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1.0 SCOPE

This specification defines the general surface texture requirements and accepted internationally recognized methods to evaluate them, for the 4 types of designated surfaces on Caterpillar Inc. drawings. Values shown in illustrations are in metric units and are shown only to illustrate the symbols. Referenced standards are American National Standards Institute (ANSI) B46.1 and Y14.36 and International Standards Organization (ISO) 1302, 3274, 4287, 4288, 5436, 8785, 11562, and 13565.

2.0 APPLICATION

2.1 To all drawings that list 1E2122 Surface Texture.

2.2 To drawings having features specifically controlled by Figures 5, 6, and 7, as per 1E0011.

3.0 DEFINITIONS OF ABBREVIATIONS, TERMS, AND SYMBOLS

3.1 Abbreviations

HFS-P&O	Hot Finished Surface - Pickled and Oiled
Ln	Full Stylus Assessment Length (Assessment Length)
Rsm	Average Roughness Spacing
Rz	Average Roughness Peak to Valley Height
Wc	Average Peak to Valley Waviness Height
Ws	Average Waviness Peak Spacing
Wsm	Wavelength Average Mean Line Spacing
Wt	Maximum Waviness Peak to Valley Height
Zp _i	Highest Peak Height (Positive Value) from the Mean Line in the i th Sampling Length
Zv _i	Lowest Valley Depth (Positive Value) in the i th Sampling Length
λ _s (or L _s)	Lower bound of wavelengths that are considered part of the roughness profile, specified in μm.
λ _c (or L _c)	The roughness cutoff which is the boundary between surface features that are considered part of the roughness profile and surface features that are considered part of the waviness profile, specified in mm. "Lc" can also be used to indicate the roughness sampling length.
λ _f (or L _f)	The upper bound of wavelengths that are considered part of the waviness profile, specified in mm. "Lf" can also be used to indicate the waviness cutoff or sampling length.
Pt	Maximum Peak to Maximum Valley Distance in the P Profile.
Pa	Arithmetic Average of the Absolute Values of the Peak to Valley Deviations in the P Profile.
Pv	Centerline to Deepest Valley depth in the P Profile.

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SURFACE TEXTURE

DATE
03 DEC 2015

CHG NO
21

NUMBER
1E2122

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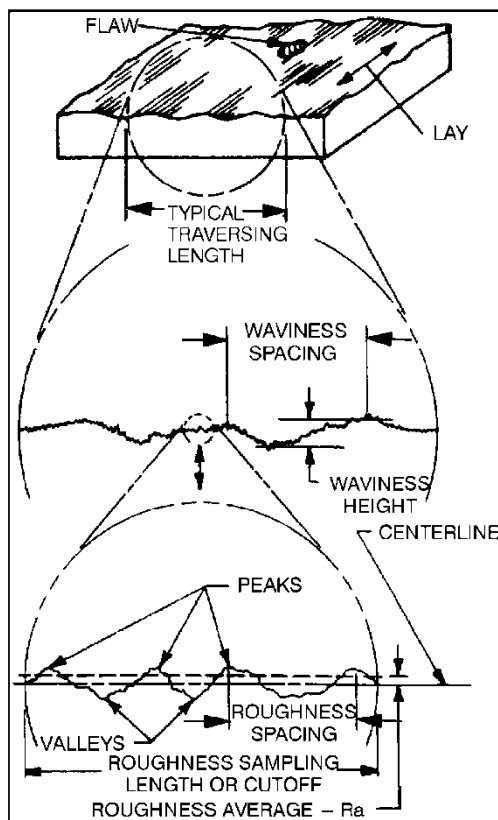


Figure 1 - Pictorial Display Of Surface Characteristics

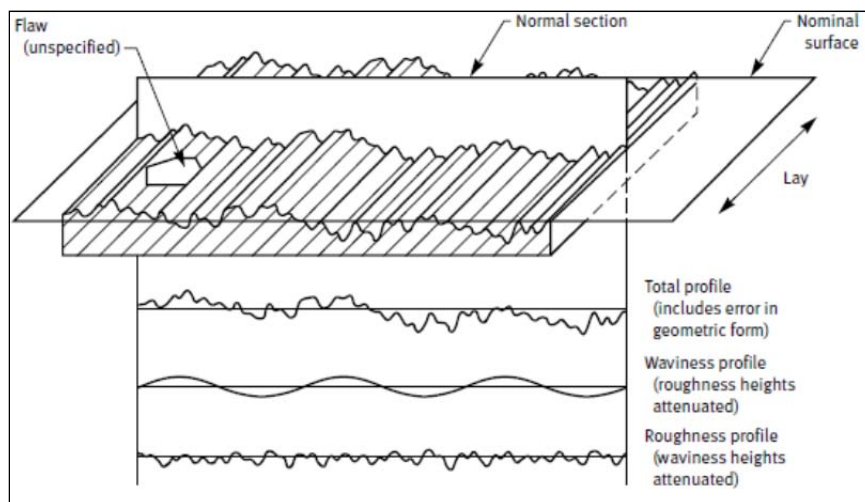


Figure 2 - Pictorial Display of Separation of Roughness And Waviness Profiles From The Total Profile

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3.2 Surface - The boundary which separates an object from another object, substance, or space.

