks, and holes are typical flaws.

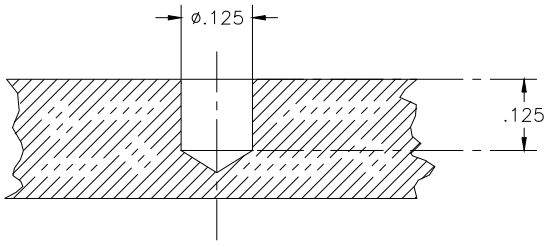
5.37 FLUSH – On a level with an adjacent feature. The limit applied is the maximum (in either direction) that the feature may vary from the reference. The total indicated reading may be two times the applied tolerance when the feature varies from the reference to the extremes in both directions.

5.37.1 The limit may be applied in one direction (i.e., flush to .XXX" underflush) and the maximum total indicated reading is the same as the applied tolerance.

5.38 FULL INDICATOR READING – See TOTAL INDICATOR READING.

5.39 GOUGE – An irregular shaped abrasion.

5.40 HOLE DEPTH – Unless otherwise specified, the depth of a hole will be measured from the surface to the depth of the hole full diameter, exclusive of the drill point.



5.41 LAMINATED – Material which is flaky or composed of layers.

5.42 LAP – A fold in the surface of a part caused by incorrect flow during forming.

5.43 LIMITS – The maximum and minimum values of a dimension.

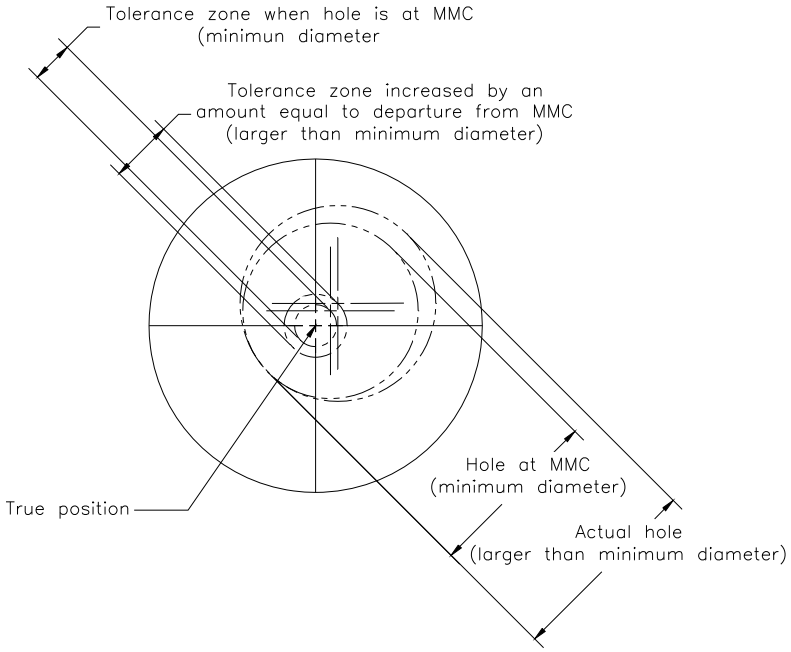
Example: .999” - The maximum limit is .99900”

.997” - The minimum limit is .99700”

5.44 LMC – Least Material Condition – The condition when internal features are at their maximum size and external features are at their minimum size. When LMC is specified, rather than RFS or MMC, variations in size from the least material condition permit corresponding increases in the tolerance of form or position specified.

5.44.1 If no modifying symbol is specified (RFS, MMC, or LMC) RFS applies.

5.45 MMC – Maximum Material Condition – The condition when internal features are at their minimum size and external features are at their maximum size. When MMC is specified, rather than RFS or LMC, variations in size from maximum material condition permit corresponding increases in the tolerance of form or position specified.




5.45.1 If no modifying symbol is specified (RFS, MMC, or LMC), RFS applies.

5.46 NOMINAL – The value midway between maximum and minimum when tolerances are shown. When tolerances are not involved, a close approximation of a standard or commercial size, weight, or volume. The use of nominal dimensions does not imply that any automatic tolerances or special practices are applicable. These dimensions will not be subject to inspection.

5.47 OUT-OF-ROUND – The total deviation from a true circle. It is measured as the total difference between the maximum and minimum diameters.

5.48 PARALLEL – Plane surfaces equally spaced at all points, which if extended, would not intersect.

5.49 PARALLELISM – The degree of deviation from parallel. The limit applied must not be exceeded by the difference between the minimum and maximum measurements from the surface intended to be parallel to the reference surface.

5.49.1 Where straightness is a factor to be considered, its limits should also be specified.

5.50 PERPENDICULAR – At right angles (90°) to a line, axis, or surface.

5.51 PERPENDICULARITY – (All forms except cylindrical) – The degree of deviation from perpendicular. The limit applied must not be exceeded by the difference between the minimum and maximum measurement on the surface intended to be perpendicular to the reference.

5.52 PINHOLE POROSITY – Small voids about 1/8” in diameter or less, in castings, that are a result of the entrapment of evolved gases in the melt.

5.53 PITCH (Thread) – The pitch of a thread is the distance measured parallel to its axis between corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis (See diagram for THREAD NOMENCLATURE).

5.54 POROSITY – The degree to which a material contains fine holes or pores. Microporosity is porosity of a microscopic order. In castings, microporosity is usually caused by solidification.

5.55 RADIUS – 1) One-half (1/2) of a diameter. 2) A smooth continuous convex curve joining adjacent surfaces. (For diagram and concave curves see FILLET).

5.56 REFERENCE DIAMETER – That diameter which, or the center of which, is zeroed out for purposes of maintaining or checking, that the limits of concentricity or other features are within specified boundaries.

5.57 REFERENCE LINE, PLANE OR SURFACE – A line, plane, or surface established as zero from which other dimensions are to be measured or inspected.

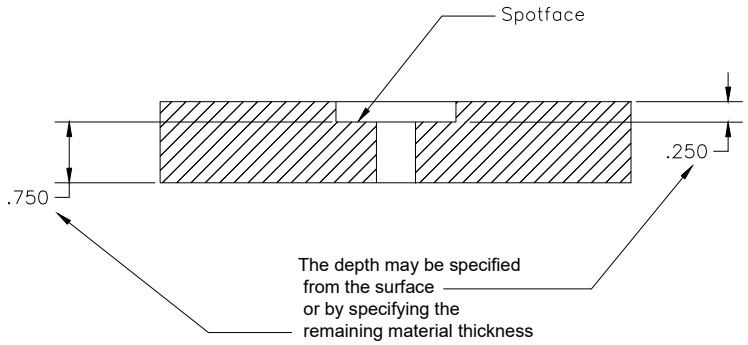
5.58 RFS – Regardless of Feature Size – This indicates that the form or position must be within the limits specified, regardless of the size of the feature(s) concerned. It applies to True Position Dimensioning where indicated and to other types of dimensioning whether indicated or not.

5.58.1 If no modifying symbol is specified (RFS, MMC, or LMC) RFS applies.

5.59 RUNOUT – Runout as applied to a circular hole or circular external surface is the total movement of a point in contact with the circumference during a complete revolution. The runout (Total Indicator Reading) due to eccentricity equals twice the amount of eccentricity.

5.60 SHOULDER – The abrupt change to a larger diameter from a smaller diameter.

5.61 SPOTFACE – The machined surface generally used at the face of a hole and intended to serve as a bearing surface. It is perpendicular to the axis of the hole and is cut to the diameter and depth specified. It shall be specified by a diameter and a depth. The depth may be specified from the surface or by specifying the remaining material thickness after spotfacing. If the drawing does not specify depth or thickness, the material removed shall be the minimum required to produce the full diameter of the spotface.

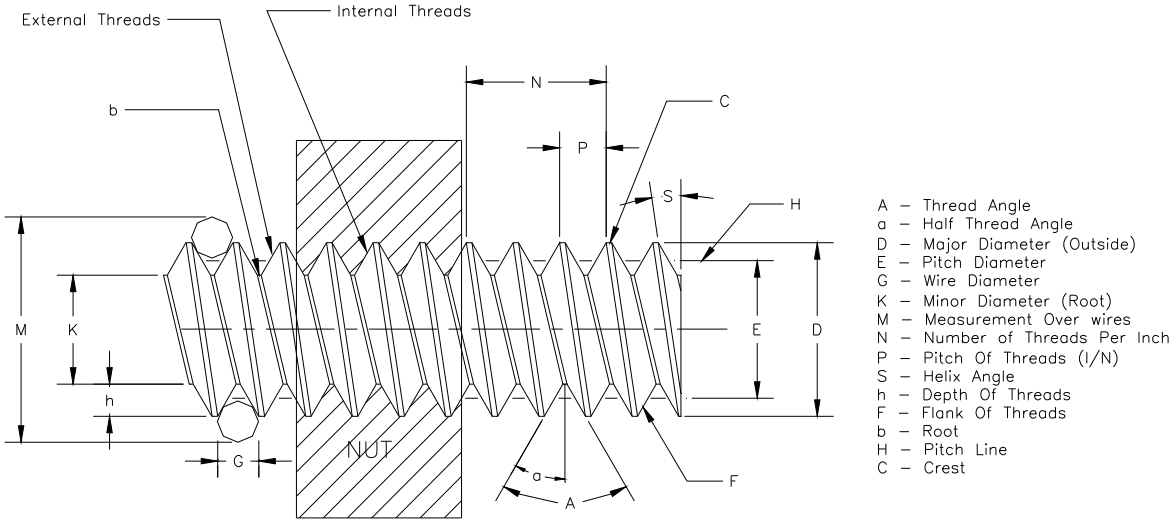



5.62 STRAIGHT – Any line free of curvature or bends.

5.63 STRAIGHTNESS – The degree of deviation from straight. The total difference between the plane of the high points and the plane of the low points shall not exceed the limit specified.

5.64 THREAD DEPTH – The specified depth of a threaded hole shall mean there will be full threads to that depth.

5.65 THREAD NOMENCLATURE




5.66 TOTAL INDICATOR READING – The total movement of an indicator between the minimum and the maximum scale reading, when properly applied to a surface to measure its variation.

5.67 TRUE POSITION – The theoretically exact location of a feature established by basic dimensions.

5.68 TYPICAL (TYP) – A reference applied to specifications to indicate that the dimension or feature identified by this reference appears elsewhere on the part and is identical in size and configuration.

## 6.0 QUALITY REQUIREMENTS

6.1 **The Supplier shall provide the Williamsport Facility with a certificate of conformance for all purchase order items that have a Williamsport part number.**

6.2 The supplier or subcontractor shall maintain an effective system that will assure those parts, materials, and services submitted to the Williamsport facility for acceptance conform to the purchase order or contract requirements. The system shall, at a minimum, conform to the requirements of this document.

6.3 The purchasing document, along with drawings, specifications, procedures, etc. which are referenced shall be reviewed by the supplier or subcontractor prior to part fabrication so that there is no question of intent or misinterpretation of requirements. Inspections and/or tests to the extent necessary to substantiate product conformance shall be performed. As a minimum, final inspection must be performed on all shipments and a record of final inspection must be maintained and kept available for review for a minimum of five years along with certificates of compliance and analysis. The system employed should minimize redundant inspections and maximize techniques consistent with that which is required as indicated by product quality history.

6.3.1 The quality control / assurance responsibility shall be clearly designated within the supplier's organization. Personnel having this responsibility shall have sufficient authority to assure that product quality not be compromised.

6.3.2 When required, the supplier may obtain copies of pertinent drawings, specifications, procedures, etc. through the Williamsport purchasing department. The supplier is **prohibited** from using marked-up or redlined documents, unless they are identified and accompanied by an approved Engineering Change Order.

6.3.3 In the event that requirements are not completely clear, or where special assistance is needed, Williamsport will provide qualified personnel to consult with the supplier. Requests for clarification or assistance shall be made via the Williamsport purchasing department. If inquiries pertain to quality aspects of supplies or services being procured, Williamsport Quality Assurance should be contacted.

6.4 The Williamsport facility reserves the right of entry to its supplier's facility for the purpose of conducting surveys and/or performing surveillance of the supplier's quality system. The purpose of which is to evaluate the degree of ability to comply with the requirements of this document and any other applicable requirements, or to assist in the resolution of quality problems. As necessary, our customer may accompany a Williamsport quality assurance representative during the performance of these functions.

6.5 Customer or government inspection or release of product prior to shipment is not required unless specifically stated on the purchase order as a requirement.

6.6 Materials and/or components supplied to the company may be utilized in equipment which has been or will be subject to Federal Aviation Administration (FAA) type certification or Technical Standard Order Authorization. Your facility and quality system are subject to surveillance by authorized representatives of the Federal Aviation Administration. If this occurs, upon request, the companies' suppliers shall provide all reasonable facilities and assistance to the authorized FAA representatives.

6.7 Surveillance inspection and / or test conducted by the company or representatives of any customer or government agency at the supplier's or Williamsport facility shall not relieve the supplier of their responsibility in meeting the requirements of the purchase order.

6.8 Inspection and testing procedures used by the supplier shall be clear, complete, and current. When required, the instructions shall assure inspection and test of materials, work in process and completed items. These instructions should include the criteria for approval and rejection.

6.8.1 Raw material procured by the supplier or subcontractor for the purpose of fabrication of parts, etc., specified on the purchase order or contract will require certification of material analysis that satisfies the requirements of the appropriate material specification. When required by the purchase order, a copy of this certification must accompany the product when delivered, in addition, when specified on the purchase order or contract a sample of the material used must also accompany the product.

6.8.2 The supplier is responsible for compliance with any other certification requirements referenced on the purchase order and for maintaining records evidencing compliance with such requirements, regardless of whether the work was performed by the supplier or lower-tier suppliers.

6.8.3 The contractor shall maintain adequate records of inspections and tests necessary to assure compliance to requirements. When appropriate, the records shall indicate the nature and number of observations made, the deficiencies found and the quantities approved and rejected.

6.9 The supplier shall perform inspection and/or test on end items covered by the purchase order prior to delivery or submission to the Williamsport facility. Inspection/test of supplies, which cannot be readily examined in the completed product, must be performed at the appropriate in-process stages of manufacturing. Adequate records of inspection/tests must be maintained by the supplier.

6.9.1 The supplier shall maintain a positive system for identifying the inspection status of parts, materials, or services. This may be accomplished by the use of stamps, tags, routing cards, move tickets, tote box cards, etc.

6.10 The Williamsport facility reserves the right to use sampling procedures in accordance with the procedures of ANSI / ASQC Z1.4-1993 for the acceptance or rejection of supplies. If a lot is rejected by the sampling procedure, the entire lot may be returned to the supplier for screening at the supplier's expense, or the Williamsport facility may screen the rejected lot at the supplier's expense if agreed to by the supplier.

6.11 The supplier or subcontractor's system shall provide for assurance that supplies are fabricated, inspected and tested to the latest applicable drawings, specifications, or other procurement requirements, as well as authorized changes thereto, as specified on the purchase order or contract. All changes shall be processed in a manner that will assure incorporation on the affected supplies at the specified effectivity.

6.12 The supplier shall maintain a system to assure that supplier procured supplies and services conform to drawing and specification requirements. Applicable requirements shall be conveyed to suppliers in every tier. The implementation of such controls shall be subject to surveillance by the Williamsport facility.

6.13 The supplier shall establish a system to assure special or critical processes are controlled. Special or critical processes are defined as thermal, chemical, metallurgical or other critical processes, the control of which cannot be readily determined by inspection of the part. Competent personnel using proper procedures shall perform these processes, in accordance with requirements, in adequate facilities.

6.13.1 When critical or special processes are performed outside the supplier's facility, it shall be the supplier's responsibility to assure proper performance of all such processes through surveys, certifications, testing, etc.

6.14 The supplier or subcontractor shall maintain an effective system for controlling nonconforming material. Nonconforming material that cannot be completed or reworked to print or specification may be submitted to the Williamsport facility for evaluation. Requests for review of discrepant materials shall be made through the Williamsport purchasing department. The williamsport facility does not extend Material Review Board authority to its suppliers or subcontractors; therefore any deviations from requirements must be approved prior to shipment through use of LQA 1800-0155 – Supplier Deviation / Waiver Request.

6.14.1 In no case will nonconforming material be reworked to an out-of-tolerance or specification configuration without prior written approval by the Williamsport facility.

6.14.2 Non-conforming supplies shall be positively identified to prevent use, shipment, and intermingling with conforming supplies.

6.14.3 The supplier shall notify Williamsport purchasing or quality departments if a non-conformance is discovered that may affect the form, fit, function, usability, or reliability of material, parts, or assemblies that have already been shipped.

6.15 The supplier or subcontractor system shall provide a means for ready detection of discrepancies and for taking action to correct assignable conditions that have resulted or could result in submission of parts, materials and services that do not conform to requirements. Corrective action must be positive and specific to the extent necessary to prevent recurrence of defects.

6.15.1 The supplier is responsible for initiating prompt replies to “Supplier Corrective Action Reports” and implementation of required corrective actions.

6.16 The supplier shall have an adequate system of age control of materials. This system shall be applicable to all materials whose acceptability is limited by the maximum age of the material. The system shall include a method for identifying the age of such materials, and provisions for the rotation of stock and purging of material beyond its useful life.

6.17 All tooling and/or test equipment fabricated by the supplier at Williamsport expense, or supplied by Williamsport for supplier use, shall be considered property of the Williamsport facility and/or their customer. Such tooling and test equipment shall be inspected, maintained and calibrated. Tooling and test equipment controls shall be accomplished by the supplier and may be reviewed by Williamsport or its customers. Government owned tooling and equipment at supplier facilities shall be maintained in accordance with the applicable FAR’s as outlined in LQA 1800-109, Government Property Control Procedure.

6.18 The supplier or subcontractor shall have a system to provide and maintain accurate gages and other measuring and testing devices necessary to assure that the parts, materials, or services supplied conform to requirements. This system shall assure that the inherent accuracy of the equipment is compatible with the requirements of the products being tested, and that the required measurements are adequately performed. To assure continued accuracy, the devices shall be calibrated at established intervals against certified standards that have known relationship to national standards.

