AEROSPACE RECOMMENDED PRACTICE

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Definitions and Limits, Metal Material Defects and Surface and Edge Features, Fluid Couplings, Fittings, and Hose Ends

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE G-3, Aerospace Couplings, Fittings, Hose, Tubing Assemblies Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) is intended to provide definitions of and recommendations for drawing limits pertaining to surface and edge features on machined metal fluid fittings and is subject to change to keep pace with experience and technical advances. The subject includes: features, descriptions and definitions, examples, limits, inspection methods and standard drawing callouts where applicable. Fittings may retain unmachined material surfaces that exhibit similar surface features as machined surfaces and may be inspected to the same criteria. These unmachined surfaces may also contain unique features that are addressed separately. See Figure 1 for the relationship of surface and edge features.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2630 Ultrasonic Inspection Product Over 0.5 inch (12.5 mm) Thick
AMS 2631 Ultrasonic Inspection Titanium and Titanium Alloy Bar and Billet
SAE Dictionary Of Aerospace Engineering, 1992

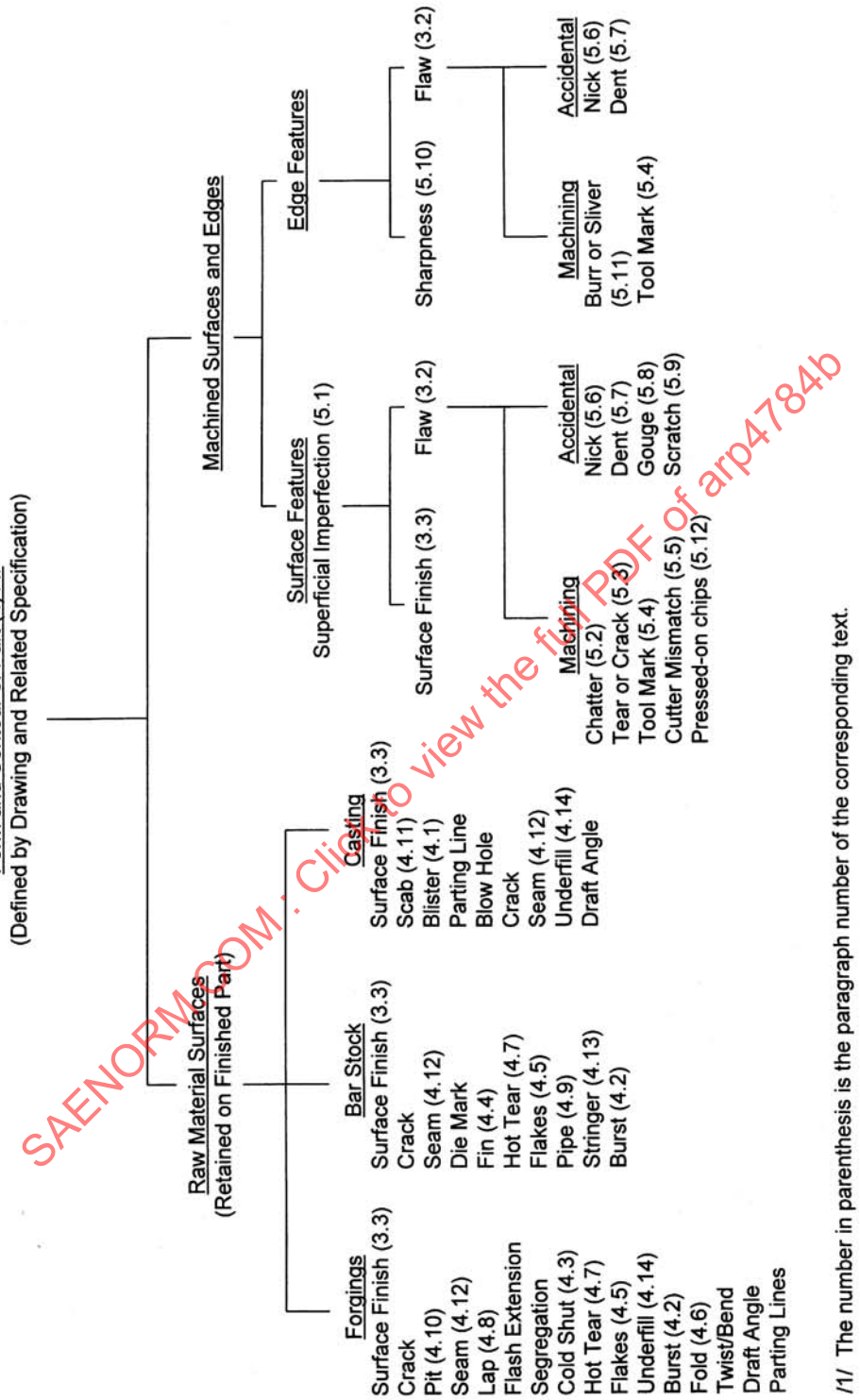

FIGURE 1 - Fluid Fittings, Surface and Edge Features

2.1.2 ANSI/ASME Publications: Available from the American Society of Mechanical Engineers, 345 East 47th Street, NY 10019.

ASME B46.1	Surface Texture (Surface Roughness, Waviness, and Lay)
ASME Y14.5M	Dimensioning and Tolerancing
ASME Y14.36M	Surface Texture Symbols

2.1.3 American Society for Metals Publications: Available from American Society for Metals, Metals Park, OH 44074.

Metals Handbook, 10th Edition:	Volume 9 Metallography and Microstructures
	Volume 10 Materials Characterization
	Volume 11 Nondestructive Inspection
	Volume 14 Forming and Forging
	Volume 17 Nondestructive Evaluation

2.1.4 American Society for Testing and Materials Publications: Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

ASTM E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 Definitions:

BLOW HOLE: Pocket of gas trapped during solidification of a cast metal. [2.3 b.]

BURST: A surface fissure or rupture caused by metal movement during rolling or forging.

BURR: A thin, turned over edge produced by grinding, cutting, shearing or other material removal or forming process. [2.3 b.]

CHATTER: Regular waves, ridges, undulations or riblike markings on surfaces or edges caused by vibration of a cutting tool or part during machining.

COLD SHUT: A portion of a part that is partially separated from the main body of metal by oxide, or by the failure of two streams of metal to fuse. [2.3 b.]