3.3 Surface Texture Representations - Figure 1 depicts what a typical surface would appear like in a microscopic view. Figure 2 shows how a tracing of such a surface can be divided into the components of waviness, roughness and total profile. Figure 2 and the following definitions are referenced from ANSI B46.1, ISO 4287, and ISO 11562.

3.4 Surface Texture - The repetitive or random deviations from the nominal surface which form the three dimensional topography of the surface. Surface texture characteristics include roughness, waviness, and lay. (See Figure 1 and Figure 2).

3.5 Centerline - The graphical centerline is the line about which roughness is measured and is a line parallel to the general direction of the profile within the limits of sampling length, such that the sums of the areas contained between the graphical centerline and the parts of the profile, peaks, and valleys which lie on either side of it are equal.

3.6 Profile - The contour of the surface in a plane perpendicular to the surface (normal section), unless another angle is specified.

3.7 Peak - An outwardly directed (from the part material toward the surrounding medium) excursion of the assessment profile point above the profile centerline and between two crossings of the profile centerline.

3.8 Valley - An inward directed (into the part material) excursion of the profile below the profile centerline and between two crossings of the profile centerline.

3.9 Roughness - The finer irregularities of the surface texture, usually including those irregularities which result from the inherent action of the production process. Roughness includes all irregularities whose spacing is greater than the minimum roughness wavelength (stylus cutoff λ_s or L_s) and less than the roughness cutoff λ_c (or L_c). (See Figure 3). The roughness cutoff is also known as the roughness sampling length. These are considered to include traverse feed marks and other irregularities within the limits of the roughness cutoff. Roughness is considered to be superimposed on a “wavy” surface.

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3.10 Waviness - The more widely spaced component of surface texture. Waviness results from such factors as machine or part deflections, vibration, chatter, heat treatment, warping strains, or other factors. Waviness includes all irregularities whose spacing is greater than the roughness cutoff λ_c (or L_c) and less than the waviness cutoff λ_f (or L_f). (See Figure 3). The waviness cutoff is equal to the waviness sampling length which in most cases works best to be equal to the roughness measurement length (roughness assessment length). (Note: Waviness is only able to be measured using a skidless surface texture instrument. (See Paragraph 7.4.4.1).

3.11 R, W, And P Profiles - When acquiring a single trace using a surface texture instrument, the unfiltered trace often includes all aspects of roughness, waviness and form deviation. The process of filtering is intended to separate this unfiltered trace into the components of roughness, waviness and form, to assist in control of functional surface quality so that it will reliably accomplish the intended performance and to assist in control of manufacturing to attain this desired functional surface quality. The filtering function then results in extracting from this unfiltered trace, the separated roughness, waviness and form profiles. The waviness profile is effectively then the centerline for the roughness profile and the form profile is effectively the centerline for the waviness profile. The roughness profile is called the R Profile, used to determine R parameter values, and the waviness profile is called the W Profile used to determine W parameter values (See Figures 1 and 2 and ISO 3274). Surface texture instruments are more often used to acquire and analyze these two profiles, (since surface texture is viewed to be the combination of the two) and less often used to acquire the form profile. One other profile of interest is the primary profile, called the P Profile, which is the combination of the R and W Profiles (only form error removed), which is used to determine P parameter values.

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3.12 Transmission Band - A surface texture measurement has three cutoffs (λ_s , λ_c , and λ_f), as mentioned above, that define the transmission bands for the signal processing used to transform the raw traces into roughness and waviness information. λ_s (or L_s) is the lower bound of wavelengths considered part of the roughness profile and is specified in μm . λ_c (or L_c) is the roughness cutoff which is the boundary between surface features considered part of the roughness profile and surface features considered part of the waviness profile and is specified in mm. λ_f (or L_f) is the upper bound of wavelengths that are considered part of the waviness profile and is specified in mm. "Lc" or "Lf" can also be used to refer to cutoff or sampling length. Whether for roughness or waviness, cutoffs are designated in millimeters and are equivalent in value to the respective sampling length. All the cutoff values are at the 50% transmission point of the notch filter used to separate the roughness and waviness profiles from the primary profile of the surface. The filter transmission bands are shown in Figures 3 and 4 below. If any instrument in use has the ability to select Gaussian filter, 2CR filter, or phase correct filter, the Gaussian filter shall always be selected. Roughness sampling length is indicated as L_c sampling length or the cutoff length.