6.18.1 All equipment used to determine acceptance of supplies shall be subject to, as a minimum, an initial inspection, calibration and re-calibration at prescribed intervals (determined by the supplier, but not to exceed yearly).

6.18.2 All tools and test equipment, unless size or use prohibits, shall be identified with a tag permanently attached that contains the following information:

6.18.2.1 Tool identification number.

6.18.2.2 Calibration/inspection date.

6.18.2.3 Re-calibration/re-inspection due date.

6.18.2.4 Initials of the calibration/inspection technician.

6.18.2.5 If Williamsport property – “Property of Stellant Systems”

6.18.3 The supplier shall be responsible for maintaining adequate records for all gages or other test and measurement devices that could affect product quality. These records shall indicate the periodic calibrations performed and shall be readily available for review by the Williamsport facility and/or government/customer agencies.

6.19 If no specific packaging or preservation instructions are invoked in the purchase order the following applies:

6.19.1 All material subject to corrosion (such as rust) shall be cleaned of corrosion and protected through the application of a suitable corrosion preventative. The corrosion preventative must adhere to the requirements of section 7.0.

6.19.2 All materials intended for Williamsport shall be protected against the usual hazards of corrosion, contamination, deterioration, etc. at the supplier's facility and in transit. No storage method or packaging material shall introduce risks of corrosion, contamination, deterioration, etc. Materials intended for Williamsport shall not have tape applied directly to its surfaces. When tapes or other adhesives are used, a protection barrier must remain between the adhesives and the surface of the parts.

6.19.3 All materials intended for Williamsport shall be packaged with suitable protection to prevent damage through handling, storage at the supplier's, in transit and storage at the Williamsport facility.

6.20 No supplier shall buy, sell, trade, or transfer Williamsport related materials, parts, devices, assemblies or end equipment for purposes other than the performance of Williamsport business, without prior written approval. Furthermore, no Williamsport part numbers or information related to those part numbers shall be disclosed to entities other than the Williamsport facility without prior written approval.

6.21 Reporting of measurements and test results

6.21.1 DETERMINATION OF SIGNIFICANT DIGITS - The Absolute Method shall be used to establish uniform methods of indicating the number of significant digits in an observed or calculated test value or result for purposes of determining conformance with specifications.

6.21.2 The Absolute Method considers all digits in a test value as significant for purposes of determining conformance with specifications. Under these conditions, the specified limits are referred to as absolute limits.

6.21.3 Test values with a plus and/or minus tolerance or a maximum and/or minimum are considered to be absolute values and are not to be rounded-off unless otherwise specified. Reported values that are an average of two or more test values are to be rounded-off to the same number of significant digits as the individual test value even though the specification requirements are considered absolute.

## 7.0 Coolants and Lubricants

7.1 The parts procured used by the Williamsport facility are used in high vacuum devices. Because of this, great care must be exercised to avoid contamination of the surfaces of parts. Experience has shown that many cutting oils leave a film of contamination that is difficult, if not impossible, to remove. Treatments such as barrel tumbling of chemical dips can also present problems.

7.2 Coolants, lubricant and solvents that are approved for use are listed in the Williamsport procedure PI-4042, Qualified Product List – Coolants, Lubricants and Solvents.

7.3 No substitutions for the approved coolants, lubricants and solvents are permitted without prior authorization by the Williamsport facility. Authorization for the use of un-approved or proposed additions to the approved listing of coolants, lubricants and solvents shall be requested, evaluated and approved / disapproved by the Williamsport facility in accordance with PI-4042, Qualified Product List – Coolants, Lubricants and Solvents.

## 8.0 Restrictions on Material Used for Tools, Dies, Jigs, Fixtures and Gauges

8.1 Materials in the form of tools, dies, jigs, fixtures and gauges which may leave an objectional deposit (which is not removable by normally specified cleaning processes) on a part or assembly shall not be used on internal parts of the tube structure.

## 9.0 Threads

9.1 General

9.1.1 All threads, unless otherwise specified on the drawing shall conform to the unified tabulations and formulations of the National Bureau of Standards Handbook H28. Unified Form Threads, American National Form Threads, Special Threads and Unified Miniature Screw Threads shall be defined by the Unified System.

9.1.2 The class of fit shall be Class 2A for external threads and Class 2B for internal threads unless otherwise specified on the drawing.

9.2 Metric Threads

9.2.1 Metric threads shall conform to the ISO. Metric System (International Organization for Standardization) unless otherwise specified, Ref. ANSI B1.16.

9.2.1.1 ISO metric threads are basically designated by the letter “M” followed by the nominal size in millimeters, separated by the “X”.
Example: M16 X 1.5.

9.2.1.2 The class of fit for metric threads shall be “6G’ for external threads and “6H” for internal threads unless otherwise specified on the drawing.

9.3 Where tolerances of form or position are applicable to a screw thread and /or datums are referenced to screw threads, it shall be understood to apply to the pitch diameter of the thread. If requirements necessitate an exception to this, a qualifying notation will supplement the symbol or note, e.g., “Major Dia.”

9.3.1 Thread Form will typically be checked at Williamsport by the use of “Go” / “No Go” thread gauges.

9.3.2 Threaded hole position will typically be checked at Williamsport by the use of tapped hole location gages.

## 10.0 Machined Parts

10.1 Burrs

10.1.1 A burr is defined as any undesirable projection or displacement of metal (ridge, sliver, particle, or fragment of base metal) projecting above the surface, into holes or from any edge or corner, or which interrupts the normal symmetry of the part plane or surface.

10.1.1.1 It shall be standard practice to remove burrs from the edges of all surfaces, even if this requirement is not noted on the drawing or other requirements.

10.1.1.2 Unless otherwise noted on the drawing or other requirements, burrs shall be removed to the extent that they are not visible when viewed with 7X magnification under a high intensity lamp.

10.1.1.3 Any method of de-burring must not introduce part contamination, and all loose particles must be removed.

10.1.1.3.1 Note: Scotch Bright may not be used on any internal tube parts.

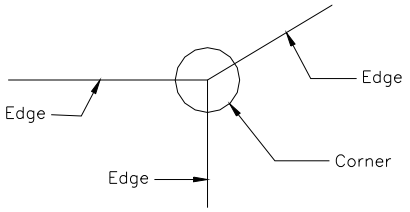
10.1.1.4 In no case shall dimensional tolerances be exceeded as a result of a burr or burr removal.

10.1.1.5 Unless otherwise specified, edge break resulting from burr removal shall not exceed .005 inch radius or chamfer.

10.1.1.6 If “Sharp Edge” is specified on the drawing, edge break shall not exceed .002 inch radius or chamfer.

10.2 Edges and Corners

10.2.1 Edges and corners are defined as the theoretical apex of the angle or point formed by the intersection of two or more planes.




10.2.1.1 A “Sharp Edge” / “Sharp Corner “ is an edge or corner with a .002 inch or less radius or chamfer.

10.2.1.1.1 It shall be standard practice to remove all sharp edges unless otherwise specified.

10.2.1.2 Outside edges shall be broken by either a 45° chamfer or a radius. If limits of edge break are not specified, a .005 inch maximum chamfer or radius is acceptable for lengths less than 1 inch, otherwise .005 inch / inch of the smallest adjacent width or diameter shall be applied.

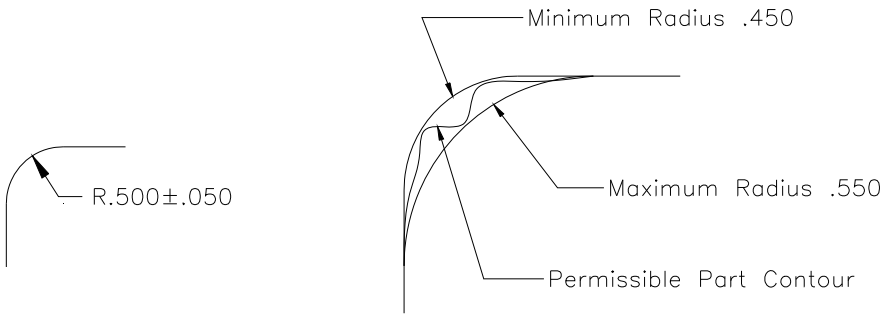
10.2.1.3 Inside corners shall have a maximum inside corner radius, chamfer, or fillet of .005 inch unless otherwise specified.

10.2.1.3.1 Undercutting at inside corners is not permitted unless otherwise specified.

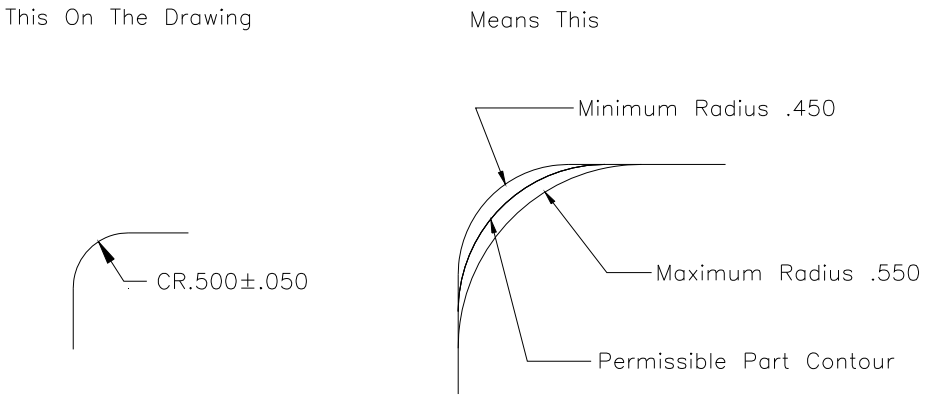
## 10.3 Radii

### 10.3.1 Radius Tolerance

10.3.1.1 A radius symbol **R** creates a zone defined by two arcs (the minimun and maximum radii). The part surface must lie within this zone.




10.3.1.2 A controlled radius symbol **CR** creates a tolerance zone defined by two arcs (the minimun and maximum radii) that are tangent to the adjacent surfaces . When a controlled radius is specified the part contour within the crescent-shaped tolerance zone must be a fair curve without reversals



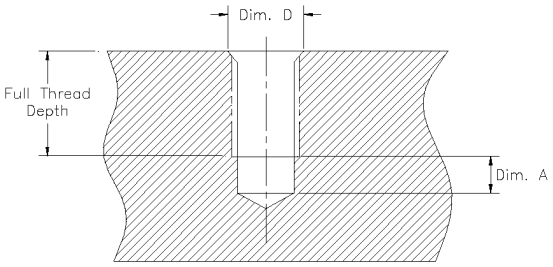

## 10.4 Threaded Holes

10.4.1 In gaging a threaded hole, the “NO-GO” gage shall not penetrate more than 3 turns. The “Go” gage shall freely penetrate the full length of the depth specified.

10.4.2 Unless otherwise specified on the drawing breakthrough is not acceptable.

10.4.3 In order to provide clearance for the lead of the tap, blind tapped holes may have the tap drill extend deeper than the required full thread depth per the limits of the following table (Dim. A), as long as no breakthrough occurs.

10.4.4 Unless otherwise specified, on material greater than four threads thick, the entrance end of internal threads shall be countersunk 80 to 120º included angle and have a maximum diameter (Dim. B below) equal to the thread major diameter + .020” and minimum diameter equal to the thread major diameter + .005”.




| Thread Size | "D" Dia. Min. | "D" Dia. Max. | Max. Depth "A" |
|---|---|---|---|
| 2 (.086) | .094 | .125 | .125 * |
| 3 (.099) | .109 | .141 | .125 * |
| 4 (.112) | .125 | .156 | .188 * |
| 6 (.138) | .156 | .188 | .219 * |
| 8 (.164) | .188 | .219 | .219 * |
| 10 (.190) | .219 | .250 | .266 * |
| 1/4 (.250) | .281 | .312 | .375 * |
| 5/16 (.312) | .344 | .375 | .422 * |
| Over 5/16 | Maj. ø +.030" | Maj. ø +.060" | 1X Thread ø* |

* Breakthrough is not acceptable unless otherwise noted

10.5 External Threads

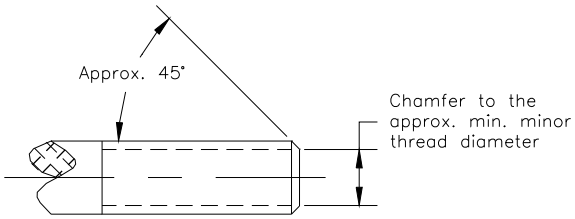
10.5.1 In gaging an external threaded, the threaded piece shall not penetrate more than 2 turns into the thread “No-Go” gage. The “Go” gage shall turn freely onto the piece to the full thread length specified.

10.5.2 Unless otherwise specified on the drawing the length of threads shall be the length of complete (full) threads and incomplete threads are permitted beyond this dimension to allow for the lead of the die.

10.5.3 External threads shown to a shoulder on a drawing, without mention of an undercut, may have the last complete (full) thread at a distance of not more than twice the pitch (2 thread lengths) from the shoulder.

10.5.3.1 An undercut shall not be used unless specified on the drawing.

10.5.4 Unless otherwise specified the end of all externally threaded parts shall be chamfered to an included angle of 90º+/-5º to a minimum depth of the minor diameter and a maximum depth of ½ the thread depth below the minor diameter.

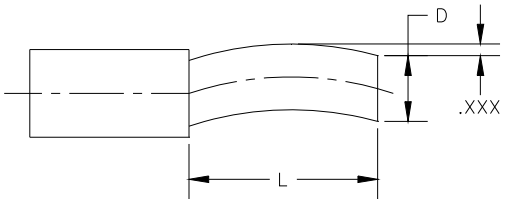


10.6 Straightness Not Specified

10.6.1 When there is no requirement for straightness on the drawing, the below requirements shall apply.

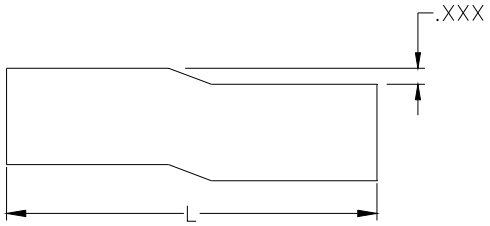
10.6.1.1 The following table lists the allowable deviation from straightness of cylindrical and conical features:

| Length (L) | Diameter (D) | Max. Deviation (XXX) |
|---|---|---|
| 0 - .9999” | 0 – 1.0” | .0015” |
| 1.0000” – 1.9999” | 0 – 1.0” | .0020” |
| 2.0000” – 2.9999” | 0 – 1.0” | .0025” |
| 3.0000” – 5.0000” | 0 – 3.0” | .0030” |




10.6.1.2 The following table lists the allowable deviation from straightness of a plane surface or element having other than a cylindrical or conical cross section:

| Length (L) | Max. Deviation (XXX) |
|---|---|
| 0 - 1.9999” | .0020” |
| 2.0000” – 2.9999” | .0025” |
| 3.0000” – 4.9999” | .0030” |
| 5.0000 – 7.9999 | .0035 |
| 8.0000 – 9.9999 | .005 |
| 10.0000” – 15.0000” | .0080” |



10.7 Grinding or Turning Centers

10.7.1 Unless otherwise specified on the drawing, grinding or turning centers are not permissible.

10.8 Breakthrough

10.8.1 Unless otherwise stated on the drawing, breakthrough of holes, plane or threaded is not acceptable.

10.9 Surface Conditions

10.9.1 Appearance: All surfaces shall have an appearance characteristic of the material specified, and shall be free from oxide, orange peel, cracks, wrinkles, delaminations, etc.

10.9.2 There shall be no embedded material.

10.9.3 There shall be no cracks in the material.

10.9.4 There shall be no de-laminating of material.

10.9.5 Flaws and/or scratches are permitted only within the confines of good workmanship as determined by the Williamsport facility (See para. 10.13)

10.9.6 All surfaces shall have an appearance characteristic of the material specified, and shall be free from oxide, cracks, wrinkles, and orange peel.

10.9.7 The finish requirement for machined surfaces shall be 125 microinches or better unless otherwise specified.

10.9.7.1 Surface finish requirements apply to all surfaces not otherwise specified.

10.9.7.2 Flaws are not included in surface finish measurements.

10.9.8 Commercial stock finish is acceptable only when “Stock” is specified as a requirement.

10.10 Un-restrained Diameters

10.10.1 Unless otherwise specified, the diameter limits specified on an individual part drawing are the limits within which the average un-restrained diameters must fall.