CRACK: A clean (crystalline) fracture passing through or across grain boundaries, normally caused by overstressing the metal during forging, machining or other forming operations, or during casting and heat treatments. [2.3 b.]

CUTTER MISMATCH: Step or height difference on the same defined surface due to two different machining passes that do not meet perfectly.

2.2 (Continued):

DEFECT: Nonconformance of a unit or product with specified requirements, a departure of any quality characteristic from its specified or intended value that is severe enough to constitute cause for rejecting the product. [2.3.b.]

DENT: Indentation on the edge or surface produced by forceful impact or abrasion with a length generally less than three times longer than the width, occurs as a single random indentation, has a rounded contour at the bottom. [2.3 b.]

DIE MARK: Lines or markings on formed, drawn or extruded metal parts caused by imperfections on the surfaces of the die. [2.3 e.]

DISCONTINUITY: An interruption occurring on a defined and otherwise continuous surface or edge caused by normal forming or machining practices; considered to be a defect only when its nature, degree, frequency or location is detrimental to the quality or performance of the part. [2.3 b.]

DRAFT ANGLE: The angle of taper, usually 5° to 7°, given to the sides of a casting and the sidewalls of its mold or forging or the sidewalls of an impression die to facilitate removal of the pattern from its mold or forging from the dies. [2.3 c.]

EDGE: The intersection of two surfaces.

FEATURE: The general term applied to a physical portion of a part.

FIN: Thin projection formed when metal is forced under pressure into die interfaces. [2.3 c.]

FLASH EXTENSION: That portion of flash remaining on a forged part after trimming; usually included in the normal tolerances. [2.3 c.]

FLAW: Unintentional, unexpected, and unwanted interruptions in the topography typical of a part surface; such topographical interruptions are considered flaws only when agreed on by purchaser and seller. [2.3 a.]

FLAKE: Short, discontinuous internal cracks in ferrous metals caused by stresses produced by localized transformation and hydrogen solubility effects during cooling after hot working; also known as fisheye, shattercrack, snowflake or hairline cracks. [2.3 b., 2.3 d.]

FLASH: Metal in excess of that required to fill the forging impression of a set of dies completely; extends out as a thin plate at the line where the dies meet and is subsequently removed by trimming. [2.3 c.]

FOLD: A forging defect caused by doubling over of metal back onto its own surface during flow in the cavity. [2.3 b., 2.3 c.]