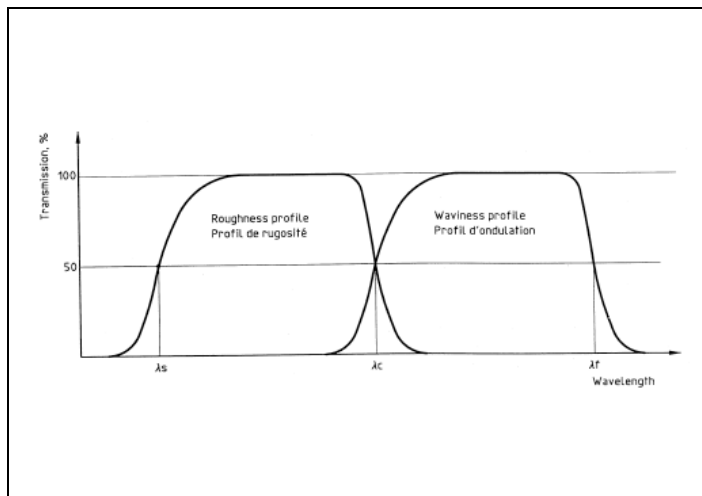


Figure 3 - Graphical Representation Of Waviness And Roughness Profile Filters (Refer To ISO 4287-1997)

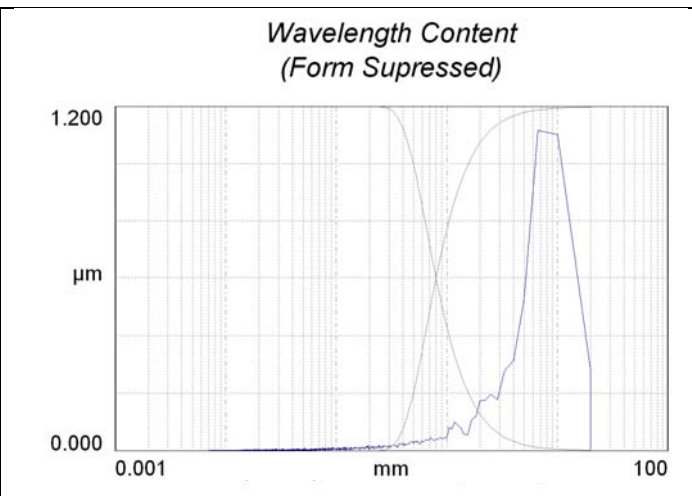


Figure 4 - Wavelength Content Of Actual Surface Shown With Waviness And Roughness Profile Filters Superimposed

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3.13 Roughness Assessment Length (Ln) - The length Ln of profile to be assessed by the stylus to establish a representative measurement. In general, a number of sampling lengths Lc or Lf defined here are combined to comprise the assessment length. The roughness sampling length is the length over which roughness parameters are evaluated. The roughness assessment length, if possible, shall include a minimum of five or more roughness cutoff or sampling lengths, but may be longer as necessary. The roughness cutoff shall be selected based on the required surface function or the roughness from the selected process (See Figures 9 and 10), not based on available surface length. If it is not possible to have five sampling or cutoff lengths at the prescribed cutoff in the available surface, then multiple trace lengths shall be taken at different locations until five cutoffs are reached. Then the resulting parameter value shall be the average of the parameter values from all the traces.

3.14 Required Form Removal For Waviness Evaluation - In order to evaluate waviness properly on any surface, the upper waviness cutoff Lf shall be realized by using some filtering or fitting method to remove intentional form and unintentional form error in the direction of the surface trace that has wavelength above or equal to the Lf value. Intentional form can be the crown across a cam lobe, gear tooth or roller, or the involute across a gear tooth. Unintentional form error is long wavelength hollow, crown, “~”, “w”, or “m”, shape or other long wave shape across the part feature being traced, created unintentionally by the machining or other material removal process. (Note: Waviness is only able to be measured using a skidless surface texture instrument. See Paragraph 7.4.4.1).

3.15 Filtering Or Fitting Method For Form Removal - To evaluate waviness the longer wavelength surface profile features shall be removed by filtering, or by fitting shapes and removing the fitted shape. Fitting methods can be by least squares fitting (for example circular arcs, involutes, etc.). Filtering methods can be spline filtering, Gaussian convolution filtering, etc.

3.16 Parameters - Many surface parameters exist that statistically calculate some characteristic of the surface. There are three types of parameters - height, spacing, and special. Height parameters characterize the deviation of the measured surface from the nominal surface. Spacing parameters characterize the distance between significant features along the surface. Special parameters characterize specific features that have been determined to be of interest to design or manufacturing engineering (e.g., bearing area, Abbott-Firestone (kernel), probabilistic parameters, etc.). Parameters that are calculated from the Primary profile are designated by “P”, those calculated from the Roughness profile are designated by “R”, and those calculated from the Waviness profile are designated by “W”. Refer to ANSI B46.1 and ISO 4287 for a list of standard parameters and their definitions.