10.11 Tolerances and Dimensions

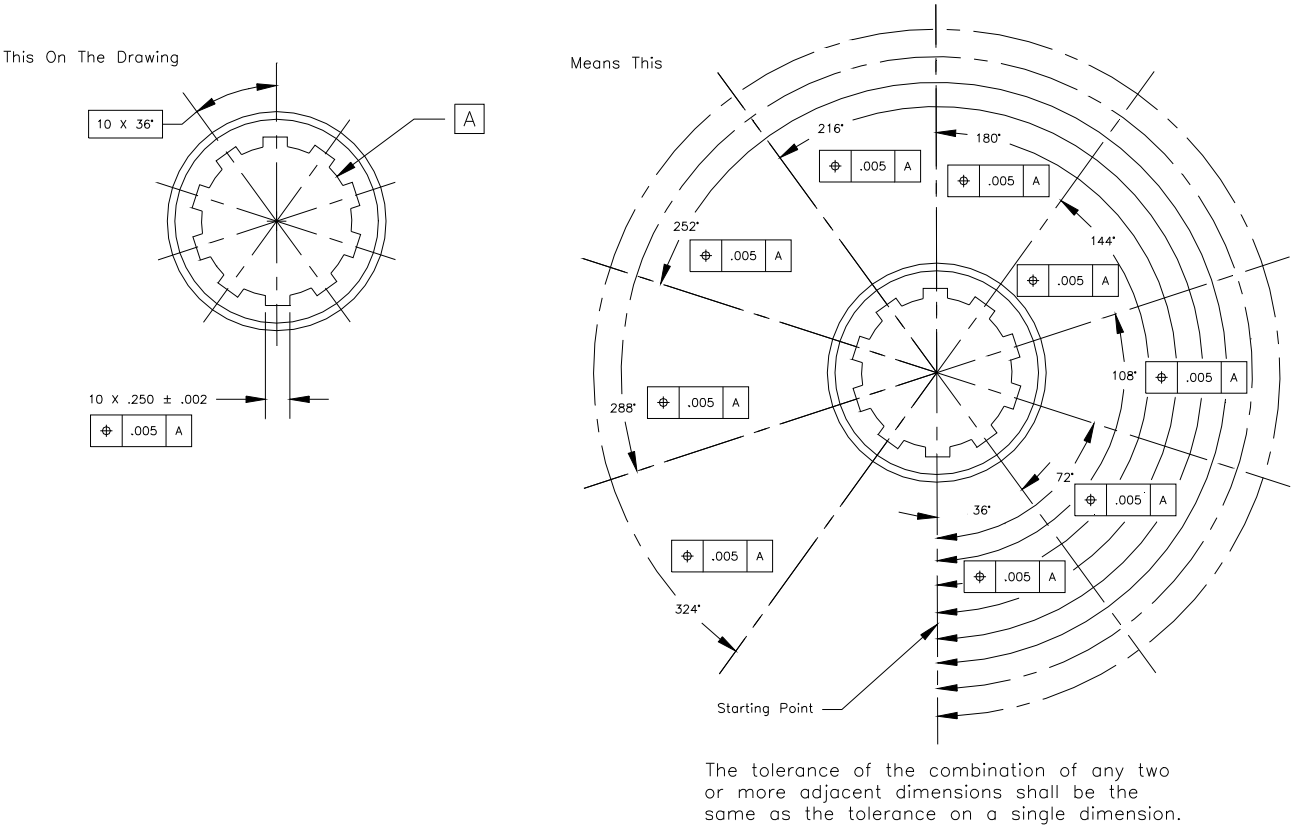
10.11.1 All dimensions on parts must be met after all processing has been completed. Processing includes all manufacturing operations such as heat treating, bead blasting, machining, polishing, grinding, plating and chemical finishes. When paints, enamels, electro films, etc. are used, all dimensions must be met prior to application unless otherwise specified.

10.11.2 When comparing measured values with a dimension and it’s stated tolerance, it is not permissible to round the digit in the decimal place one place beyond the last digit in the stated tolerance in order to reflect conformance.

10.11.3 Any variation from a target dimension permitted by this document shall in no case permit the part to extend beyond the tolerance zone of the drawing controlling dimension.

10.12 Cumulative Tolerances

10.12.1 Tolerances are not cumulative. The maximum variation between two or more of a group of repetitive features is controlled by the tolerance on the dimension between the features.




The tolerance of the combination of any two or more adjacent dimensions shall be the same as the tolerance on a single dimension.

10.13 Flaws

10.13.1 The following are not acceptable unless otherwise specified:

10.13.1.1 Splits, tears, cracks and voids.

10.13.1.2 Displaced metal, folds (ironed in or smeared over scratches and burrs).

10.13.1.3 Inclusions (imbedded particles – chips, burrs, foreign material).

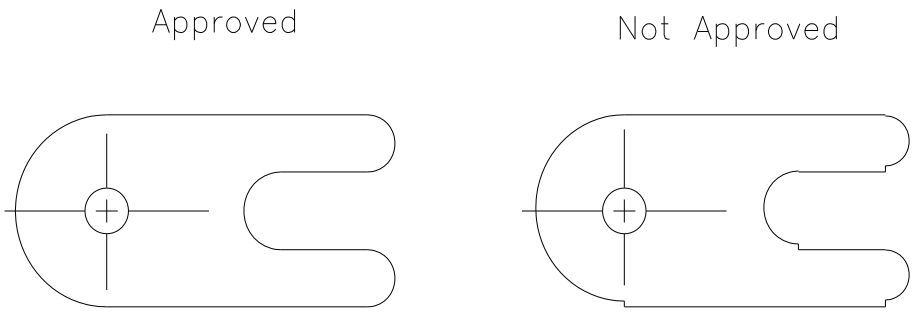
10.13.1.4 Oxide (rust or corrosion)

10.13.1.5 Seams.

10.13.1.6 See paragraph 17.0 for examples and definition of surface imperfections.

10.14 Blending surfaces

10.14.1 All connecting curved surfaces, or curved and plane surfaces shown as tangent must bend smoothly.




10.15 Out of round limits defined

10.15.1 Out of round – Circular features must meet the specified limits for both size and roundness.

10.15.1.1 Rigid parts – A rigid part or a non-rigid part bearing notes such as “In the free state” or similar, must meet the limits of size, and the ovality of the part shall be within the two circles representing the high and low limits of size. This holds true unless the requirement is either relaxed or tightened by the addition of a separate circularity tolerance requirement.

10.15.1.2 Non-rigid parts – For the purpose of this standard a non-rigid part is one which does not maintain circular form due to flexing. This free state variation occurs after removal of forces applied during manufacture. This distortion is principally due to weight and flexibility of the part and the release of internal stresses resulting from fabrication. A part of this kind – for example, a part with a very thin wall in proportion to its diameter – is referred to as a non-rigid part.

10.15.1.3 Any limits of circularity of non-rigid parts in the free state or in a restrained condition will be stated on the drawing or specification.

10.15.1.3.1 When a concern arises or circularity of non-rigid parts is not specified with respect to “free state” or “restrained” measurement, contact the purchasing department for clarification.

## 11.0 Drawn / Formed Parts

11.1 Burrs

11.1.1 A burr is defined as any undesirable projection or displacement of metal (ridge, sliver, particle, or fragment of base metal) projecting above the surface, into holes or from any edge or corner, or which interrupts the normal symmetry of the part plane or surface.

11.1.2 Unfinished parts, which are to be trimmed or cut, may exhibit burrs which are normal to the process used and not critical to product performance or safety.

11.1.3 Finished parts

11.1.3.1 It shall be standard practice to remove burrs from the edges of all surfaces, even if this requirement is not noted on the drawing or other requirements.

11.1.3.2 Unless otherwise noted on the drawing or other requirements, burrs shall be removed to the extent that they are not visible when viewed with 7X magnification under a high intensity lamp.

11.1.3.3 Any method of de-burring must not introduce part contamination, and all loose particles must be removed.

11.1.3.3.1 Note: Scotch Bright may not be used on any internal tube parts.

11.1.3.4 In no case shall dimensional tolerances be exceeded as a result of a burr or burr removal.

11.1.3.5 Unless otherwise specified, edge break resulting from burr removal shall not exceed .005 inch radius or chamfer.

11.1.3.6 If “Sharp Edge” is specified on the drawing, an edge break shall not exceed .002 inch radius or chamfer.

11.2 Corners

11.2.1 Inside corners on drawn / formed parts may have a nominal radius of twice the stock thickness unless otherwise specified.

11.3 Surface Condition

11.3.1 Appearance: All surfaces shall have an appearance characteristic of the material specified, and shall be free from oxide, orange peel, cracks, wrinkles, de-laminations, etc.

11.3.2 There shall be no embedded material.

11.3.3 The finish requirement for machined surfaces on drawn / formed parts shall be 125 microinches or better unless otherwise specified.

11.3.3.1 Surface finish requirements apply to all surfaces not otherwise specified.

11.3.3.2 Flaws are not included in surface finish measurements.

11.3.4 De-lamination – There shall be no de-lamination of material.

11.3.5 Cracks in refractory metals (Molybdenum, Tungsten, etc.) – Axial cracks shall not exceed more than 25% through the thickness of the section where they appear. Cracks other than axial, are not permissible.

11.3.5.1 In instances where vacuum seals are made, or other requirements indicate the need for material free from cracks, a note shall appear on the drawing.

11.4 Flaws

11.4.1 The following are not acceptable unless otherwise specified:

11.4.1.1 Splits, tears, and voids.

11.4.1.2 Displaced metal, folds (ironed in or smeared over scratches and burrs).

11.4.1.3 Inclusions (imbedded particles – chips, burrs, foreign material).

11.4.1.4 Oxide (rust or corrosion)

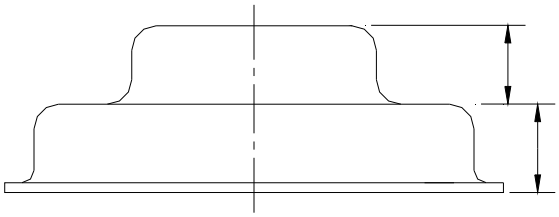
11.4.1.5 Seams.

11.4.1.6 See paragraph 17.0 for examples and definition of surface imperfections.

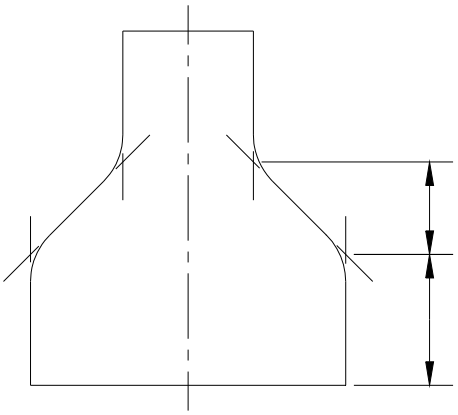
11.5 Length Dimensioning (Between changes in diameters):

11.5.1 Where parts have measurable shoulders between changes in diameter, the length shall be that distance between a shoulder and any other locating feature.

11.5.2 Where the length of transition permits projection, the length shall be measured



between the point of intersection of the projected transition (sloping surface) with the projected sides.



11.5.3 Where there is no clearly defined shoulder or where the length of transition from one diameter to another is too short to permit a projection, the length shall be measured from the point of tangency of the corner shape to the next locating feature as specified.

11.6 Out of round

11.6.1 Out of round conditions are limited to specified tolerance limits on the drawing for the given diameter unless otherwise specified.

11.7 Wall thickness variation

11.7.1 The wall thickness shall not deviate from the mean specified stock thickness by more than 10 percent plus the specified variation in stock thickness.

11.8 Taper

11.8.1 Taper is permissible providing the specified diameters and wall thickness are maintained.

## 12.0 Magnets

12.1 Surface Condition - All magnet surfaces shall be free of foreign materials.

12.2 Chips and Burrs - Magnets shall be free of loose chips and burrs. They shall be free of imperfections which will result in loose chips or particles under normal conditions of handling, shipping, assembly and service.

12.2.1 A chipped edge or surface shall be acceptable if no more than 10 percent of the edge or 5 percent of the surface is removed, provided no loose particles remain at the edge or surface, and further provided the magnet under examination meets the magnetic specification as defined on the drawing.

12.3 Other Physical Defects – Imperfections such as minor hairline cracks, porosity, voids, cold flow, shrinkage, pipes and others, all of the type commonly found in cast or sintered metallic magnets, shall be judged acceptable if the following conditions are met.

12.3.1 The magnet meets the minimum magnetic performance criteria as defined and as tested.

12.3.2 The imperfections do not create loose particles or other conditions, which will interfere with proper functioning of the end device.

12.3.3 In the case of visible cracks or imperfections, they do not extend through more than 25 percent of any cross section, and 50 percent in the case of Alnico 9.

12.3.4 Sheathed Magnets – Magnets requiring cast sheathing must be free of sheathing separation from the base magnet.

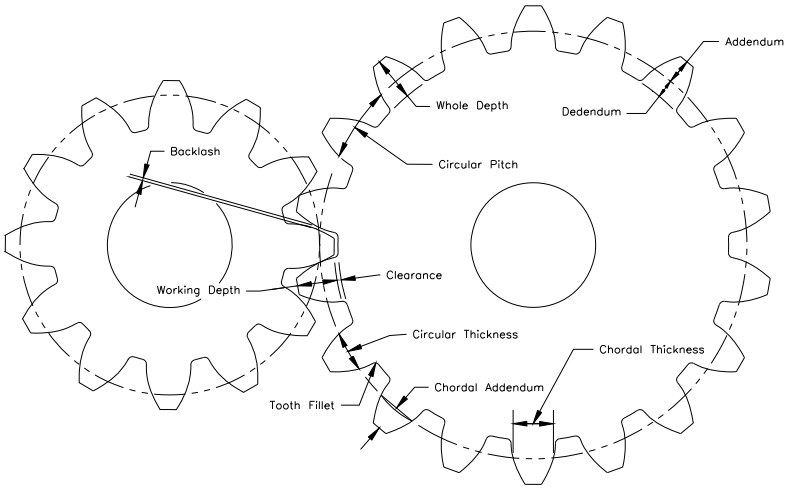
12.3.5 Magnet Dimensions and Tolerances – Dimensions shall be as specified on the drawing and within the tolerances given therein.

## 13.0 Gears

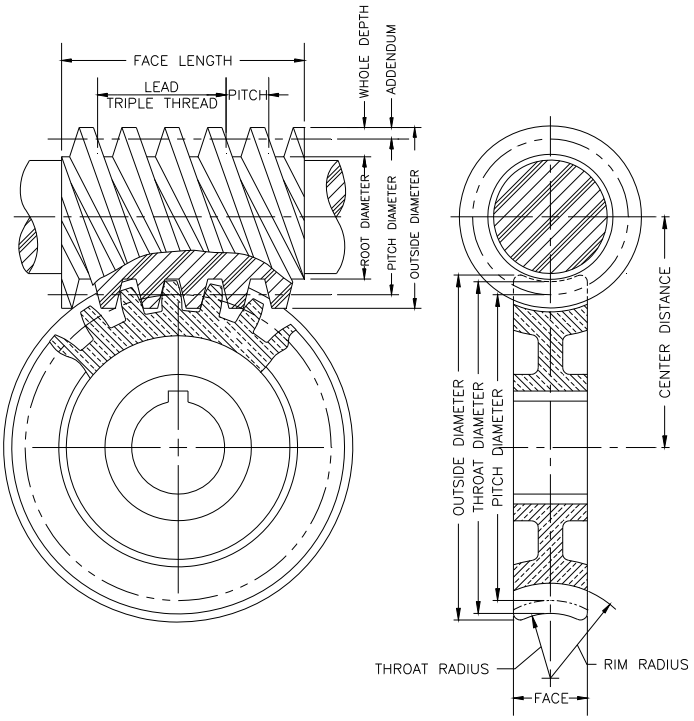
13.1 All gears shall be made in accordance with the requirements of the American Gear Manufacturers Association (AGMA) standards and the gear data as specified on the drawing for a specific gear type.

13.2 Gear Nomenclature

13.2.1 Spur Gears




13.2.2 Worm Gears



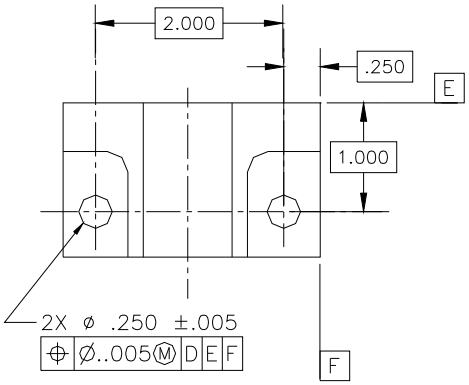
## 14.0 DIMENSIONING AND TOLERANCING

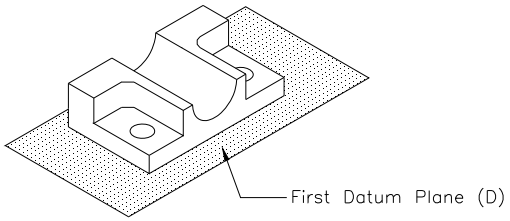
14.1 Explanation of geometric and true position symbols used on Williamsport drawings are interpreted per ASME Y14.5-2009, Dimensioning and Tolerancing.

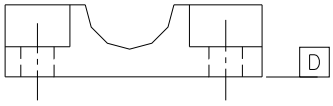
| | | | |
|---|---|---|---|
| STRAIGHTNESS | — | BASIC DIMENSION | .500 |
| FLATNESS | ▱ | REFERENCE DIMENSION | (.500) |
| CIRCULARITY | ○ | DATUM FEATURE | * A |
| CYLINDRICITY | ⌭ | DIMENSION ORIGIN | ⌖ |
| PROFILE OF A LINE | ⌒ | FEATURE CONTROL FRAME | ⌖ Ø.005Ⓜ A B C |
| PROFILE OF A SURFACE | ⌓ | CONICAL TAPER | |
| ALL AROUND | | SLOPE | |
| ANGULARITY | ∠ | COUNTERBORE / SPOTFACE | ⌴ |
| PERPENDICULARITY | ⊥ | COUNTERSINK | ⌵ |
| PARALLELISM | // | DEPTH / DEEP | ↧ |
| POSITION | ⌖ | SQUARE | □ |
| CONCENTRICITY | ◎ | DIMENSION NOT TO SCALE | .150 |
| SYMMETRY | ⌯ | NUMBER OF PLACES | 8X |
| CIRCULAR RUNOUT | * ↗ | ARC LENGTH | ⌒.300 |
| TOTAL RUNOUT | * ⌰ | RADIUS | R |
| AT MAXIMUM MATERIAL CONDITION | Ⓜ | SPHERICAL RADIUS | SR |
| AT LEAST MATERIAL CONDITION | Ⓛ | SPHERICAL DIAMETER | SØ |
| REGARDLESS OF FEATURE SIZE | Ⓢ | CONTROLLED RADIUS | CR |
| PROJECTED TOLERANCE ZONE | Ⓟ | BETWEEN | * ◄► |
| TANGENT PLANE | Ⓣ | STATISTICAL TOLERANCE | ST |
| FREE STATE | Ⓕ | DATUM TARGET | Ø.50 A1 or A1 Ø.550 |
| DIAMETER | Ø | TARGET POINT | ✕ |

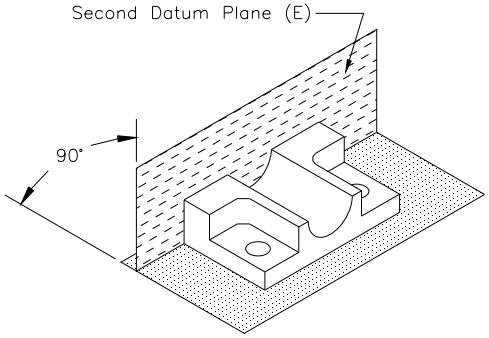
14.2 The following illustrations are a few commonly used dimensioning and tolerancing techniques used on Williamsport drawings, included is the generally accepted interpretation per ASME Y14.5-2009

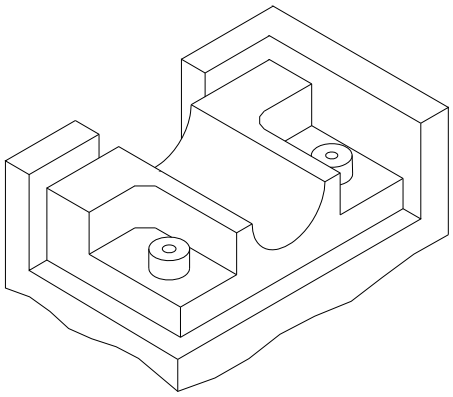
14.2.1 Plane surfaces as datum features and how the sequence of datum features relates the part to a datum reference frame.