2.2 (Continued):

GOUGE: Indentation on the surface produced by forceful impact or abrasion with a length generally three or more times longer than the width, occurs as a single random indentation, has a curved or sharp contour at the bottom.

HOT TEAR: A fracture, typically on the surface of a part, formed in a metal during solidification, due to hindered contraction.

INSPECTION AT MAGNIFICATION: Visual inspection with the aid of a magnifying device of specified power.

INSPECTION, VISUAL: Inspection with the unaided or corrected eye having a minimum acuity of 20/25.

LAY: The direction of the predominant surface pattern, ordinarily determined by the production method used. [2.3 a.]

LAP: Similar to a seam or fold, may result from improper rolling practices or, in the case of a forging, the metal being folded over but failing to fuse into a single piece. [2.3 b.]

MISMATCH: Lateral offset between two halves of a casting or forging die, which produces distortion in shape across the parting line. [2.3 c.]

NICK: Indentation on the edge or surface produced by forceful impact or abrasion with a length generally less than three times longer than the width, occurs as a single random indentation, has a sharp contour at the bottom. [2.3 b.]

PIPE: Discontinuity in the center of a rolled bar caused by internal cavities in the ingot formed during solidification and which have become elongated in the rolling operations. [2.3 b.]

PARTING LINE: Line along the surface of a forging where the dies meet, usually at the largest cross-section of the forging. [2.3 c.]

PIT: Small surface cavity in the surface of a metal part or coating usually caused by corrosion, or formed during electroplating. [2.3 b.]

PRESSED-ON CHIPS: Small chip of material produced by a cutting tool that is subsequently pressed onto the surface or edge of a part with such force that it adheres to the surface of the part and requires substantial force to remove.

SCAB: Surface defect on a cast or rolled metal product consisting of a thin flat piece of metal partly detached from the substrate. [2.3 b.]

2.2 (Continued):

SCRATCH: Indentation on the surface with a length usually three or more times the width, generally much longer, may have a sharp or contoured bottom, caused by a harder edge or point being dragged or pushed across the surface.

SEALING SURFACE: Surface on a fluid system component that when mated with a similar surface on a second component is intended to prevent the passage of fluid across the mated interface.

SEAM: Usually a surface crack resulting from a defect obtained in casting, forging or rolling, caused by materials not homogeneous with the base metal, typically oxides; usually straight, narrow and continuous. [2.3 b., 2.3 c.]

SEGREGATION: Nonuniform distribution of alloying elements, impurities or phases in a metal microstructure. [2.3 d.]

SHARP EDGE: An edge that can readily cut or tear.

SLIVER: A long, thin burr attached only at a small part of the length.

STRINGER: Solid nonmetallic impurity often the result of an inclusion that has been stretched during a rolling process, commonly associated with elongated oxide or sulfide inclusions in steel. [2.3 b., 2.3 e.]

SUPERFICIAL IMPERFECTIONS: Visible mark or burnish of no measurable depth typically caused by contact with gauges or fixtures.

SURFACE: The boundary that separates that object, from another object, substance or space. [2.3 a.]

SURFACE FINISH: Consists of the finer irregularities of the surface texture, including those irregularities that result from the inherent action of the production process; if flaws, as specified (see definition above) are not present, or have not been specified, then interruptions in the surface topography may be included in the measurement of the surface finish. Also referred to as roughness. [2.3 a.]

SURFACE TEXTURE: The repetitive or random deviation from the nominal surface that forms the three dimensional topography of the surface; includes roughness, waviness, lay, and flaws. [2.3 a.]

TEAR: Generally short, jagged surface discontinuities at right angles to the direction of machining caused by too heavy a cut, a dull tool or dragging the tool over the metal when not cutting cleanly.

TOLERANCE: Permissible variation in the dimension of a part, permissible deviation from a specified value. [2.3 b.]

2.2 (Continued):

TOLERANCE LIMITS: The extreme upper and lower boundaries of a specified range, computed from the nominal value and its tolerance. [2.3 b.]

TOOL MARK: Grooves of shallow depth produced by the movement of manufacturing tools over the surface of the part, may be of a regular, repeating pattern or of a irregular, random nature.

TWIST/BEND: Distortion similar to warpage caused during forging or trimming operations. When the distortion is along the length of the part, it is termed bend; when across the width, it is termed twist. [2.3 c.]

UNDERFILL: A portion of a forging or casting that has insufficient metal to give it the true shape of the impression. [2.3 c.]