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3.17 Stylus - The contacting interface of the measurement instrument to the surface being measured in contact measurements (also called stylus or trace measurements). The stylus used influences the measurement by acting as a mechanical filter and establishes a lower limit on the wavelength of features that can be measured. The proper stylus to use is detailed in Article 7.0 for Type 1 surfaces and Article 8.0 for Type 2 surfaces. Typical styli are 2, 5, and 10 μm in radius and have a conical shape with 60 or 90 degree included angle. Pyramidal (i.e., chisel) shapes are less typical, but sometimes specified.

3.18 Lay - The direction or description of the predominant surface pattern, ordinarily a result of the production method used. (See Paragraph 11.1).

3.19 Flaws - Unintentional surface discontinuities which occur at one place or at relatively infrequent intervals on the surface. Flaws are not necessarily defects, but do include such defects as cracks, blow holes, inclusions, checks, tool drag marks, gouges, and ridges. Flaws are not intended to be controlled by surface roughness measurements. Flaws are considered defects only when agreed upon in advance (before components are produced) by the producer and the user. If defects are defined, the surface shall be inspected specifically to determine whether defects are present, and rejected or accepted, prior to performing surface texture measurements. If defects are not present or not defined, then interruptions in the component surface shall be included in roughness measurements unless exclusion is specifically noted on the drawing or other documentation.

3.19.1 Surface Defect Control Indications On Caterpillar Drawings - Control of surface defects shall be by one or more notes on the drawing, or an Engineering Specification called out on the drawing, or in instructions in the supply agreement or contract that is part of the purchase agreement of parts from a supplier. Such Engineering Specifications for components are 1E4334A, 1E4334B, 1E4334C, and 1E4334D. These specifications reference respectively 1E4436 Class A1, Class A2, Class B, and Class C for quality level, which reference 1E1821 for picture examples of defects. Another such surface defect controlling specification is 1E2943. ISO 8785 also lists and illustrates several types of surface imperfections.

3.19.2 Default Worst Case Surface Defect Quality Level Requirement For Each Caterpillar Type Surface - In the absence of any surface defect control indicator, the default worst case acceptable for surface defect quality is listed in the Articles detailing methods for assessment of each Caterpillar Type of Surface (See Paragraphs 7.3, 8.4, 9.3, and 10.3).

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3.19.3 Process Change Defaults For Defects - In the absence of any new surface flaw or defect quality instructions, if an existing component surface has a process change or the existing component is moved to an outside supplier or there is a change of outside supplier, the defect condition of the surfaces from the new process or the new supplier shall be similar to or an improvement over the defect status of component surfaces prior to this change

3.19.4 Measurement Of Flaws Or Defects For Comparison To 1E4436 Quality Classes - 1E4436 state that there are dimensional limits to flaws, in depth, length, and area for the different surface quality class designations (Class A1, Class A2, Class B, Class C, Class AC, and Class AF). Depth of a flaw such as a scratch, nick, hollow, etc., can be measured utilizing a surface texture instrument. The surface texture instrument shall be skidless (See Paragraph 7.4.4.1), with encoded stylus travel of at least the depth of the defect being evaluated, utilizing a 5 μ m stylus tip. The surface texture instrument shall be set up to trace across the flaw at a location that is representative of its apparent largest width and/or depth. The trace shall start on the surface in the non-flawed region before the flaw and extend into the non-flawed surface region after the flaw. The trace is then to be displayed or printed in the "Primary Profile" mode of the instrument, with the surface sufficiently leveled so that the portion from the pre- and post-flaw regions are leveled on the display. The depth of the flaw is then visible in the displayed depth below the pre- and post-flaw leveled portions of the trace. Flaw depth, width, or area can be evaluated graphically from the instrument print-out of the trace. Alternatively, the parameter Pt or Pv available in some analysis software can be set up to record the maximum depth, and the parameter Pa can be set up to record the full integrated area of the flaw in the traces. Several such traces can be made across the extent of the flaw if desired in order to map its extended depth profile. This method also can be used to evaluate wear areas in load bearing surfaces after some period of performance or testing. Alternative, flaws can be measured by linear optical scanning devices such as "Keyence systems", or by areal 3D scanning devices such as "Artec higher precision systems".

4.0 DEFINITION OF SURFACE TYPE

4.1 Type 1 Surfaces - Surfaces with specific engineered requirements where characterizing parameter(s) and numerical value(s) are specified. Required measurement parameters shall be specified in the drawing callout. Type 1 surfaces require some form of machining to be produced, and as such, shall have roughness and/or waviness numerical specifications. These surfaces generally provide tribological function for wear, sealing, load carrying, or combinations thereof. (See Article 7.0 for drawing symbol interpretation and metrology requirements).