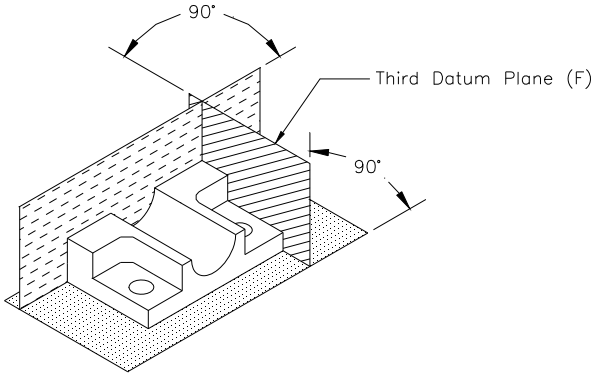


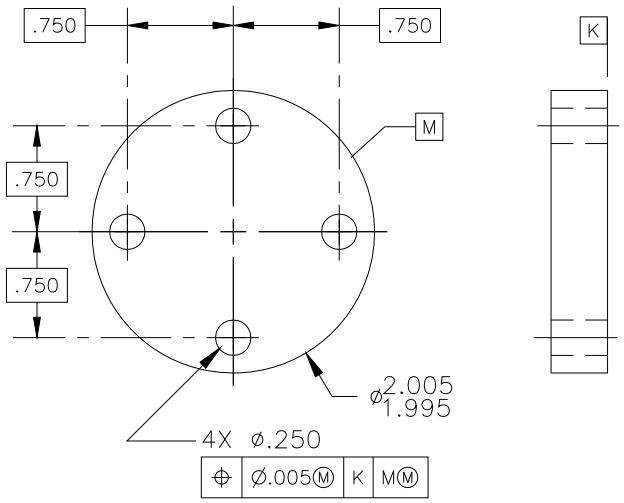



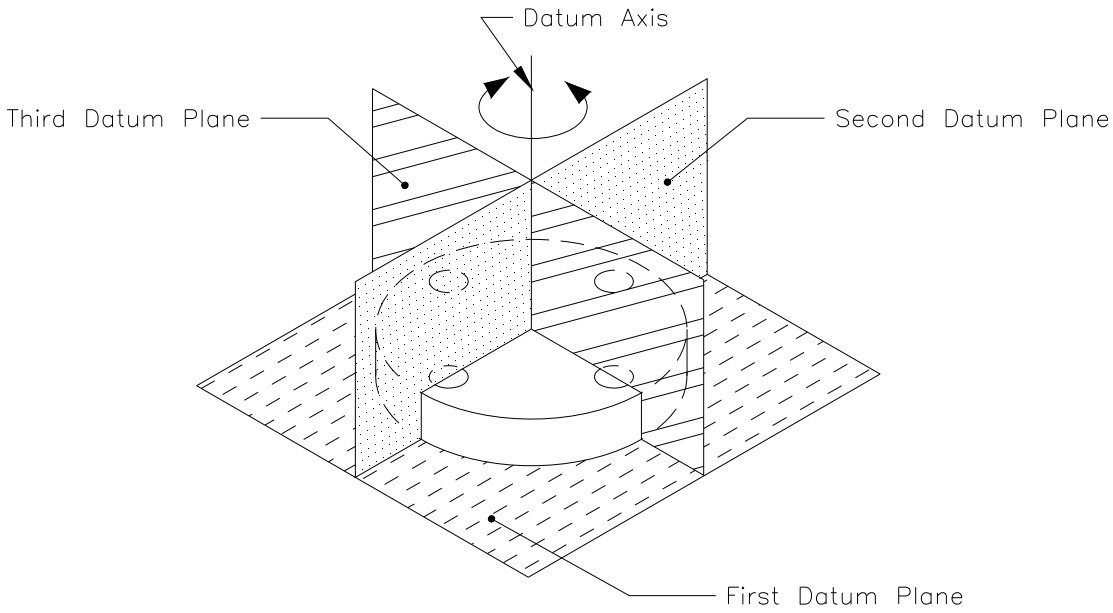



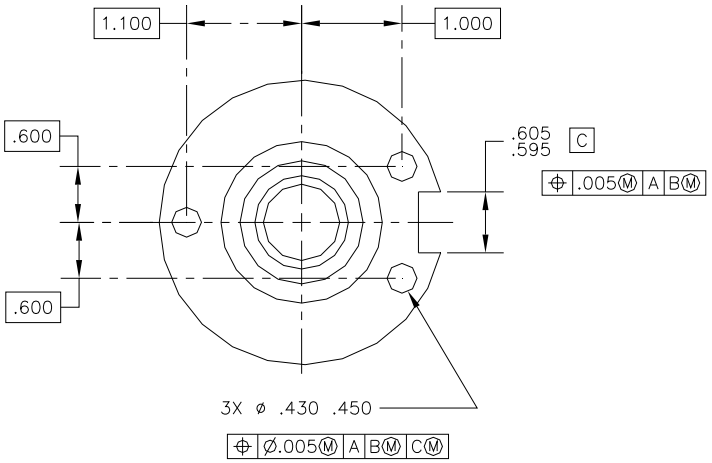


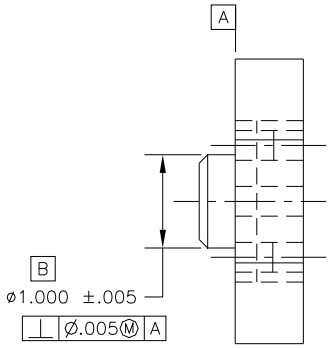
14.2.2 Part with a cylindrical datum feature.

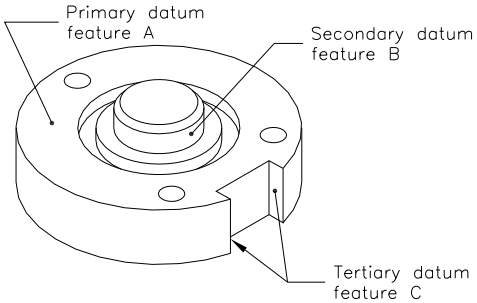


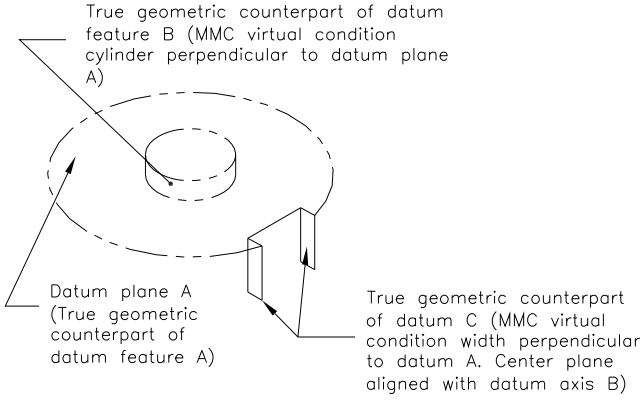
14.2.3 Part where angular orientation is important.



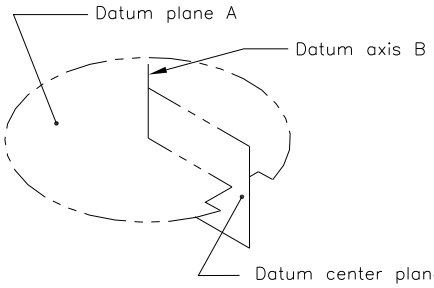



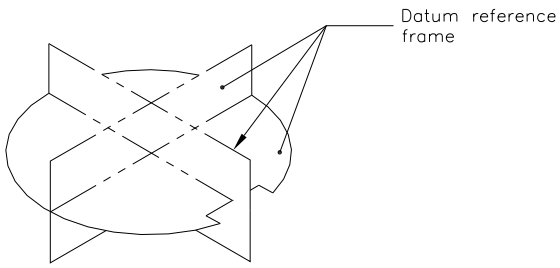

Datum features




True geometric counterparts

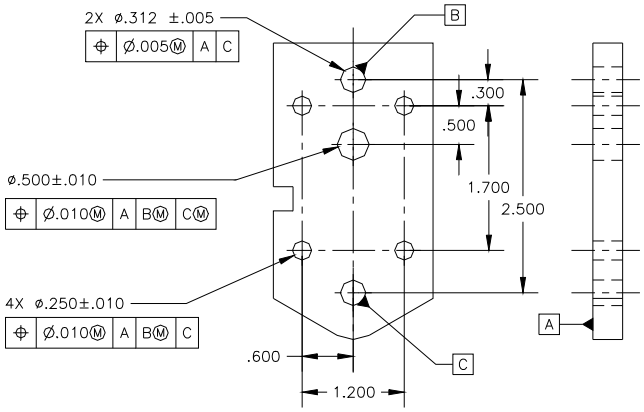


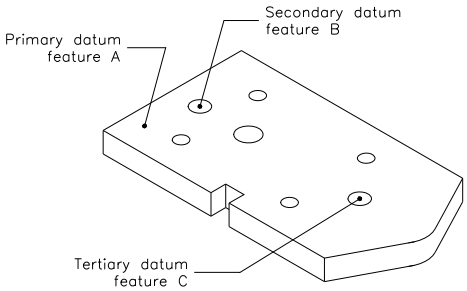

Datum planes and axis established from the true geometric counterparts



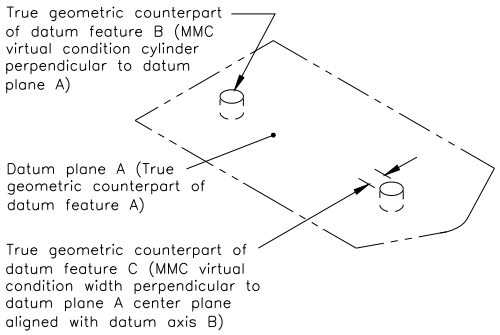

Datum reference frame

14.2.4 Orientation of two datum planes through a hole.

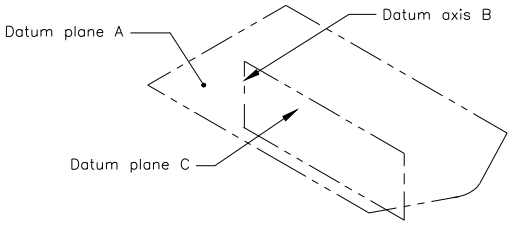


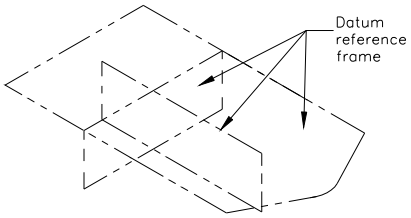

Datum features




True geometric counterparts

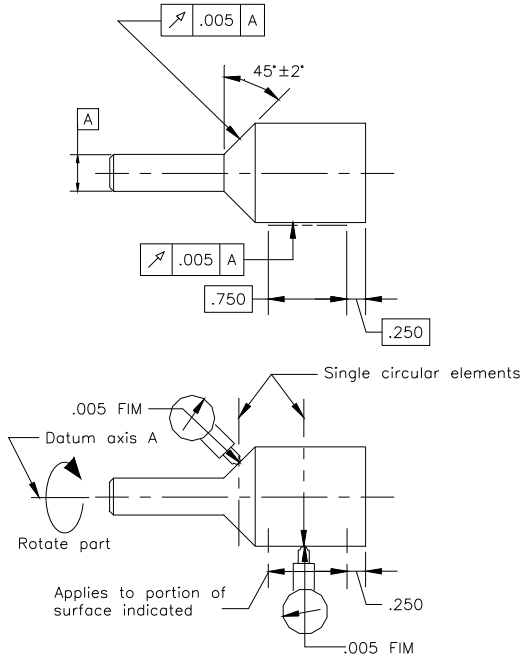



Datum planes and axis established from the true geometric counterparts



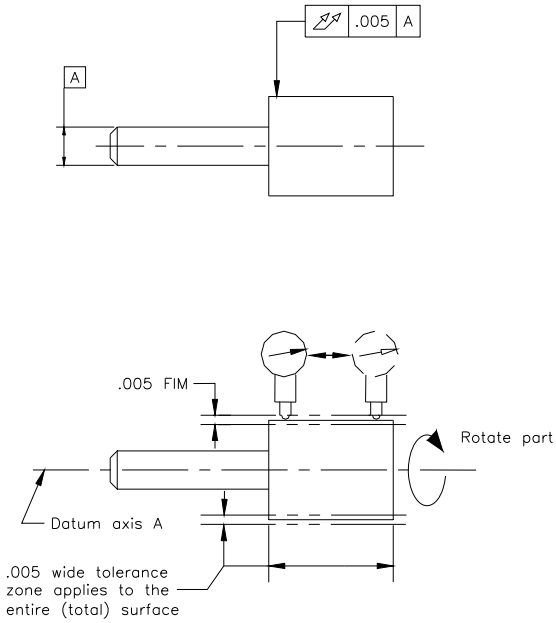

Datum reference frame

## 14.2.5 Specifying circular and total runout relative to a datum diameter.



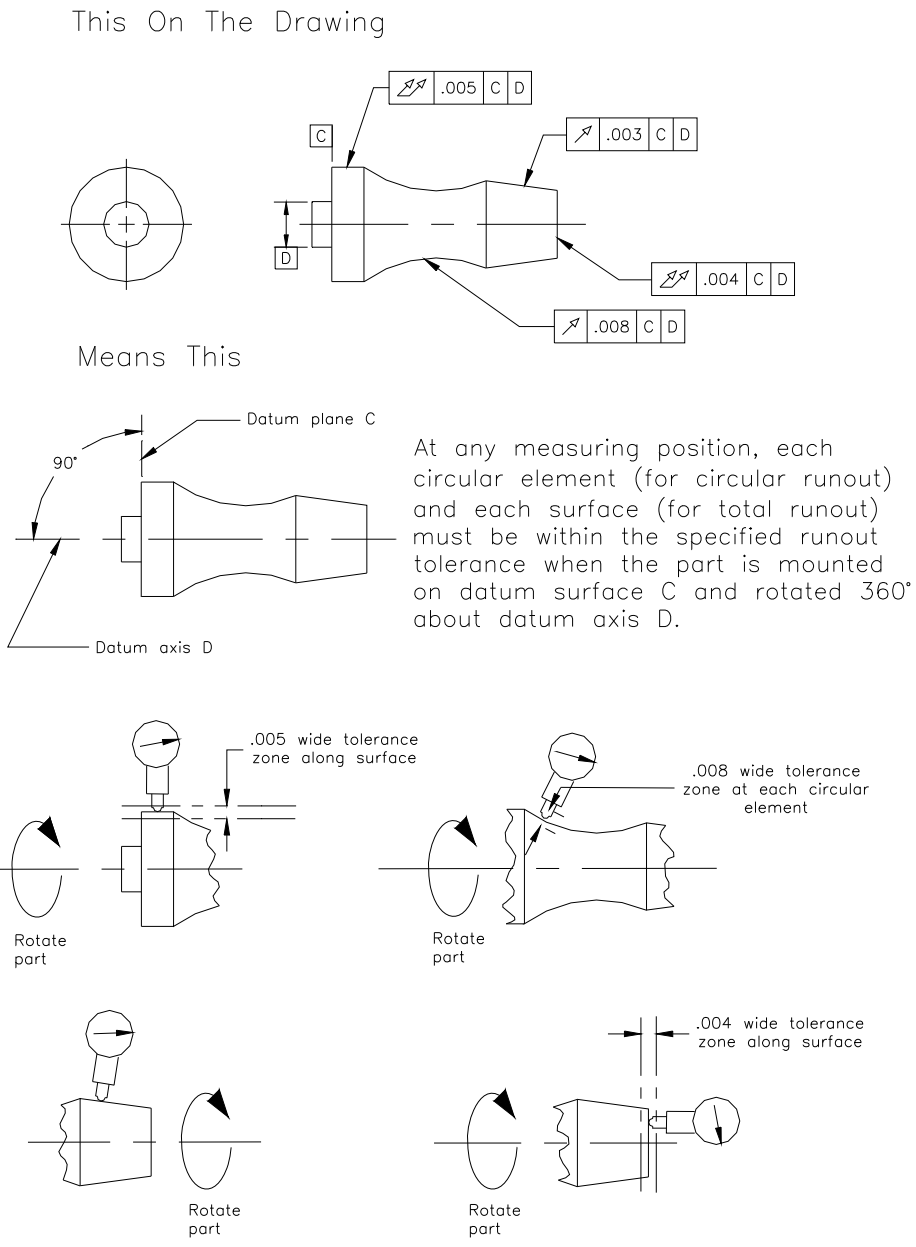

At any measuring position, each circular element of these surfaces must be within the specified runout tolerance (.005 full indicator movement) when the part is rotated 360° about the datum axis with the indicator fixed in a position normal to the true geometric shape. The feature must be within the specified limits of size.