WAVINESS: The more widely spaced component of surface texture; to include all irregularities whose spacing is greater than the roughness sampling length and less than the waviness sampling length; may result from such factors as machine or work deflections, vibrations, chatter, heat treatment, or warping strains; roughness may be considered as superimposed on a wavy surface. [2.3 a.]

2.3 Sources for Definitions:

The following publications were used for definitions in 2.2, as indicated by the reference following the definition.

a. ANSI/ASME B46.1-1985, Surface Texture (Surface Roughness, Waviness, and Lay)
b. SAE Dictionary of Aerospace Engineering, 1992
c. ASM Metals Handbook Ninth Edition, Volume 14 Forming and Forging, 1988
d. ASM Metals Handbook Ninth Edition, Volume 9 Metallography and Microstructures, 1985
e. ASM Metals Handbook Desk Edition, 1985

3. DRAWING FEATURES, DESCRIPTIONS AND LIMITS:

3.1 Dimension:

3.1.1 Description: A numerical value expressed in an appropriate unit of measure and used to define the size, location or geometric characteristic of a part or part feature.

3.1.2 Example: 0.610 ± 0.005

3.1.3 Limits: All limits are absolute. Dimensional limits, regardless of the number of decimal places, are used as if they were continued with zeros. The low limit of 0.605 is 0.605000…etc. And the high limit of 0.615 is 0.615000…etc. Any numerical value outside of the specified limit signifies nonconformance.

3.1.4 Inspection Methods: Measuring methods should be 10 times more accurate than the dimension being measured. Dimensions in thousandths should be measured with equipment capable of measuring to tenths of thousandths.

3.1.5 Standard Drawing Callout: Dimensions will normally be in 0.001 increments. More decimal places may be used if required.

3.2 Depth Limit of Flaws:

The depth of individual surface features considered flaws, such as machining tears or cracks or tool marks shall not exceed the limits of Table 1 for unmachined surfaces, or of Table 2 for machined surfaces, unless otherwise specified. The limits in Table 1 are based on structural integrity of the part under normal operating conditions expected in aerospace hydraulic applications. The limits in Table 2 are based on usage requirements expected of surfaces with these finishes. Known exceptions are stated in the text of this document. Other exceptions may be made on the referencing document.

TABLE 1 - Depth Limits of Features Considered Flaws Based for Raw Material Surfaces

Nominal Wall Thickness	Maximum Permissible Depth of Flaws[1]
.020 and under	10% of nominal wall thickness
.021 through .030	.0020
.031 through .040	.0025
.041 through .050	.0030
.051 through .066	.0040
.067 through .085	.0060
above .085	.0080

[1] Minimum wall thickness specified for the part must be maintained.

TABLE 2 - Depth limits of Features Considered Flaws for Machined Surfaces

Surface Finish Requirement Ra (µin)	Maximum Permissible Depth of Flaws (in)
8	.0002
16	.0005
32	.0008
63	.001
125	.002
250	.004

3.3 Surface Finish:

3.3.1 Description: The measurement of surface texture and its constituents.

3.3.2 Limits: Use the surface roughness values listed in Table 3 unless otherwise noted on the drawing. If flaws are defined, the surface should be inspected specifically to determine whether flaws are present, and rejected or accepted prior to performing final surface finish measurements. If defined flaws are not present, or if flaws are not defined, then interruptions in the part surface may be included in roughness measurements.

TABLE 3 - Surface Roughness Values

Surface or Feature	Ra (µin)
Fluid sealing surfaces	63
Threaded surfaces	63
All machined surfaces not otherwise listed	125
Hex flats	250
Forged surfaces	250
Rolled or drawn bar surfaces	250
Cast surfaces	250

3.3.3 Inspection Methods: Visual comparison to a sample gage or average measurement with a profilometer.

4. UNMACHINED MATERIAL FEATURES, DESCRIPTIONS AND LIMITS:

4.1 Blister:

4.1.1 Description: A raised spot on the surface caused by expansion of subsurface gas during heating. Blisters may break open during rolling and produce a defect that looks like a gouge or surface lamination.

4.1.2 Limits: The depth of a blister in an unmachined surface on a finished part shall not exceed the limits in Table 1. The length and width shall be less than twice the depth.

4.1.3 Inspection Method: Visual, micrometer device on a microscope.

4.2 Burst:

4.2.1 Description: Surface fissure or rupture caused by metal movement during rolling or forging.

4.2.2 Limits: The depth of a burst in an unmachined surface of a finished part shall not exceed the limits in Table 1. The length and width shall be less than twice the depth.