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4.2 Type 2 Surfaces - Surfaces with more general roughness requirements designated by a letter value (F, H, K, N) that require some form of machining to be produced. These surfaces shall not have waviness specifications or measurement parameters specified in the drawing callout. These surfaces are generally non-tribological, but still have requirements for product function and/or for subsequent manufacturing processes. (See Article 8.0 for drawing symbol interpretation and metrology requirements.)

4.3 Type 3 Surfaces - Surfaces designated by a letter value (L, P, R, S, T). These surfaces are generally produced by some form of First Operations and are non-tribological, but still have requirements for subsequent manufacturing processes. (See Article 9.0 for drawing symbol interpretation and metrology requirements.)

4.4 Type 4 Surfaces - Surfaces as-received on direct purchased material (e.g., castings, forgings, plate steel, etc.). Generally the surface callout on the drawing only restricts the manufacturing process used; however this can be used in combination with a Type 2 or Type 3 roughness specification. (See Article 10.0 for drawing symbol interpretation and metrology requirements.)

SYMBOL	INTERPRETATION
	Type 1 Surface Texture Control - (See Article 7.0) a. A parameter and value placed above the short leg of the symbol designates a Type 1 surface to be inspected by use of a stylus type instrument to the roughness parameter indicated. When only a number is placed, the default roughness parameter, roughness average (Ra), is implied. b. Numbers placed above the horizontal bar designate waviness conditions. A number placed below the horizontal bar designates the roughness cutoff (Lc). When no number occurs below the horizontal bar, then the default cutoff of 0.8 mm is required (See Paragraph 7.4). c. The horizontal bracket above the short leg of the symbol indicates a machined surface which shall be checked with a chisel shaped stylus.
	Type 2 Surface Texture Control - (See Article 8.0). a. A letter F, H, K, or N placed above the short leg of the symbol designates a Type 2 surface.

Figure 5 - Symbol Interpretation (Continued On Next Page)

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SYMBOL	INTERPRETATION
	Type 3 Surface Texture Control - (See Article 9.0) a. A letter L, P, R, S, or T placed above the short leg of the symbol designates a Type 3 surface.
	Type 4 Surface Texture Control - (See Article 10.0) a. "HFS" or "CFS" designates bulk mill stock surfaces. b. "CAST" or "FRG" designates casting or forging requirements.
	Supplemental Controls Related To Processing - (See Article 11.0) a. Horizontal bar indicates "Machining Required". The number on the left side of the symbol indicates the Basic Machine Allowance from the surface required by engineering. b. Circle in symbol indicates "Machining Prohibited". c. Symbols under the long leg of the symbol indicate specific process or surface controls as described in Article 11.0.
	Plastic Parts - (See Article 11.0) a. E1 - E10 placed to the right of the long leg designates lay patterns for plastic parts to be inspected by comparison to comparators listed in Article 11.0.

Figure 5 - Symbol Interpretation (Continued)

5.0 GENERAL REQUIREMENTS

5.1 Surface Texture Callout Coverage - The surface texture symbol applies to the entire surface within the dimensions of that surface.

5.2 Adjacent Finished Machined Transition Surfaces - Fillets, radii, chamfers, and irregular contours of transition surfaces shall conform to the texture of the roughest adjacent machined surface if not otherwise specified.

5.3 Surface Texture Callouts Apply To Finished Machined Parts - Specified surface texture requirements apply to the surface of the completed part (on metallic plated surfaces, the requirements apply after plating. On surfaces with non-metallic coatings, the requirements apply before coating).

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5.4 Flaws Not Generally Controlled By Surface Texture Callouts - The surface texture symbol controls the predominant surface characteristics but in general, does not control flaws defined in Paragraph 3.19.

5.5 Processes Used To Meet Surface Texture Callouts - For Type 1 or Type 2 surfaces, any process except “cold finishing” (CFS) or “hot finishing” (HFS) is acceptable to produce the surface if it produces the required surface texture.

5.6 Absence Of The Surface Texture Symbol - When 1E2122 Surface Texture is specified on the drawing, the absence of a “√” symbol on a given surface shall mean either that the texture of that surface is not controlled, or the default texture is indicated according to Article 6.0.

5.7 Tool Drag Marks - Tool drag marks are not permitted on any surface specified Ra 0.5 μm or smoother. For surfaces rougher than Ra 0.5 μm, engineering shall designate on the drawing whether tool drag marks are permitted. (See Figure 22 for how the “no – tool – drag – marks” indication is specified on drawings).

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6.0 DEFAULT ROUGHNESS CONTROLS ON SURFACES

6.1 The following are requirements for specific features when no designation appears on the feature and 1E2122 is specified on the drawing.