(This controls only the circular elements of the surfaces, not the total surface.)

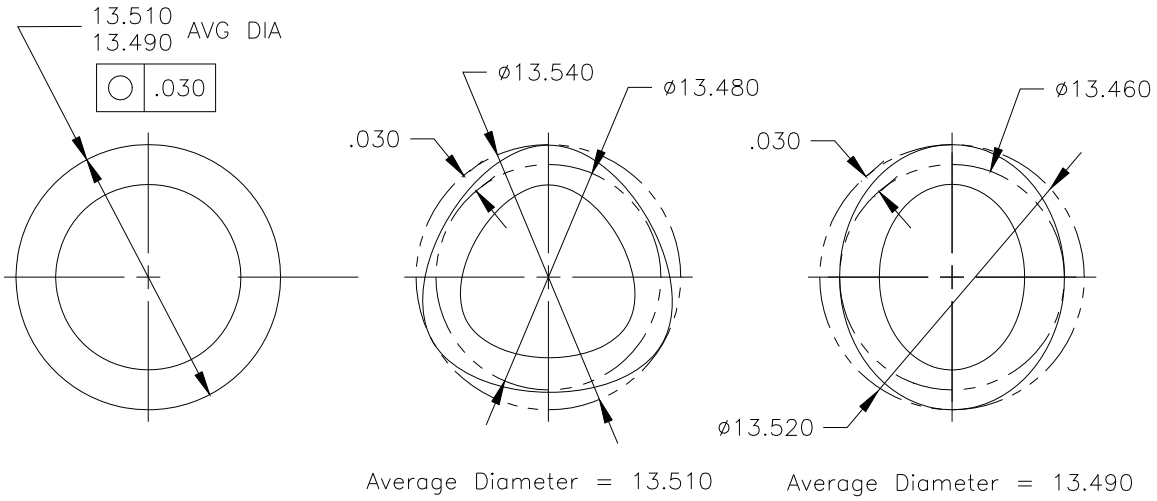



The entire surface must lie with the specified runout tolerance zone (.005 full indicator movement) when the part is rotated 360° about the datum axis with the indicator placed at every location along the surface in a position normal to the true geometric shape without reset of the indicator. The feature must be within the specified limits of size.

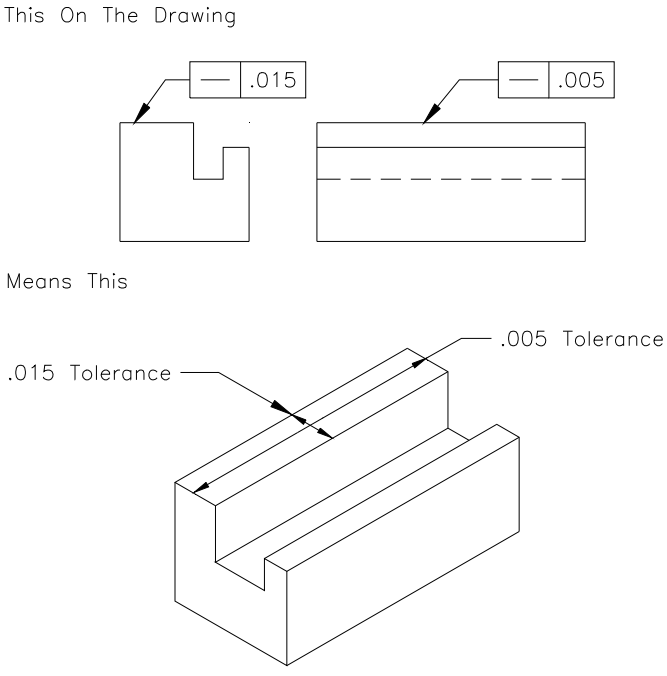
14.2.6 Specifying runout relative to a datum surface and a diameter.



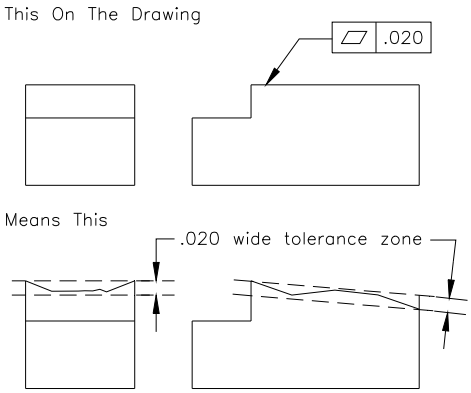
### 14.2.7 Specifying free state variation.




### 14.2.8 Specifying straightness on flat surfaces.

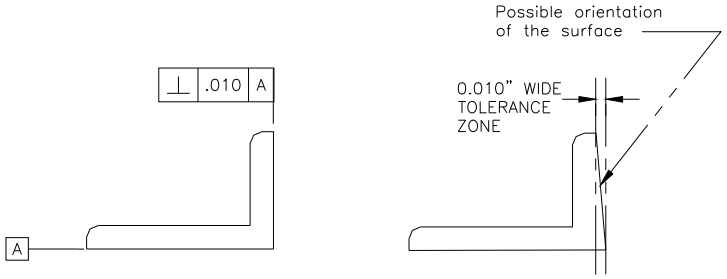


### 14.2.9 Specifying flatness.



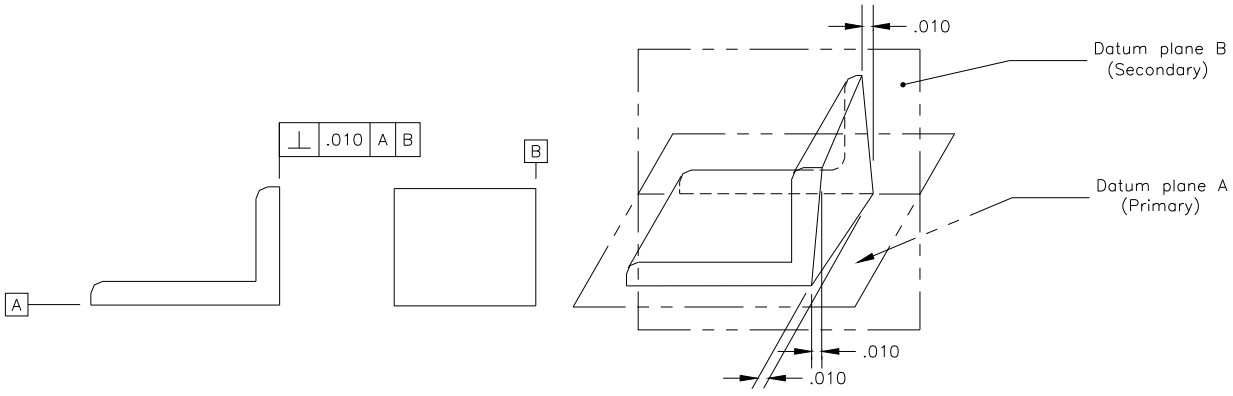

The surface must lie between two parallel planes .020 apart. The surface must be within the specified limits of size.

### 14.2.10 Specifying perpendicularity for a plane surface.




The surface must lie between two parallel planes 0.010" apart which are perpendicular to datum plane A. The surface must be within the specified limits of size.

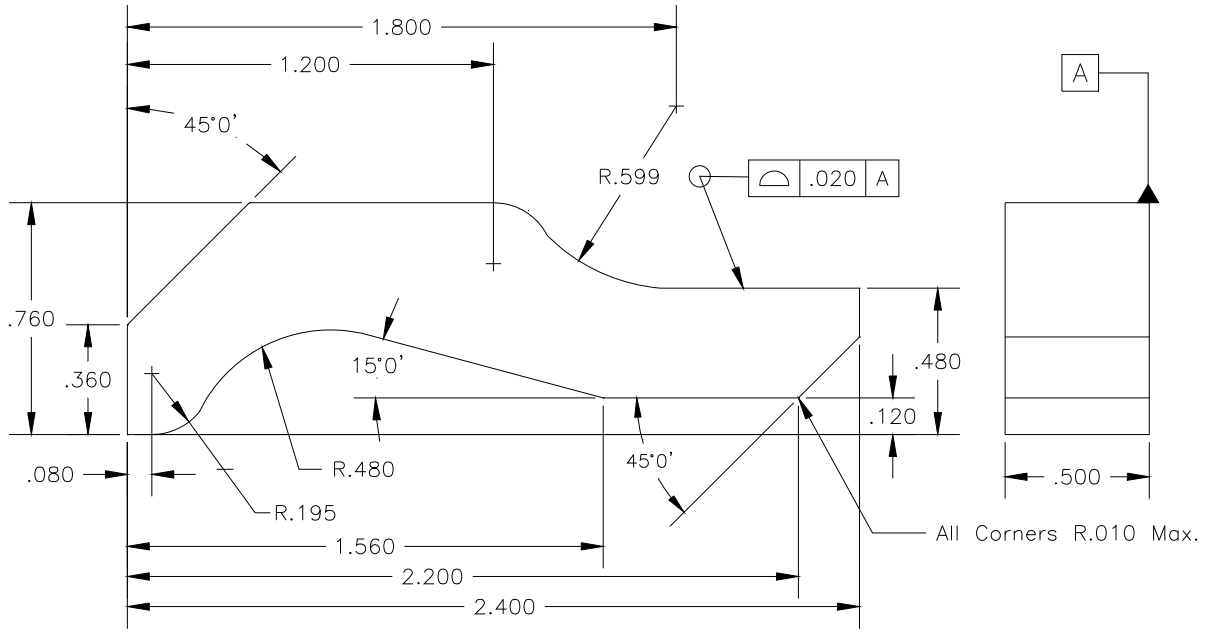
### 14.2.11 Specifying perpendicularity for a plane surface relative to two datums.




The surface must lie between two parallel planes 0.010" apart which are perpendicular to datum planes A and B. The surface must be within the specified limits of size.

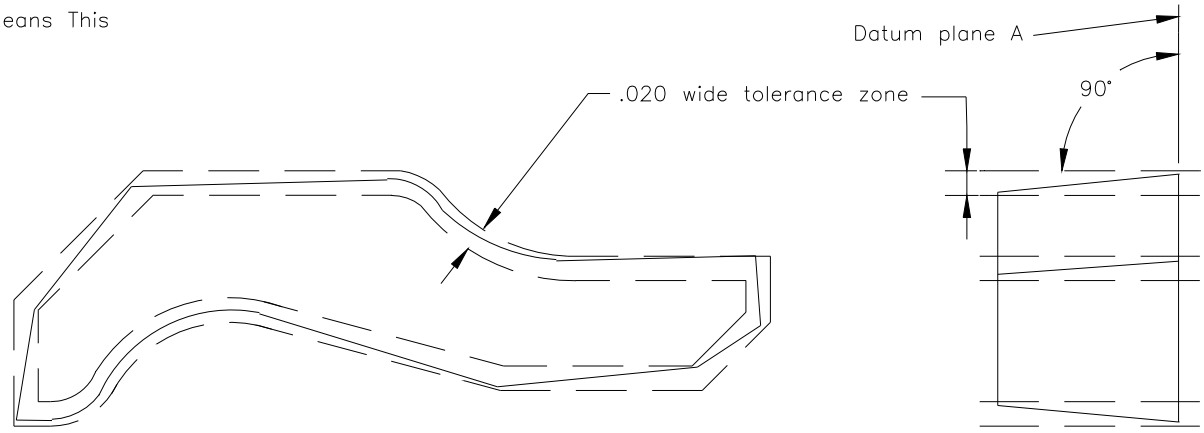
## 14.2.12 Specifying profile of a surface all around.

This On The Drawing




Untoleranced Dimensions Are Basic

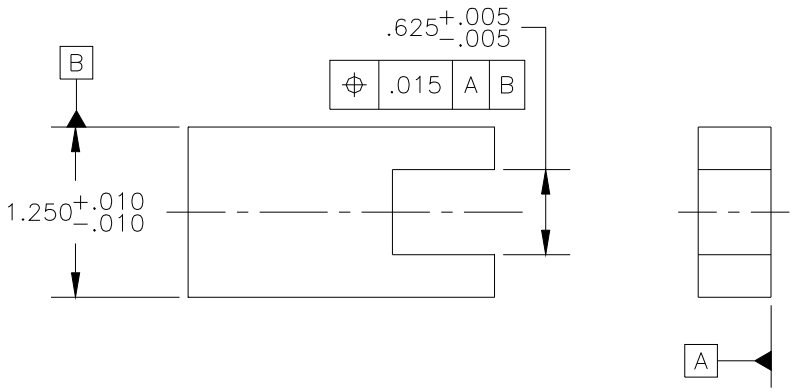
Means This



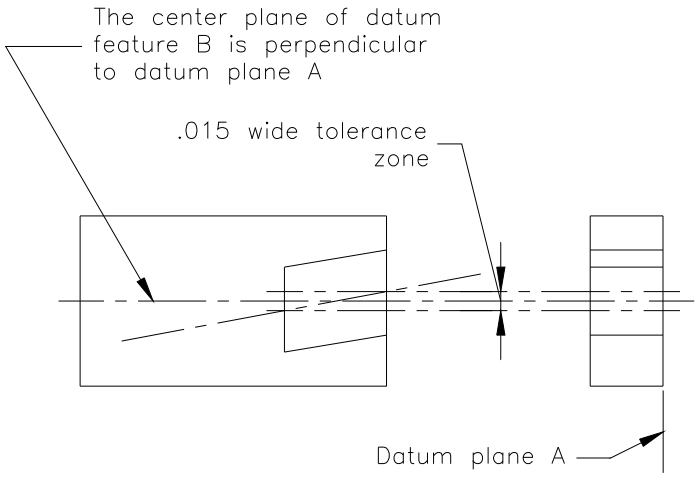

The surfaces, all around the part outline, must lie between two parallel boundaries .020 apart perpendicular to datum plane A and equally disposed about the true profile. Radii of part corners must not exceed .010.

14.2.13 Positional tolerance for RFS-RFS for symmetrical features.

This On The Drawing



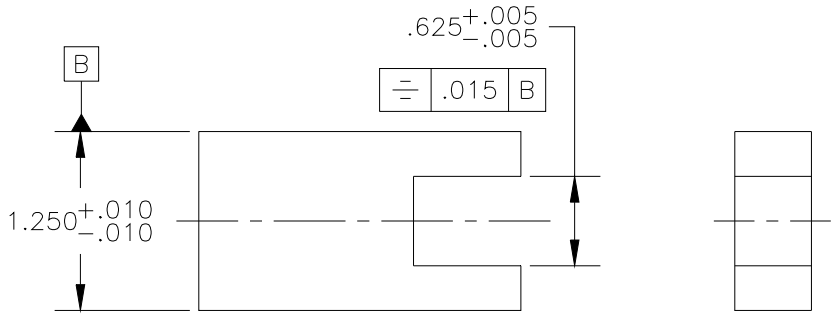

Means This



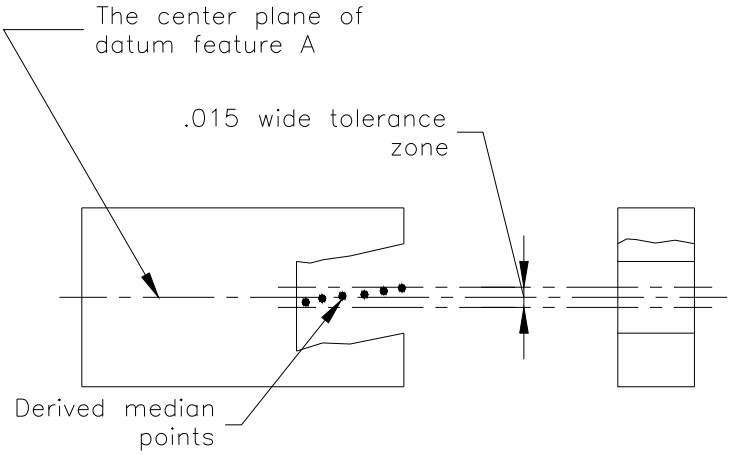

The center plane of the actual mating envelope of the slot must lie between two parallel planes .015 apart, equally disposed about the center plane of datum B. The specified tolerance and the datum reference can only apply on an RFS basis.

### 14.2.14 Symmetry tolerance

This On The Drawing



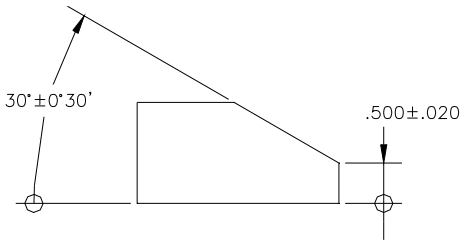

Means This



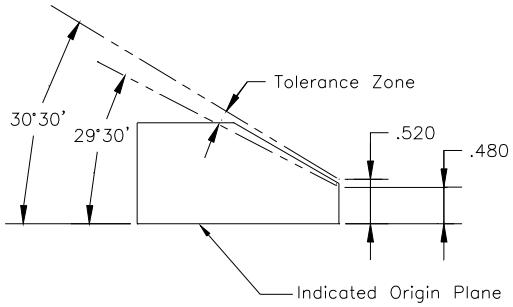

Within the limits of size and regardless of feature size, all median points of opposed elements of the slot must lie between two parallel planes .015 apart, the two planes being equally disposed about datum plane B. The specified tolerance and the datum reference can only apply on an RFS basis.

## 14.2.15 Tolerancing an angular surface

This On The Drawing

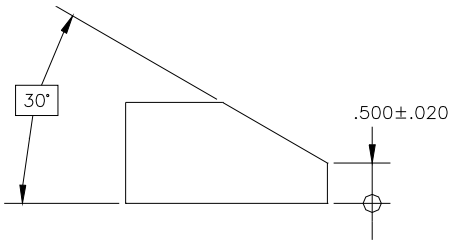



Means This

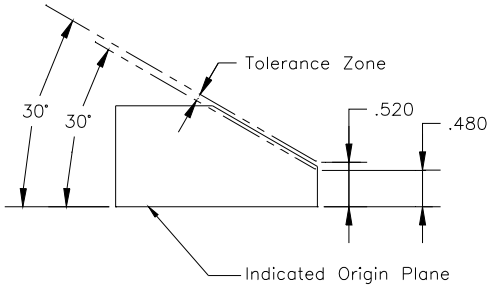



The surface controlled by the angular dimension may be anywhere within the tolerance zone with one restriction: its angle must not be less than 29°30' nor more than 30°30'.