4.2.3 Inspection Method: Visual, micrometer device on a microscope.

4.3 Cold Shut:

4.3.1 Description: Surface discontinuity resulting when lumps of softened metal come together inside a mold but fail to fuse. A portion of the part is partially separated from the main body of metal by the failure of two streams of metal to unite.

4.3.2 Limits: The depth of cold shuts in an unmachined surface of a finished part shall not exceed the limits in Table 1. The length shall be less than twice the allowable depth, and the width shall not exceed 0.0005.

4.3.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen, or ultrasonic inspection per AMS 2630 or per AMS 2631 for titanium alloys.

4.4 Fin:

4.4.1 Description: Protrusion of material formed by incorrect reduction during hot working.

4.4.2 Limits: Fins less than or equal to 0.003 in length on material up to and including 0.040 thick are acceptable and fins less than or equal to 0.006 in length on material greater than 0.040 thick are acceptable.

4.4.3 Inspection Method: Visual inspection, micrometers or comparator.

4.5 Flake:

4.5.1 Description: Short, discontinuous internal fissures caused by localized transformation stresses and decreased solubility of hydrogen during cooling after hot working. In a fractured surface flakes appear as bright silvery areas, on an etched surface they appear as short cracks. This condition is typically found in carbon steel forgings with cross-sections greater than 2.500. Flakes are also referred to as “shatter cracks” and “snowflakes”.

4.5.2 Limits: When samples are prepared and examined per ASTM E 381 evidence of flaking shall not be visible at a magnification of 100X.

4.5.3 Inspection Method: Microscopic examination of a mounted specimen at a magnification of 100X.

4.6 Fold:

4.6.1 Description: A forging flaw caused by folding metal back onto its own surface. Folds typically occur at diameter changes, shoulders and heads.

4.6.2 Limits: The depth of a fold in an unmachined surface of a finished part shall not exceed the limits in Table 1. The length shall be less than twice the allowable depth.

4.6.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen.

4.7 Hot Tear:

4.7.1 Description: A fracture, usually on the surface of the part, formed in a metal during solidification because of hindered contraction.

4.7.2 Limits: The depth of a hot tear in an unmachined surface of a finished part shall not exceed the limits in Table 1. The length shall not be more than twice the depth, and the width shall not exceed 0.0005.

4.7.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen.

4.8 Lap:

4.8.1 Description: A surface discontinuity, on the surfaces of rolled or drawn products appearing as a fold or tangential seam, which occurs when a protrusion of metal is folded over and rolled into the surface. Presence of oxide on the internal surface of the lap prevents the metal from joining.

4.8.2 Limits: The depth of a lap in an unmachined surface of a finished part shall not exceed the limits in Table 1.

4.8.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen, or ultrasonic inspect per AMS 2630 or per AMS 2631 for titanium alloys.

4.9 Pipe:

4.9.1 Description: An internal flaw in a rolled, cast or forged product. Pipe is caused by internal cavities in the ingot formed during solidification. If the shrink cavity is not cut away or cropped prior to rolling or forging it may become elongated or stretched, showing up as voids (pipe) in the finished product.

4.9.2 Limits: Suspect material or parts shall be ultrasonic inspected per of AMS 2630 Class A1, or AMS 2631 Class A1 for titanium alloys, and shall show no indication of piping or voids.

4.9.3 Inspection Method: Ultrasonic inspect per AMS 2630 Class A1or per AMS 2631Class A1 for titanium alloys.

4.10 Pit:

4.10.1 Description: Individual hole chemically produced, typically irregular in shape.

4.10.2 Limits: The depth of pits in an unmachined surface of a finished part shall not exceed the limits in Table 1. The depth of pits in a machined surface due to post machining processing shall not exceed the limits in Table 2. No pits shall be detectable on sealing surfaces during macroscopic examination in accordance with Section 6, at up to 10X magnification.

4.10.3 Inspection Method: Visual, micrometer device on a microscope.

4.11 Scab:

4.11.1 Description: A flaw resulting from improper pouring of a casting, in which liquid metal is splashed against the mold wall. This scab tends to stick to the wall and become oxidized. This typically results in a poor surface finish.

4.11.2 Limits: Scabs must be removed from the raw material prior to further processing. The depth of any voids shall not exceed the limits in Table 1. Dimensional and surface roughness requirements of the finished part shall be met.