FEATURES	SUB FEATURES	DEFAULT ROUGHNESS
End Faces	Parts Cut From Bar Stock	$\sqrt{K}$
End Faces	Shafts	$\sqrt{K}$
Shoulders	See Figure 7 - Shoulder	$\sqrt{H}$
Undercuts & Reliefs – Sides & Bottoms	Grind Reliefs	$\sqrt{H}$
Undercuts & Reliefs – Sides & Bottoms	Thread Reliefs & Adjacent Shoulder	$\sqrt{H}$
Undercuts & Reliefs – Sides & Bottoms	Gear & Spline Undercuts	$\sqrt{K}$
V-Belt Pulley Grooves	Angular Surfaces in Contact with V-Belt & Adjacent Radius Outside Diameter	$\sqrt{F}$
V-Belt Pulley Grooves	Bottom of Groove	$\sqrt{K}$
Keyslot and Keyway	Sides	$\sqrt{H}$
Keyslot and Keyway	Bottom	$\sqrt{K}$
SpotFace	SpotFace	$\sqrt{K}$

Figure 6 – Default Roughness Controls On Surfaces

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6.2 Shoulder Between Two Diameters - Between two diameters with a radial width of 6.35 mm (.25 inch) or less $\sqrt{H}$ (See Figure 7).

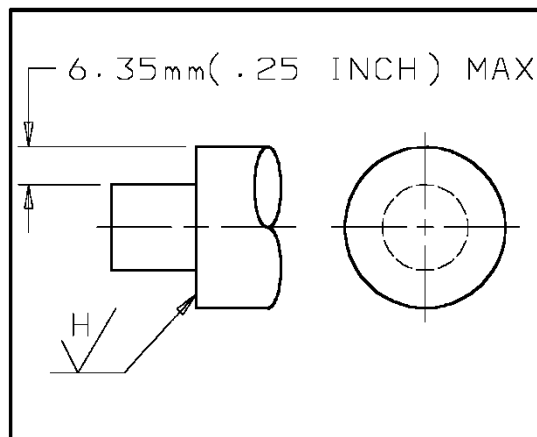


Figure 7 - Shoulder

7.0 TYPE 1 SURFACES

7.1 Roughness Parameters - Type 1 surface roughness “R” parameters are derived from the profile data filtered to isolate the roughness transmission band between λ_s (or L_s) and λ_c (or L_c). Type 1 surface roughness is specified on the part drawing by a characterizing “R” parameter and numerical value designated on the drawing above the short leg of the symbol. When the numerical value is specified above the short leg of the symbol and no characterizing parameter is indicated as shown in Figure 8, the value specified is the upper limit for roughness average (Ra) that is acceptable.

7.1.1 Micrometers Or Microinches - Metric drawings have roughness average (Ra) designated in micrometers (0.000001 meter or 0.001 mm). Some previous metric drawings and all non-metric drawings have roughness average designated in microinches (0.000001 inch).

7.1.2 Other Parameters Besides Ra - There are other parameters for evaluating surfaces and controlling their functionality and performance. ANSI/ASME B46.1 and ISO 4287 define a large array of different parameters that are available. Two or more roughness parameters can be specified by stacking them above the short leg of the symbol with the parameter designation (Rz, Rsm, etc.) and it’s limit value. There are a couple of parameters of particular use within Caterpillar other than Ra:

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SURFACE TEXTURE

DATE
03 DEC 2015

CHG NO
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NUMBER
1E2122

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7.1.3 Rz - One parameter other than roughness average (Ra) that is widely used in industry has the symbol Rz (See Figure 5) and is called the ten point height or the average maximum height of the profile. If Zp_i is the maximum peak height (positive value) from the mean line in the i^{th} sampling length, and Zv_i is the maximum valley depth (positive value) in the i^{th} sampling length, then for an assessment length of 5 sampling lengths, Rz is calculated by the equation:

$$Rz = [(Zp_1 + Zp_2 + Zp_3 + Zp_4 + Zp_5) + (Zv_1 + Zv_2 + Zv_3 + Zv_4 + Zv_5)]/5$$

7.1.4 Rsm - Another parameter used within Caterpillar is average roughness spacing Rsm which is the average of all the mean line lengths extending from any one zero to the second zero crossing over from it, averaged over all zero crossings in the roughness trace.

7.1.5 16% Rule For One-Sided Tolerances - When a single roughness value is specified, it is the upper limit for roughness on that surface. The surface is considered acceptable if no more than 16% of all the measured values of that surface exceed the specified value in accordance with ISO 4288.

7.1.6 One-Sided Lower Hard Tolerances - When a single roughness specification is followed by the designation MIN, as in Figure 8, it is the minimum allowable value on that surface. The surface is considered acceptable if no measured values of that surface are less than the specified value in accordance with ISO 4288.

7.1.7 One-Sided Upper Hard Tolerances - When a single roughness specification is followed by the designation MAX, as in Figure 8, it is the maximum allowable value on that surface. The surface is considered acceptable if no measured values of that surface exceed the specified value in accordance with ISO 4288.