This On The Drawing

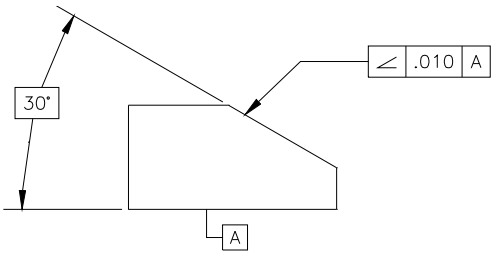



Means This

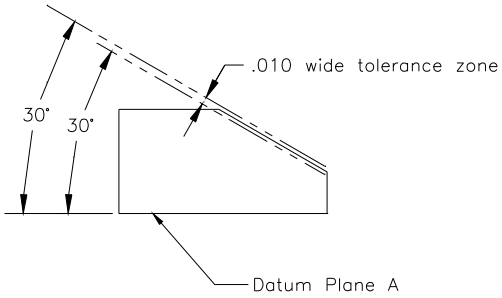



The surface controlled by the angular dimension may lie anywhere within the tolerance zone having parallel boundaries inclined at the basic angle.

This On The Drawing




Means This




The surface must lie anywhere within the tolerance zone having parallel boundaries .010 apart which are inclined at the basic angle to datum A. The surface must be within the specified limits of size.

## 15.0 Handy References

### 15.1 Degree/ Minute/Second To Decimal Degree Conversion Chart.

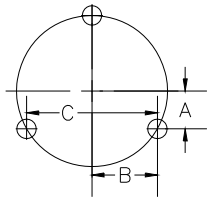
# MINUTES AND SECONDS
## Expressed as Decimals of 1 Degree

| | Seconds | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min. | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| 0 | 0.0000 | 0.0014 | 0.0028 | 0.0042 | 0.0056 | 0.0069 | 0.0083 | 0.0097 | 0.0111 | 0.0125 | 0.0139 | 0.0153 |
| 1 | 0.0167 | 0.0375 | 0.0194 | 0.0208 | 0.0223 | 0.0236 | 0.0250 | 0.0264 | 0.0278 | 0.0292 | 0.0306 | 0.0319 |
| 2 | 0.0333 | 0.0542 | 0.0361 | 0.0375 | 0.0389 | 0.0403 | 0.0417 | 0.0431 | 0.0444 | 0.0458 | 0.0472 | 0.0486 |
| 3 | 0.0500 | 0.0708 | 0.0528 | 0.0542 | 0.0556 | 0.0569 | 0.0583 | 0.0597 | 0.0611 | 0.0625 | 0.0639 | 0.0653 |
| 4 | 0.0667 | 0.0875 | 0.0694 | 0.0708 | 0.0723 | 0.0736 | 0.0750 | 0.0764 | 0.0778 | 0.0792 | 0.0806 | 0.0819 |
| 5 | 0.0833 | 0.1042 | 0.0861 | 0.0875 | 0.0889 | 0.0903 | 0.0917 | 0.0931 | 0.0944 | 0.0958 | 0.0972 | 0.0986 |
| 6 | 0.1000 | 0.1208 | 0.1028 | 0.1042 | 0.1056 | 0.1069 | 0.1083 | 0.1097 | 0.1111 | 0.1125 | 0.1139 | 0.1153 |
| 7 | 0.1167 | 0.1375 | 0.1194 | 0.1208 | 0.1223 | 0.1236 | 0.1250 | 0.1264 | 0.1278 | 0.1292 | 0.1306 | 0.1319 |
| 8 | 0.1333 | 0.1542 | 0.1361 | 0.1375 | 0.1389 | 0.1403 | 0.1417 | 0.1431 | 0.1444 | 0.1458 | 0.1472 | 0.1486 |
| 9 | 0.1500 | 0.1708 | 0.1528 | 0.1542 | 0.1556 | 0.1569 | 0.1583 | 0.1597 | 0.1611 | 0.1625 | 0.1639 | 0.1653 |
| 10 | 0.1667 | 0.1875 | 0.1694 | 0.1708 | 0.1723 | 0.1736 | 0.1750 | 0.1764 | 0.1778 | 0.1792 | 0.1806 | 0.1819 |
| 11 | 0.1833 | 0.2042 | 0.1861 | 0.1875 | 0.1889 | 0.1903 | 0.1917 | 0.1931 | 0.1944 | 0.1958 | 0.1972 | 0.1986 |
| 12 | 0.2000 | 0.2208 | 0.2028 | 0.2042 | 0.2056 | 0.2069 | 0.2083 | 0.2097 | 0.2111 | 0.2125 | 0.2139 | 0.2153 |
| 13 | 0.2167 | 0.2375 | 0.2194 | 0.2208 | 0.2223 | 0.2236 | 0.2250 | 0.2264 | 0.2278 | 0.2292 | 0.2306 | 0.2319 |
| 14 | 0.2333 | 0.2542 | 0.2361 | 0.2375 | 0.2389 | 0.2403 | 0.2417 | 0.2431 | 0.2444 | 0.2458 | 0.2472 | 0.2486 |
| 15 | 0.2500 | 0.2708 | 0.2528 | 0.2542 | 0.2556 | 0.2569 | 0.2583 | 0.2597 | 0.2611 | 0.2625 | 0.2639 | 0.2653 |
| 16 | 0.2667 | 0.2875 | 0.2694 | 0.2708 | 0.2723 | 0.2736 | 0.2750 | 0.2764 | 0.2778 | 0.2792 | 0.2806 | 0.2819 |
| 17 | 0.2833 | 0.3042 | 0.2861 | 0.2875 | 0.2889 | 0.2903 | 0.2917 | 0.2931 | 0.2944 | 0.2958 | 0.2972 | 0.2986 |
| 18 | 0.3000 | 0.3208 | 0.3028 | 0.3042 | 0.3056 | 0.3069 | 0.3083 | 0.3097 | 0.3111 | 0.3125 | 0.3139 | 0.3153 |
| 19 | 0.3167 | 0.3375 | 0.3194 | 0.3208 | 0.3223 | 0.3236 | 0.3250 | 0.3264 | 0.3278 | 0.3292 | 0.3306 | 0.3319 |
| 20 | 0.3333 | 0.3542 | 0.3361 | 0.3375 | 0.3389 | 0.3403 | 0.3417 | 0.3431 | 0.3444 | 0.3458 | 0.3472 | 0.3486 |
| 21 | 0.3500 | 0.3708 | 0.3528 | 0.3542 | 0.3556 | 0.3569 | 0.3583 | 0.3597 | 0.3611 | 0.3625 | 0.3639 | 0.3653 |
| 22 | 0.3667 | 0.3875 | 0.3694 | 0.3708 | 0.3723 | 0.3736 | 0.3750 | 0.3764 | 0.3778 | 0.3792 | 0.3806 | 0.3819 |
| 23 | 0.3833 | 0.4042 | 0.3861 | 0.3875 | 0.3889 | 0.3903 | 0.3917 | 0.3931 | 0.3944 | 0.3958 | 0.3972 | 0.3986 |
| 24 | 0.4000 | 0.4208 | 0.4028 | 0.4042 | 0.4056 | 0.4069 | 0.4083 | 0.4097 | 0.4111 | 0.4125 | 0.4139 | 0.4153 |
| 25 | 0.4167 | 0.4375 | 0.4194 | 0.4208 | 0.4223 | 0.4236 | 0.4250 | 0.4264 | 0.4278 | 0.4292 | 0.4306 | 0.4319 |
| 26 | 0.4333 | 0.4542 | 0.4361 | 0.4375 | 0.4389 | 0.4403 | 0.4417 | 0.4431 | 0.4444 | 0.4458 | 0.4472 | 0.4486 |
| 27 | 0.4500 | 0.4708 | 0.4528 | 0.4542 | 0.4556 | 0.4569 | 0.4583 | 0.4597 | 0.4611 | 0.4625 | 0.4639 | 0.4653 |
| 28 | 0.4667 | 0.4875 | 0.4694 | 0.4708 | 0.4723 | 0.4736 | 0.4750 | 0.4764 | 0.4778 | 0.4792 | 0.4806 | 0.4819 |
| 29 | 0.4833 | 0.5042 | 0.4861 | 0.4875 | 0.4889 | 0.4903 | 0.4917 | 0.4931 | 0.4944 | 0.4958 | 0.4972 | 0.4986 |
| 30 | 0.5000 | 0.5208 | 0.5028 | 0.5042 | 0.5056 | 0.5069 | 0.5083 | 0.5097 | 0.5111 | 0.5125 | 0.5139 | 0.5153 |
| 31 | 0.5167 | 0.5375 | 0.5194 | 0.5208 | 0.5223 | 0.5236 | 0.5250 | 0.5264 | 0.5278 | 0.5292 | 0.5306 | 0.5319 |
| 32 | 0.5333 | 0.5542 | 0.5361 | 0.5375 | 0.5389 | 0.5403 | 0.5417 | 0.5431 | 0.5444 | 0.5458 | 0.5472 | 0.5486 |
| 33 | 0.5500 | 0.5708 | 0.5528 | 0.5542 | 0.5556 | 0.5569 | 0.5583 | 0.5597 | 0.5611 | 0.5625 | 0.5639 | 0.5653 |
| 34 | 0.5667 | 0.5875 | 0.5694 | 0.5708 | 0.5723 | 0.5736 | 0.5750 | 0.5764 | 0.5778 | 0.5792 | 0.5806 | 0.5819 |
| 35 | 0.5833 | 0.6042 | 0.5861 | 0.5875 | 0.5889 | 0.5903 | 0.5917 | 0.5931 | 0.5944 | 0.5958 | 0.5972 | 0.5986 |
| 36 | 0.6000 | 0.6208 | 0.6028 | 0.6042 | 0.6056 | 0.6069 | 0.6083 | 0.6097 | 0.6111 | 0.6125 | 0.6139 | 0.6153 |
| 37 | 0.6167 | 0.6375 | 0.6194 | 0.6208 | 0.6223 | 0.6236 | 0.6250 | 0.6264 | 0.6278 | 0.6292 | 0.6306 | 0.6319 |
| 38 | 0.6333 | 0.6542 | 0.6361 | 0.6375 | 0.6389 | 0.6403 | 0.6417 | 0.6431 | 0.6444 | 0.6458 | 0.6472 | 0.6486 |
| 39 | 0.6500 | 0.6708 | 0.6528 | 0.6542 | 0.6556 | 0.6569 | 0.6583 | 0.6597 | 0.6611 | 0.6625 | 0.6639 | 0.6653 |
| 40 | 0.6667 | 0.6875 | 0.6694 | 0.6708 | 0.6723 | 0.6736 | 0.6750 | 0.6764 | 0.6778 | 0.6792 | 0.6806 | 0.6819 |
| 41 | 0.6833 | 0.7042 | 0.6861 | 0.6875 | 0.6889 | 0.6903 | 0.6917 | 0.6931 | 0.6944 | 0.6958 | 0.6972 | 0.6986 |
| 42 | 0.7000 | 0.7208 | 0.7028 | 0.7042 | 0.7056 | 0.7069 | 0.7083 | 0.7097 | 0.7111 | 0.7125 | 0.7139 | 0.7153 |
| 43 | 0.7167 | 0.7375 | 0.7194 | 0.7208 | 0.7223 | 0.7236 | 0.7250 | 0.7264 | 0.7278 | 0.7292 | 0.7306 | 0.7319 |
| 44 | 0.7333 | 0.7542 | 0.7361 | 0.7375 | 0.7389 | 0.7403 | 0.7417 | 0.7431 | 0.7444 | 0.7458 | 0.7472 | 0.7486 |
| 45 | 0.7500 | 0.7708 | 0.7528 | 0.7542 | 0.7556 | 0.7569 | 0.7583 | 0.7597 | 0.7611 | 0.7625 | 0.7639 | 0.7653 |
| 46 | 0.7667 | 0.7875 | 0.7694 | 0.7708 | 0.7723 | 0.7736 | 0.7750 | 0.7764 | 0.7778 | 0.7792 | 0.7806 | 0.7819 |
| 47 | 0.7833 | 0.8042 | 0.7861 | 0.7875 | 0.7889 | 0.7903 | 0.7917 | 0.7931 | 0.7944 | 0.7958 | 0.7972 | 0.7986 |
| 48 | 0.8000 | 0.8208 | 0.8028 | 0.8042 | 0.8056 | 0.8069 | 0.8083 | 0.8097 | 0.8111 | 0.8125 | 0.8139 | 0.8153 |
| 49 | 0.8167 | 0.8375 | 0.8194 | 0.8208 | 0.8223 | 0.8236 | 0.8250 | 0.8264 | 0.8278 | 0.8292 | 0.8306 | 0.8319 |
| 50 | 0.8333 | 0.8542 | 0.8361 | 0.8375 | 0.8389 | 0.8403 | 0.8417 | 0.8431 | 0.8444 | 0.8458 | 0.8472 | 0.8486 |
| 51 | 0.8500 | 0.8708 | 0.8528 | 0.8542 | 0.8556 | 0.8569 | 0.8583 | 0.8597 | 0.8611 | 0.8625 | 0.8639 | 0.8653 |
| 52 | 0.8667 | 0.8875 | 0.8694 | 0.8708 | 0.8723 | 0.8736 | 0.8750 | 0.8764 | 0.8778 | 0.8792 | 0.8806 | 0.8819 |
| 53 | 0.8833 | 0.9042 | 0.8861 | 0.8875 | 0.8889 | 0.8903 | 0.8917 | 0.8931 | 0.8944 | 0.8958 | 0.8972 | 0.8986 |
| 54 | 0.9000 | 0.9208 | 0.9028 | 0.9042 | 0.9056 | 0.9069 | 0.9083 | 0.9097 | 0.9111 | 0.9125 | 0.9139 | 0.9153 |
| 55 | 0.9167 | 0.9375 | 0.9194 | 0.9208 | 0.9223 | 0.9236 | 0.9250 | 0.9264 | 0.9278 | 0.9292 | 0.9306 | 0.9319 |
| 56 | 0.9333 | 0.9542 | 0.9361 | 0.9375 | 0.9389 | 0.9403 | 0.9417 | 0.9431 | 0.9444 | 0.9458 | 0.9472 | 0.9486 |
| 57 | 0.9500 | 0.9708 | 0.9528 | 0.9542 | 0.9556 | 0.9569 | 0.9583 | 0.9597 | 0.9611 | 0.9625 | 0.9639 | 0.9653 |
| 58 | 0.9667 | 0.9875 | 0.9694 | 0.9708 | 0.9723 | 0.9736 | 0.9750 | 0.9764 | 0.9778 | 0.9792 | 0.9806 | 0.9819 |
| 59 | 0.9833 | 1.0042 | 0.9861 | 0.9875 | 0.9889 | 0.9903 | 0.9917 | 0.9931 | 0.9944 | 0.9958 | 0.9972 | 0.9986 |
| 60 | 1.0000 | 0.0042 | 1.0028 | 1.0042 | 1.0056 | 1.0069 | 1.0083 | 1.0097 | 1.0111 | 1.0125 | 1.0139 | 1.0153 |

## 15.2 Bolt Circle Calculations

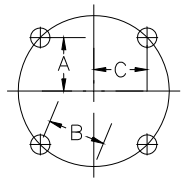
3 Holes
120° Apart

A .25000
B .43301
C .86603



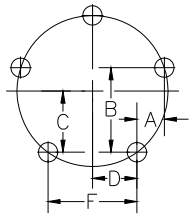

4 Holes
90° Apart

A .35355
B .38268
C .35355



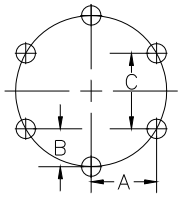

5 Holes
72° Apart

A .18164
B .55902
C .40451
D .29389
F .58779



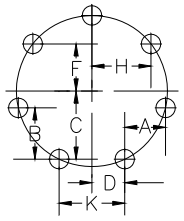

6 Holes
60° Apart

A .43301
B .25000
C .50000



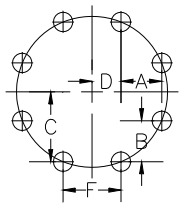

7 Holes
51.429° Apart

A .27052 H .39092
B .33922 K .43388
C .45048
D .21694
F .31175



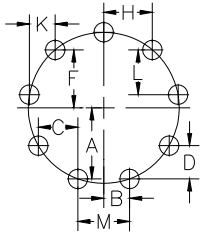

8 Holes
45° Apart

A .27060
B .27060
C .46194
D .19134
F .38268



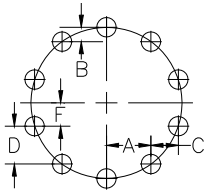

9 Holes
40° Apart

A .46985 H .32139
B .17101 K .17101
C .26200 L .29620
D .21985 M .34202
F .38302



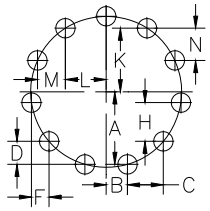

10 Holes
36° Apart

A .29389
B .09549
C .18164
D .25000
F .15451



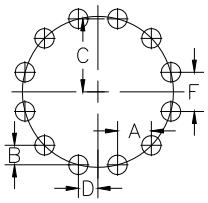

11 Holes
32.727° Apart

A .47975 H .25627
B .14087 K .42063
C .23701 L .27032
D .15232 M .18450
F .11704 N .21292




12 Holes
30° Apart

A .22415
B .12941
C .48297
D .12941
F .25882

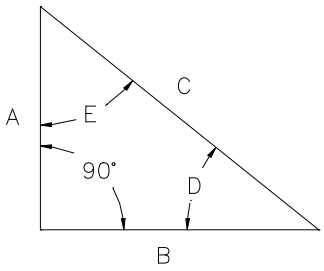



To Obtain The Above Dimensions For A Specific Bolt Circle Diameter, Multiply The Dimension Constant Value For The Dimension Needed (From The Diagram With The Correct Number Of Holes) By the Bolt Circle Diameter For The Dimensions Being Calculated.