4.11.3 Inspection Method: Visual, micrometers, average measurement with a profilometer.

4.12 Seam:

4.12.1 Description: A surface discontinuity, caused by a void or crack in rolled material, parallel to the axis of the material. Though closed, the metal has not joined.

4.12.2 Limits: The depth of a seam in an unmachined surface of a finished part shall not exceed the limits in Table 1. Machined surfaces shall have all seams removed by the machining process.

4.12.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen, ultrasonic inspect per AMS 2630 or per AMS 2631 for titanium alloys.

4.13 Stringer:

4.13.1 Description: A microstructural configuration of alloy constituents or foreign nonmetallic material in the parent metal, often the result of an inclusion that has been stretched during a rolling process.

4.13.2 Limits: Suspect material or parts shall be ultrasonic inspected perof AMS 2630 Class A1, or AMS 2631 Class A1 for titanium alloys, and shall show no indication of stringers.

4.13.3 Inspection Method: Ultrasonic inspect per AMS 2630 Class A1 or per AMS 2631 Class A1 for titanium alloys.

4.14 Underfill:

4.14.1 Description: A shortage of metal such that a portion of the forging or casting does not have the true shape of the impression.

4.14.2 Limits: The dimensions of the forging or casting must be met. Also the minimum mechanical properties of the material specification must be met.

4.14.3 Inspection Method: Visual, micrometers, tensile test.

5. MACHINED MATERIAL FEATURES, DESCRIPTIONS AND LIMITS:

Except for superficial imperfections and other exceptions stated on individual part drawings, the following machined material features are not allowed on sealing surfaces.

5.1 Superficial Imperfection:

5.1.1 Description: Superficial imperfections of no measurable depth such as burnish marks and evidence of contact with gages and fixtures are not detrimental and shall not be cause for rejection.

5.1.2 Limits: Not applicable.

5.1.3 Inspection Method: Visual inspection.

5.2 Chatter:

5.2.1 Description: Regular waves, ridges, undulations or rib-like markings on surfaces or edges caused by vibration of a cutting tool or part during machining.

5.2.2 Limits: Acceptable as long as the specified surface roughness requirements are met. Except no chatter shall be detectable on sealing surfaces during macroscopic examination in accordance with Section 6, at up to 10X magnification.

5.2.3 Inspection Method: Visual inspection.

5.3 Machining Tear or Crack:

5.3.1 Description: Generally short, jagged surface discontinuities at right angles to the direction of machining caused by too heavy a cut, a dull tool or dragging the tool over the metal when not cutting cleanly.

5.3.2 Limits: The depth of a machining tear or crack shall not exceed the limits in Table 2. The length shall be less than twice the depth, and the width shall be less than 0.0005.

5.3.3 Inspection Method: Microscopic examination of a cross-sectioned and mounted specimen.

5.4 Tool Mark:

5.4.1 Description: Grooves of shallow depth produced by the movement of manufacturing tools over the surface of the part. May be of regular repeating pattern form or of irregular random nature.

5.4.2 Limits: Tool marks are acceptable as long as the specified surface roughness requirements are met. The depth of tool marks shall not exceed the limits of Table 2, unless otherwise specified. Spiral tool marks or circumferential tool marks with a maximum depth of 0.003 are permitted in drilled holes unless otherwise specified. Random tool marks on sealing surfaces, not coinciding with the lay of the surface, shall not be detectable during macroscopic examination in accordance with Section 6, at up to 10X magnification.

5.4.3 Inspection Methods: Visual inspection, micrometer device on a microscope.

5.5 Cutter Mismatch:

5.5.1 Description: Step or height difference on the same surface due to two different machining cutter passes that do not meet perfectly.

5.5.2 Limits: The step or misalignment shall not exceed 0.010 unless otherwise specified.

5.5.3 Inspection Method: Visual inspection, comparator, micrometer.

5.6 Nick:

5.6.1 Description: An indentation that usually occurs on an edge but may occur on a surface with a length generally less than three times the width. (Longer indentations on surfaces may be identified as scratches.) Has a sharp contour at the bottom. (Indentations with rounded contours at the bottom may be identified as dents.) Occurs as a single random indentation. Caused by a harder opposing sharp corner or point being pushed, hit into or dropped onto the edge or surface. There may be material build-up over the level of the surface at the edge of the indentation.