7.1.8 16% Rule For Two-Sided Tolerances - When upper limit and lower limit roughness values are specified, the surface is acceptable if no more than 16% of all the measured values of that surface exceed the upper specified value or 16% of all the measured values exceed the lower specified value again as per ISO 4288. A MIN or MAX modifier applied to a roughness limit affects only the limit it is applied to and shall be interpreted according to Paragraphs 7.1.6 and 7.1.7. The 16% rule still applies to the other roughness limit unless both limits have a MIN or MAX modifier.

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7.1.9 Method To Measure And Accept Or Reject The Work Piece Under The 16% Rule -

Where the indicated parameter symbol does not contain the suffix MIN or MAX initially, the surface will be accepted and the test procedure stopped if:

- The first measured value does not exceed 70% of the value indicated on the drawing.
- The first value exceeds 70%, measure two more places, and these first three measured values do not exceed the specified value.
- One of these first three measured values is out of tolerance, then measure three more places, and if not more than one of these first six measured values exceeds the specified value.
- Two of the six values is out of tolerance, then measure six more places, and if not more than two of these first twelve measured values exceed the specified value.

When using this method for assessing whether the surface passes the 16% statistical tolerance limit, the value to be assigned the surface parameter being measured is the average of all of the final numbers of traces required to accept the surface. For example. If three traces had to be taken, and all three values are within the limits as in the second bullet above, then the value of the parameter to be assigned is the average of the three values that resulted from the three traces.

Note (1): It is not acceptable practice to take multiple traces and ignore results that tend toward rejecting the surface until one or more traces are taken that tend to comply toward acceptance. For example it is not acceptable practice to keep taking traces until one reaches a trace with the prescribed parameter results below 70% of the tolerance. The method described above is the statistically correct sampling method. Therefore in carrying out the measurement process, if any one of the conditions is not met, the surface is out of specification. For example if in the first measurements, two or more traces are taken that are just below or above the finish parameter tolerance (and thus not below 70% of the tolerance) then the surface finish requirement has not been met and the work piece is not compliant.

Note (2a): If engineering instructions are to assess a Part Number work piece surface by taking multiple surface traces, possibly in certain locations, then set of traces can be carried out by following the above set of rules for the number of traces prescribed. For example, engine liner bore finishes are generally instructed to be assessed by taking twelve traces in the pattern of three levels with four traces at each level. Then by the fourth bullet above up to two of these traces can have parameter results outside of the tolerance and the set of twelve traces can still make the bore acceptable. Then if the bore is acceptable in this way, the parameter results to be assigned for that bore is the averages of the twelve parameter results from the twelve traces.

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Note (2b): Alternatively, if the number of traces specified is for example two or four or five traces, then if one of these traces violates the above conditions, then additional traces can be added to the sampling of the finish, in the area of the questioned trace, until the total number traces such as three or six or twelve is taken as in the above sequence to see if the surface is still compliant with the above process. For example if two are specified and one of the two traces is above 70% of the tolerance, then a third trace can be taken to show the surface complies with the second bullet above. Then if the second bullet condition is met, the parameter result(s) for the surface for this example is not the average of two parameter results, but the average of the three.

7.1.10 EXCEPTION to 16% Default Rule - In some situations the 16% rule default will not be used, nor the MAX or MIN indications on the roughness parameters. In these cases, the roughness parameters without the MAX or MIN indications shall be interpreted as having hard limits. In particular, roughness and waviness call outs on Caterpillar engine component drawings (from Large Power Systems Division or Industrial Power Systems Division) are all to be interpreted as having hard limits.