Example: To Find Dimension "F" For an 8 Hole Bolt Circle having A ø of 2.500"

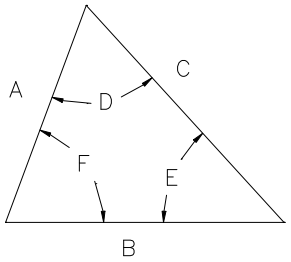
Dim. "F" = 2.5 X .38268 = .9567"

## 15.3 Right Triangle Formulas




| TO FIND | KNOWN PARTS | | ALTERNATE FORMULA | | TO FIND | KNOWN | | ALTERNATE FORMULA |
|---|---|---|---|---|---|---|---|---|
| A | C & D | $C \times \text{SIN } D = A$ | $\frac{C}{\text{COSEC } D} = A$ | | C | A&B | $\sqrt{A^2 + B^2} = C$ | |
| A | C & E | $C \times \text{COS } E = A$ | $\frac{C}{\text{SEC } E} = A$ | | D | A & C | $\frac{A}{C} = \text{SIN } D$ | $\frac{C}{A} = \text{COSEC } D$ |
| A | B & D | $B \times \text{TAN } D = A$ | $\frac{B}{\text{COT } D} = A$ | | D | B & C | $\frac{B}{C} = \text{COS } D$ | $\frac{C}{B} = \text{SEC } D$ |
| A | B & E | $B \times \text{COT } E = A$ | $\frac{B}{\text{TAN } E} = A$ | | D | A & B | $\frac{A}{B} = \text{TAN } D$ | $\frac{B}{A} = \text{COT } D$ |
| A | C & B | $\sqrt{C^2 - B^2} = A$ | | | D | E | $90° - E° = D°$ | |
| B | C & D | $C \times \text{COS } D = B$ | $\frac{C}{\text{SEC } D} = B$ | | E | B & C | $\frac{B}{C} = \text{SIN } E$ | $\frac{C}{B} = \text{COSEC } E$ |
| B | C & E | $C \times \text{SIN } E = B$ | $\frac{C}{\text{COSEC } E} = B$ | | E | A & C | $\frac{A}{C} = \text{COS } E$ | $\frac{C}{A} = \text{SEC } E$ |
| B | A & D | $A \times \text{COT } D = B$ | $\frac{A}{\text{TAN } D} = B$ | | E | A & B | $\frac{B}{A} = \text{TAN } E$ | $\frac{A}{B} = \text{COT } E$ |
| B | A & E | $A \times \text{TAN } E = B$ | $\frac{A}{\text{COTAN } E} = B$ | | E | D | $90° - D° = E°$ | |
| B | C & A | $\sqrt{C^2 - A^2} = B$ | | | AREA | A & B | $\frac{A \times B}{2} = \text{AREA}$ | |
| C | A & D | $A \times \text{COSEC } D = C$ | $\frac{A}{\text{SIN } D} = C$ | | AREA | A & D | $\frac{A^2 \times \text{COT } B}{2} = \text{AREA}$ | |
| C | A & E | $A \times \text{SEC } E = C$ | $\frac{A}{\text{COS } E} = C$ | | AREA | B & D | $\frac{B^2 \times \text{TAN } D}{2} = \text{AREA}$ | |
| C | B & E | $B \times \text{COSEC } E = C$ | $\frac{B}{\text{SIN } E} = C$ | | AREA | C & D | $\frac{C^2 \times \text{SIN } 2D}{4} = \text{AREA}$ | |
| C | B & D | $B \times \text{SEC } D = C$ | $\frac{B}{\text{COS } D} = C$ | | | | | |

## 15.4 Oblique Triangle Formulas




| TO FIND | KNOWN PARTS | |
|---|---|---|
| A | B-D-E | $\frac{B \times \sin E}{\sin D} = A$ |
| B | A-D-E | $\frac{A \times \sin D}{\sin E} = B$ |
| C | A-F-E | $\frac{A \times \sin F}{\sin E} = C$ |
| C | B-F-D | $\frac{B \times \sin F}{\sin D} = C$ |
| D | E & F | $180° - (E° + F°) = D°$ |
| D | A-B-F | $\frac{B \times \sin F}{A - (B \times \cos F)} = \tan D$ |
| D | A-B-C | $\frac{C^2 + A^2 - B^2}{2 \times C \times A} = \cos D$ |
| D | A-B-E | $\frac{B \times \sin E}{A} = \sin D$ |
| E | D & F | $180° - (D° - F°) = E°$ |
| E | A-B-F | $\frac{B \times \text{cosec } F}{A} - \cot F = \cot$ |
| E | A-C-F | $\frac{A \times \sin F}{C} = \sin E$ |
| E | A-B-D | $\frac{A \times \sin D}{B} = \sin E$ |
| F | D &E | $180° - (D° + E°) = F°$ |
| F | B-C-D | $\frac{C \times \sin D}{B} = \sin F$ |
| AREA | A-B-F | $\frac{A \times B \times \sin F}{2} = \text{AREA}$ |

## 15.5 Conversion Of Positional Tolerance Zone To / From Coordinate Tolerance Zone Rule Of Thumb

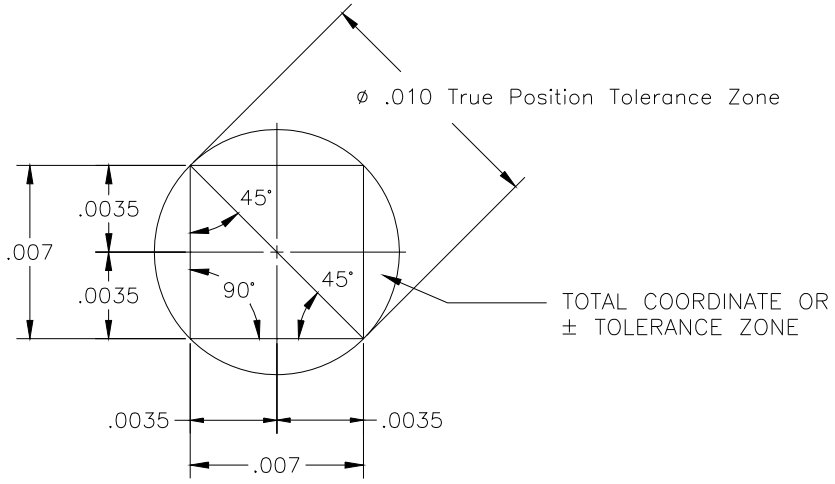
15.5.1 Conversion from the stated positional tolerance on the drawing to the equivalent +/- tolerances may be necessary.
Designers, machinist, inspectors, etc. can convert positional tolerances to equivalent +/- tolerances by use of the “Rule Of Thumb.”
Conversion from the stated coordinate (+/-) tolerance to the equivalent positional tolerance can be useful to engineers, inspectors, etc. who may wish to isolate possible problem areas; such as, where parts may assemble but have been previously rejected on the basis of the permissible coordinate tolerance on the drawing. This method may help “trouble-shoot” problems in general.
This is not the method used to determine positional tolerances in design.
Note that the +/- tolerance to position tolerance conversion should be based upon the coordinate (+/-) tolerance allotted to the one hole (or other feature) under consideration. This usually requires basing the calculated upon one-half the stated coordinate tolerance between the holes (or other features).

⌖ TO ±

TRUE POS. TOL. ZONE x .70711 = TOTAL ± TOL. ZONE (FOR FEATURE)

EXAMPLE: ø.010 TRUE POS. TOL. x .70711 = .0071
THIS MEANS A .007 TOTAL COORDINATE TOL.
OR A ± .0035

RULE OF THUMB:
USE .7 (OR 70%) OF TOTAL TRUE POS. TOL. TO CONVERT IN NON–CRITICAL APPLICATIONS, e.g., .7 x .010 = .007 (± .0035)




± TO ⌖

TOTAL ± ZONE x 1.4142 = TRUE POS. TOL. ZONE

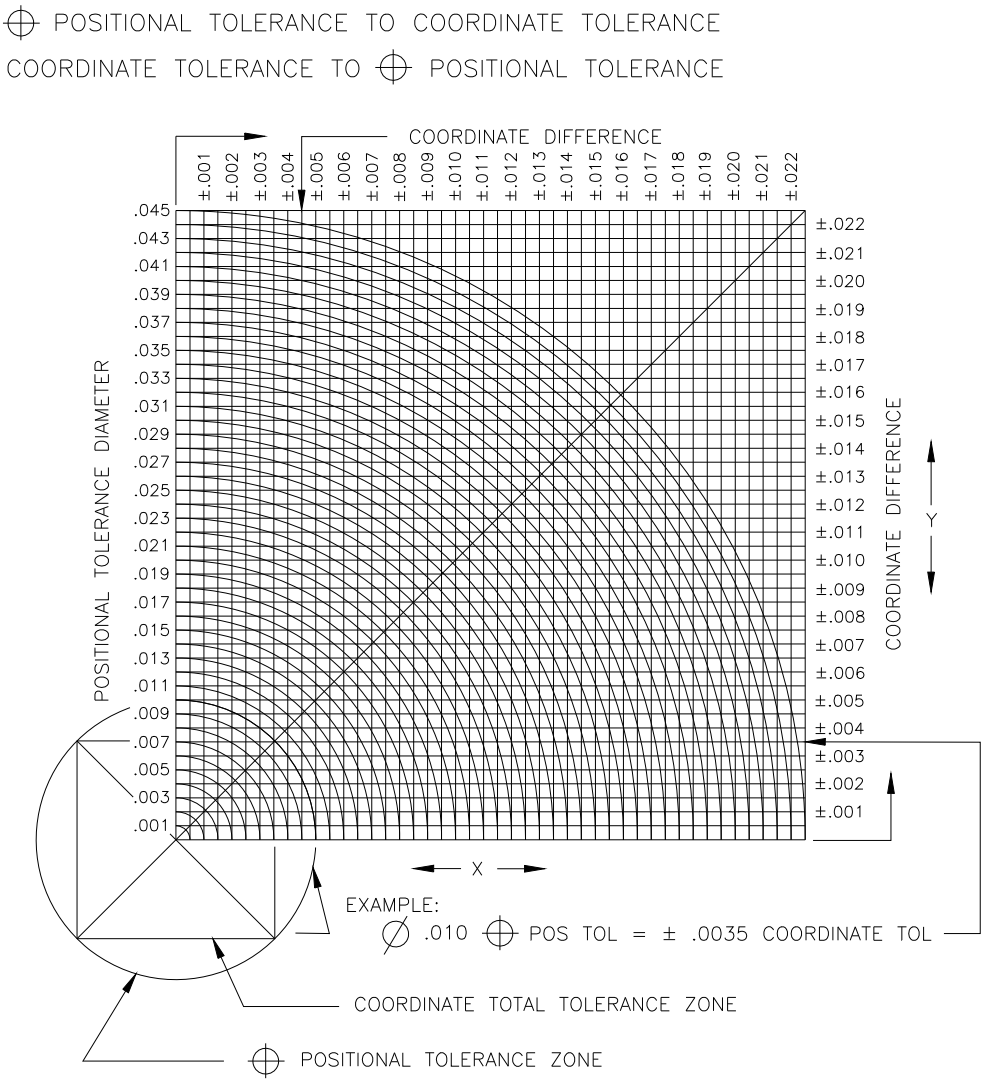
EXAMPLE: .007 TOTAL COORDINATE TOL. OR ± .0035 } X 1.4142 = ø.0099 OR TRUE POS. ø.010 TOL.

RULE OF THUMB:
USE 1.4 TIMES TOTAL ± TOL. TO CONVERT IN NON–CRITICAL APPLICATIONS. e.g., 1.4 x .007 = ø.010

## 15.6 True Position To Coordinate and Coordinate To True Position Conversion Chart – CYLINDRICAL FEATURES

Conversion from the stated positional tolerance to the equivalent coordinate (+/-) tolerance or from the coordinate (+/-) to positional tolerance can be quickly derived from the chart.
This method does not provide asured precision; its use is, thus, to be handled with discretion.
The chart is entered with either the position or the +/- tolerance to derive the opposite value. The sample application explains the method used.
The chart method may also be used to convert differentials derived in coordinate (X and Y) measurement of positionally toleranced features. That is, for example, if the measured coordinate results were:

If Hole Actual Location:
(Horizontal X) Basic (on Drawing)- Actual = X
.900 - .896 = .004 (In X Direction
(Vertical Y) Basic (on Drawing) – Actual = Y
.800 - .798 = .002 (In Y Direction)
Then Enter Chart On +/- Scale In X and Y Directions
.004 in X (Enter at +/- .004 Line)
.002 in Y (Enter at +/- .002 Line
= .009 True Position Tolerance As Converted)



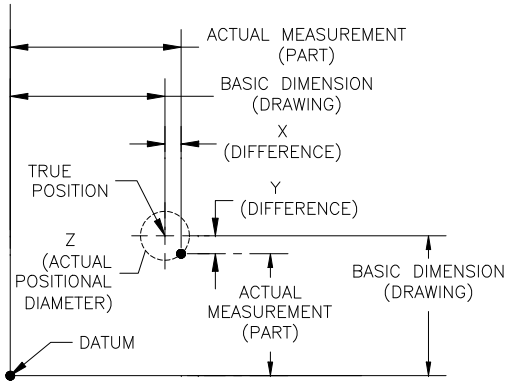
## 15.7 Conversion Of Coordinate Measurements To True Position Location

| X ↕ | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .020 | .0400 | .0402 | .0404 | .0408 | .0412 | .0418 | .0424 | .0431 | .0439 | .0447 | .0456 | .0466 | .0477 | .0488 | .0500 | .0512 | .0525 | .0538 | .0552 | .0566 |
| .019 | .0380 | .0382 | .0385 | .0388 | .0393 | .0398 | .0405 | .0412 | .0420 | .0429 | .0439 | .0449 | .0460 | .0472 | .0484 | .0497 | .0510 | .0523 | .0537 | .0552 |
| .018 | .0360 | .0362 | .0365 | .0369 | .0374 | .0379 | .0386 | .0394 | .0403 | .0412 | .0422 | .0433 | .0444 | .0456 | .0469 | .0482 | .0495 | .0509 | .0523 | .0538 |
| .017 | .0340 | .0342 | .0345 | .0349 | .0354 | .0360 | .0368 | .0376 | .0385 | .0394 | .0405 | .0416 | .0428 | .0440 | .0453 | .0467 | .0481 | .0495 | .0510 | .0525 |
| .016 | .0321 | .0322 | .0325 | .0330 | .0335 | .0342 | .0349 | .0358 | .0367 | .0377 | .0388 | .0400 | .0412 | .0425 | .0439 | .0452 | .0467 | .0482 | .0497 | .0512 |
| .015 | .0301 | .0303 | .0306 | .0310 | .0316 | .0323 | .0331 | .0340 | .0350 | .0360 | .0372 | .0384 | .0397 | .0410 | .0424 | .0439 | .0453 | .0469 | .0484 | .0500 |
| .014 | .0281 | .0283 | .0286 | .0291 | .0297 | .0305 | .0313 | .0322 | .0333 | .0344 | .0356 | .0369 | .0382 | .0396 | .0410 | .0425 | .0440 | .0456 | .0472 | .0488 |
| .013 | .0261 | .0263 | .0267 | .0272 | .0278 | .0286 | .0295 | .0305 | .0316 | .0328 | .0340 | .0354 | .0368 | .0382 | .0397 | .0412 | .0428 | .0444 | .0460 | .0477 |
| .012 | .0241 | .0243 | .0247 | .0253 | .0260 | .0268 | .0278 | .0288 | .0300 | .0312 | .0325 | .0339 | .0354 | .0369 | .0384 | .0400 | .0416 | .0433 | .0449 | .0466 |
| .011 | .0221 | .0224 | .0228 | .0234 | .0242 | .0250 | .0261 | .0272 | .0284 | .0297 | .0311 | .0325 | .0340 | .0356 | .0372 | .0388 | .0405 | .0422 | .0439 | .0456 |
| .010. | .0201 | .0204 | .0209 | .0215 | .0224 | .0233 | .0244 | .0256 | .0269 | .0283 | .0297 | .0312 | .0328 | .0344 | .0360 | .0377 | .0394 | .0412 | .0429 | .0447 |
| .009 | .0181 | .0184 | .0190 | .0197 | .0206 | .0216 | .0228 | .0241 | .0254 | .0269 | .0284 | .0300 | .0316 | .0333 | .0350 | .0367 | .0385 | .0402 | .0420 | .0439 |
| .008 | .0161 | .0165 | .0171 | .0179 | .0189 | .0200 | .0213 | .0226 | .0241 | .0256 | .0272 | .0288 | .0305 | .0322 | .0340 | .0358 | .0376 | .0394 | .0412 | .0431 |
| .007 | .0141 | .0146 | .0152 | .0161 | .0172 | .0184 | .0198 | .0213 | .0228 | .0244 | .0261 | .0278 | .0295 | .0313 | .0331 | .0349 | .0368 | .0386 | .0405 | .0424 |
| .006 | .0122 | .0126 | .0134 | .0144 | .0156 | .0170 | .0184 | .0200 | .0216 | .0233 | .0250 | .0268 | .0286 | .0305 | .0323 | .0342 | .0360 | .0379 | .0398 | .0418 |
| .005 | .0102 | .0108 | .0117 | .0128 | .0141 | .0156 | .0172 | .0189 | .0206 | .0224 | .0242 | .0260 | .0278 | .0297 | .0316 | .0335 | .0354 | .0374 | .0393 | .0412 |
| .004 | .0082 | .0089 | .0100 | .0113 | .0128 | .0144 | .0161 | .0179 | .0197 | .0215 | .0234 | .0253 | .0272 | .0291 | .0310 | .0330 | .0349 | .0369 | .0388 | .0408 |
| .003 | .0063 | .0072 | .0085 | .0100 | .0117 | .0134 | .0152 | .0171 | .0190 | .0209 | .0228 | .0247 | .0267 | .0286 | .0306 | .0325 | .0345 | .0365 | .0385 | .0404 |
| .002 | .0045 | .0056 | .0072 | .0089 | .0108 | .0126 | .0146 | .0165 | .0184 | .0204 | .0224 | .0243 | .0263 | .0283 | .0303 | .0322 | .0342 | .0362 | .0382 | .0402 |
| .001 | .0028 | .0045 | .0063 | .0082 | .0102 | .0122 | .0141 | .0161 | .0181 | .0201 | .0221 | .0241 | .0261 | .0281 | .0301 | .0321 | .0340 | .0360 | .0380 | .0400 |
| | .001 | .002 | .003 | .004 | .005 | .006 | .007 | .008 | .009 | .010 | .011 | .012 | .013 | .014 | .015 | .016 | .017 | .018 | .019 | .020 |

Y ↕

**FORMULA**

$$Z = 2\sqrt{X^2 + Y^2}$$




15.7.1 The part is set up on datum features (using datum precedence) to establish X and Y measuring planes.
Holes are measured in X and Y , reading and recording the results.
Holes are measured using RFS (tapered probes, etc.) invoking MMC principles when necessary.
Measurement differentials (from basic to actual) are determined.
Chart (or other comparable methods) converts the differentials to equivalent positional values which is compared to the stated permissible tolerance.
Where necessary the hole actual size is determined to invoke the MMC principle and derive permissible tolerance for that hole.
Coordinate measuring machines with computer capability, or programmable calculators can be utilized to perform such calculations.

## 15.8 Gage Block Length Combinations

15.8.1 A typical 81 piece gage block set contains blocks arranged in the following order:

**9 Blocks - .0001" Series**

.1001 .1002 .1003 .1004 .1005 .1006 .1007 .1008 .1009

**49 Blocks - .001" Series**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| .101 | .102 | .103 | .104 | .105 | .106 | .107 | .108 | .109 | .110 |
| .111 | .112 | .113 | .114 | .115 | .116 | .117 | .118 | .119 | .120 |
| .121 | .122 | .123 | .124 | .125 | .126 | .127 | .128 | .129 | .130 |
| .131 | .132 | .133 | .134 | .135 | .136 | .137 | .138 | .139 | .140 |
| .141 | .142 | .143 | .144 | .145 | .146 | .147 | .148 | .149 | |

**19 Blocks - .050" Series**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .050 | .100 | .150 | .200 | .250 | .300 | .350 | .400 | .450 | .500 |
| .550 | .600 | .650 | .700 | .750 | .800 | .850 | .900 | .950 | |

**4 Blocks - 1.000" Series**

1.000 2.000 3.000 4.000

15.8.2 Don't trust trial and error methods when assembling gage blocks into a gaging dimension. The basic rule is to select the fewest blocks that will suit the requirement. To construct a length of 1.3275", using a typical 81 piece set, the following procedure may be used:

| | | | |
|---|---|---|---|
| 15.8.2.1 | Write the desired dimension on a piece of paper. | 1.3275 | |
| 15.8.2.2 | Begin the selection at the top of the gage block set. | | |
| 15.8.2.3 | Reduce the last digit of the dimension to zero by selecting A block with a 5 in the fourth decimal place. In this case, The .1005 block is selected and its length is subtracted From 1.3275 to determine a remainder still to be selected. The value .1005 may be written again in an adjacent Column for subsequent proof of the selection. | - .1005<br>1.2270 | .1005 |
| 15.8.2.4 | Select a block to reduce the third decimal place to zero. | - .107<br>1.1200 | .107 |
| 15.8.2.5 | Select a block to reduce the second and first decimals to Zero. Wherever possible, such double reductions are Desirable to cut down the total number of blocks selected. | - .120<br>1.0000 | .120 |
| 15.8.2.6 | Complete the selection with the 1.000 block. | -1.000<br>0.0000 | +1.000<br>1.3275 |

15.8.3 There are times when the same gaging dimension must be assembled more than once from a single set of blocks. This may unavoidably increase the number of blocks required for the specific length. Assume that a second length of 1.3275" is required from the 81 piece set:

| | | | |
|---|---|---|---|
| 15.8.3.1 | Write the requirement. | 1.3275 | |
| 15.8.3.2 | Select two blocks to reduce the fourth decimal to zero. In this case, .1002 and .1003 | - .2005<br>1.1270 | .1002<br>.1003 |
| 15.8.3.3 | One block may now be selected to reduce three digits. | - .127<br>1.0000 | .127 |
| 15.8.3.4 | Select two blocks to form the remaining 1.000. In this case, .400 and .600. | -1.000<br>0.0000 | .400<br>+ .600<br>1.3275 |

15.9 Method Of Converting Screw Thread Number Size to Decimal Equivalent And Vice Versa.

15.9.1 Screw Thread Number Designation To Decimal Equivalent.

Number Designation
X 13
= XXX
+ 60
= Decimal Designation

15.9.2 Decimal Designation To Screw Thread Number Designation.

Decimal Designation
- 60
= XXX
/ 13
= Number Designation

## 16.0 Ceramic – Un-metalized and Metalized

16.1 Un-metalized and metalized ceramics shall be fabricated and inspected in accordance with the requirements of PI-4020, Purchase Specification for Ceramics.

## 17.0 Surface Imperfection Descriptions

### 17.1 Recessions – Inwardly directed surface imperfections

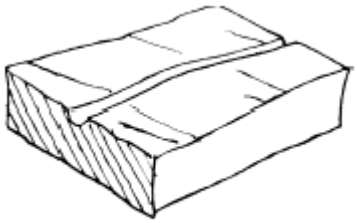


Figure 1

**Groove**

Surface imperfection which is a longitudinal recession with a rounded or flat bottom.

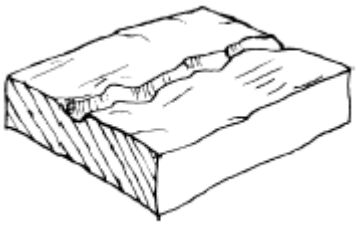


Figure 2

**Scratch**

Surface imperfection which is a recession of irregular shape and unspecified direction.

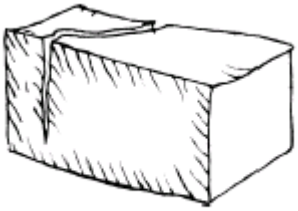


Figure 3

**Crack**

Linear recession with a sharp bottom resulting from a disturbance of the integrity of the surface, and of the parent material of the workpiece.

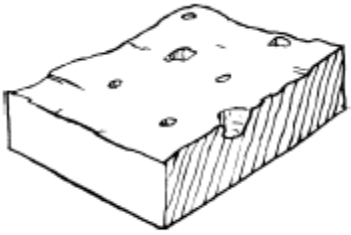


Figure 4

**Pore**

Cavity of very small size with steeply sloping walls and, normally, sharp edges, where the upper edges of the cavity are not higher than the tangential reference surface.

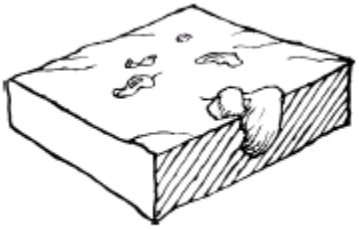


Figure 5

**Blowhole**

Surface imperfection in the form of a single recession resulting from the loss of foreign particles, from etching or from the effect of gas.

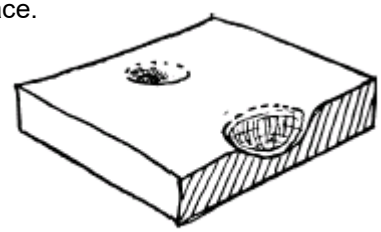


Figure 6

**Shrinkage Hole**

Recession caused by shrinkage during solidification of a casting, a weld, etc.

Figure 7

**Fissure, Crevice, Chink**

Sharp, cleft-like, irregular opening of small depth.

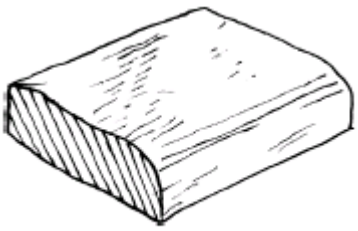


Figure 8

**Wane**

Imperfection in the form of a rounded-off part at the intersection of two workpiece surfaces.

Figure 9

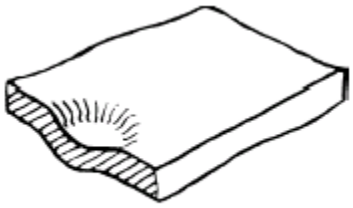


Figure 10

**(concave) Buckle**

Recession on the surface of sheet material caused by local bending.

**Dent**

Hollow with no raised portion, often caused by plastic deformation resulting from an impression or blow.

17.2 Raisings – Outwardly directed surface imperfections

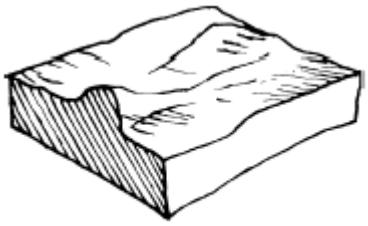


Figure 11

Figure 12

**Wart**

Ridge-like or hill-like elevation of small size and limited height.

**Blister**

Local convexity caused by a subsurface inclusion of gas or liquid.

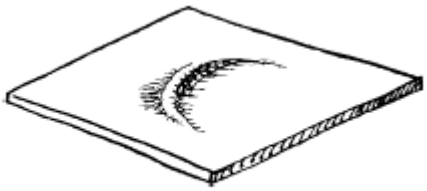


Figure 13

Figure 14

**(convex) Buckle**

Raising on the surface of sheet material caused by local bending.

**Scale**

Flake-like, partially, detached raising of small thickness, resulting from flaking of the surface layer, which is of a different composition than the parent material.

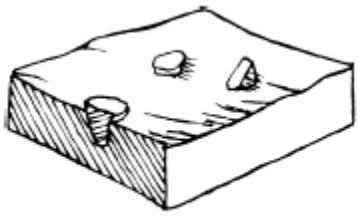


Figure 15

Figure 16

**Inclusion**

Particle of foreign material embedded in the workpiece material.

**Burr**

Raised sharp edge, frequently with a wane on the opposite side.

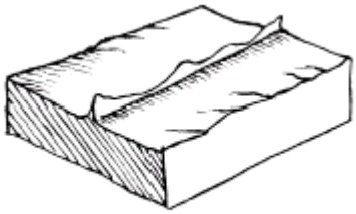


Figure 17

**Flash**

Ridge of workpiece material either expelled from the gap between mold parts or die parts when forming (die casting, forging, etc.) or formed perpendicular to the direction of pressure when resistance welding two surfaces (upset welding, flash welding, etc.).

Figure 18

**Deposits**

Build-up on a workpiece either of foreign material or of material from another workpiece.

17.3 Combined Surface Imperfections – Partially inwardly and partially outwardly directed surface imperfections.

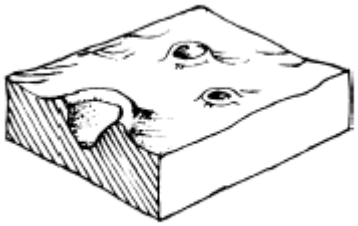


Figure 19

**Crater**

Hollow with a circular contour and raised edges resembling the mouth of a volcano; the edges are higher than the reference surface.

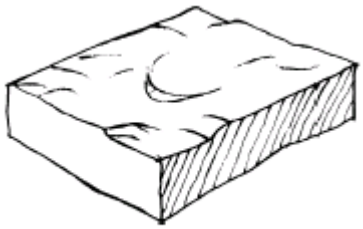


Figure 20

**Lap**

Tongue-like raising of small thickness, often in the form of a seam, caused by folding over of material and forcing it into the surface when rolling, forging, etc.

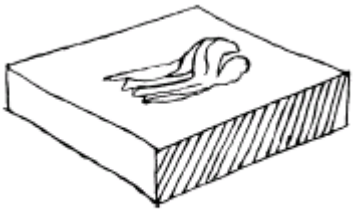


Figure 21

**Scoring**

Imperfection in the form of successive recessions and raisings caused by the expulsion of workpiece material due to the movement of a foreign body.

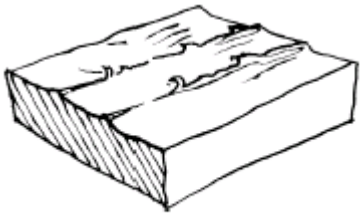


Figure 22

**Chip Rest**

Band-like raisings resulting from poor chip removal.

17.4 Area / Appearance Imperfections – Scattered imperfections in the outermost surface layer, often without sharp contours and often without practicably measurable depth or height.

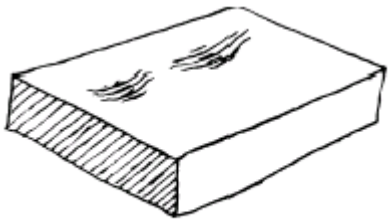


Figure 23

**Skidding**

Surface damage of, for example, ball bearings, rollers and races of bearings, of silvery frosted appearance, which occurs on discrete areas of the surface and is caused by intermittent overloading.

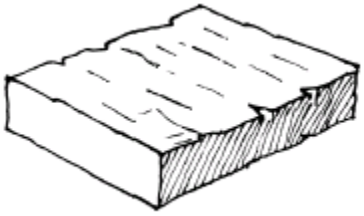


Figure 24

**Erosion**

Surface damage due to the physical destruction or wear of the surface.

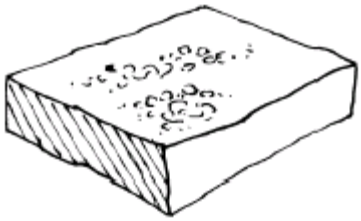


Figure 25

**Corrosion**

Surface damage due to the chemical destruction of the surface.

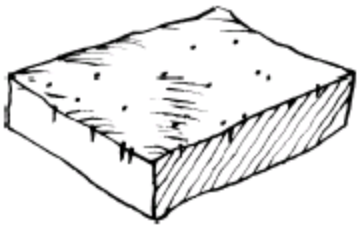


Figure 26

**Pitting**

Imperfection in the form of pits and small holes, often of large depth, dispersed over a large area of the surface

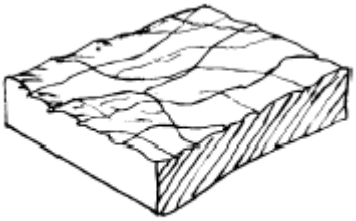


Figure 27

**Crazing**

Imperfections in the form of a network of cracks on a Surface.

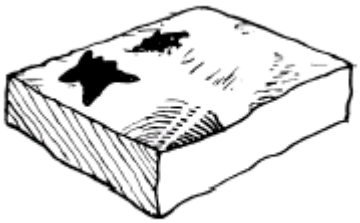


Figure 28

**Spot, Patch**

Area which differs visually from the adjacent surface.

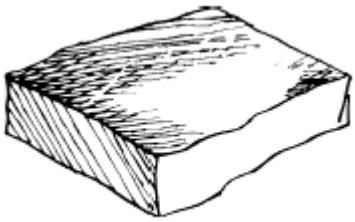


Figure 29

**Discoloration**

Discolored area on a surface.

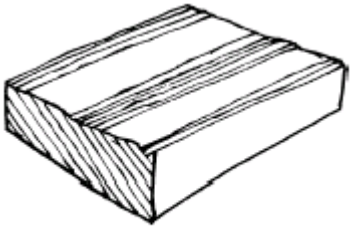


Figure 30

**Streak**

Band-like recessed area generally of small depth, or area having a different surface texture.

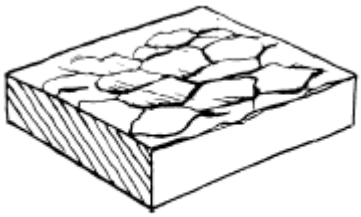


Figure 31

**Flaking, Cleavage**

Imperfection resulting from partial separation of a portion of the workpiece surface layer.

## 18.0 Printed Circuit Boards

18.1 Printed circuit boards shall meet the requirements IPC-A-600, Class 2. Printed boards shall be processed and fabricated in such a manner as to be uniform in quality and free of defects as provided by IPC-A-600, Class 2. Acceptance of imperfections or defects not specifically covered by IPC-A-600 shall be agreed upon by the Williamsport facility and the supplier.

## 19.0 Printed Circuit Boards Assemblies

19.1 Printed circuit board assemblies shall meet the requirements IPC-A-610, Class 2. Printed board assemblies and their components shall be handled, processed, assembled, conformal coated and inspected in such a manner as to be uniform in quality and free of defects as provided by IPC-A-610, Class 2. Acceptance of imperfections or defects not specifically covered by IPC-A-610 shall be agreed upon by the Williamsport facility and the supplier.

## 20.0 Cable and Wire Harness Assemblies

20.1 Cable and wire harness assemblies shall meet the requirements IPC-A-620, Class 2. Cable and wire harness assemblies and their components shall be handled, processed, assembled and inspected in such a manner as to be uniform in quality and free of defects as provided by IPC-A-620, Class 2. Acceptance of imperfections or defects not specifically covered by IPC-A-620 shall be agreed upon by the Williamsport facility and the supplier.

## 21.0 Solicitation Of Comments and/or Suggestions

21.1 The purpose of this section is to solicit beneficial suggestions or comments which will help achieve procurement of suitable quality products at a reasonable cost, or otherwise enhance the use of this document. Manufacturers / suppliers who are either active or prospective suppliers of product to the Williamsport facility are invited to submit suggestions or comments. When submitting comments or suggestions attach any pertinent data or information which may be of use for review of the comments for document improvement.

21.1.1 Suggestions or comments submitted do not constitute or imply authorization to waive any portion of this document or referenced documents or to amend purchase order or contractual requirements.

21.1.2 Suggestions and/or Comments should be sent to:

Stellant Systems
1035 Westminster Drive
Williamsport, PA 17701 Attn. Quality Assurance Manager