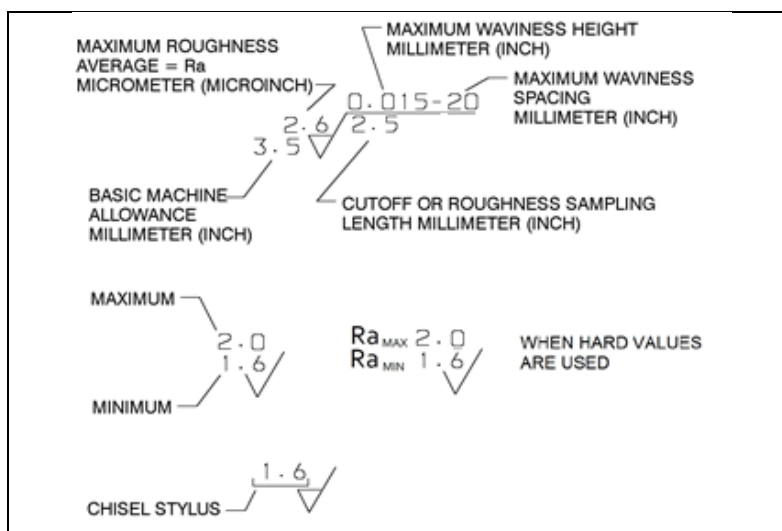


Figure 8 - Type 1 Symbol Interpretation

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7.2 Waviness Designation - Waviness height and spacing appear on top of the horizontal extension line of the surface texture symbol as shown in Figure 8. When the numerical value is specified and no characterizing parameter is specified as shown in Figure 8, the height value specified is the maximum waviness height (Wt) acceptable and the spacing value specified is the maximum wavelength average (Wsm) acceptable. Wt is the peak to valley height of the modified profile from which the roughness and flaws have been removed by smoothing, filtering or other means. Another useful parameter is Wc, the average waviness height, which is the average of all the highest highs and lowest lows between zero crossings of the waviness profile in the waviness trace length. If Wc is desired to be specified then "Wc" should be indicated before the limit value above the long leg of the symbol. Wsm is the average spacing of every other zero crossing of the measured profile within the waviness sampling length. Some Caterpillar drawings call out Ws which is the average spacing over the trace length not of zero crossings of the waviness line as for Wsm, but of the spacing of tops of the peaks of the waviness line, primarily for gasket sealing functionality. If Ws is required, then the spacing value above the extension line shall indicate "Ws" or it shall be so indicated in a note.

7.2.1 Lower Hard Limit For Waviness Spacing - The modifier MIN on (Wsm) specifies the minimum wavelength average (Wsm) that is acceptable.

7.2.2 Two-Sided Hard Limits For Waviness Height - When MAX and MIN limits are specified for the waviness height (Wt), the measured Wt shall be equal to one of the limits or be between the two limits.

7.2.3 Instrument Type For Measuring Waviness - To measure waviness parameters, the arbitrator instrument to be used is instrument detailed in ISO 3274, which is a skidless contact instrument. (See Paragraph 7.4). Such a skidless instrument shall be used for measuring waviness because the skid in a skidded instrument is meant to mechanically filter out and eliminate waviness from its measured trace.

7.3 Minimum Surface Defect Quality Level For Type 1 Surfaces - Unless otherwise stated on the drawing or in other documentation, the worst case flaw or defect quality level allowed on any Type 1 surface shall be that of 1E4334D (1E4436 Class C).

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7.4 Measurement - The arbitrator method of measurement, for surfaces specified with 2D roughness (R) and/or waviness (W) parameters, for resolution of any disputes of the surface texture conditions on work pieces, shall be by using a skidless contact stylus instrument (See Paragraph 7.4.4.1 and Refer to ISO 3274) with the measurement settings (transmission band, sampling length, and stylus size) as specified in the drawing callout. For Type 1 surfaces if no measurement settings are specified on the drawing, and Ra is between 0.1 μm and 2.0 μm then the cutoff Lc indicated is 0.8 mm as per Figures 9 and 10. Again for Type 1 surfaces, cutoffs other than 0.8 mm should appear below the horizontal bracket of the surface finish symbol, also according to Figures 9 and 10. If no measurement settings or R value are specified on the drawing, and no Article 6.0 default applies, the values in Figures 9 and 10 shall be used based on the nature of the surface. Note: (For non-periodic or random surfaces such as ground, honed, blasted, edm'd, etc. - use Figure 9. For periodic surfaces such as turned, bored, milled, etc. use Figure 10). Measurements shall comply with ISO 4288 and ISO 3274.

AVERAGE SURFACE ROUGHNESS Ra	AVERAGE PEAK TO VALLEY HEIGHT Rz	STYLUS TIP RADIUS	Ls	Lc	Ln
μm	μm	μm	μm	mm	mm
$Ra \leq 0.02$	$Rz \leq 0.1$	2	2.5	0.08	0.4
$0.02 < Ra \leq 0.1$	$0.1 < Rz \leq 0.5$	2	2.5	0.25	1.25
$0.1 < Ra \leq 2$	$0.5 < Rz \leq 10$	2	2.5	0.8	4
$2 < Ra \leq 10$	$10 < Rz \leq 50$	5	8	2.5	12.5
$10 < Ra \leq 80$	$50 < Rz \leq 300$	10	25	8	40

Figure 9 - Measurement Parameters For Type 1 Non-Periodic Surfaces

AVERAGE FEATURE SPACING Rsm	STYLUS TIP RADIUS	Ls	Lc	Ln
mm	μm	μm	mm	mm
$Rsm \leq 0.03$	2	2.5	0.08	0.4
$0.03 < Rsm \leq 0.1$	2	2.5	0.25	1.25
$0.1 < Rsm \leq 0.3$	2	2.5	0.8	4
$0.3 < Rsm \leq 1$	5	8	2.5	12.5
$1 < Rsm \leq 3$	10	25	8	40

Figure 10 - Measurement Parameters For Type 1 Periodic Surfaces

7.4.1 Stylus - The stylus used to measure the surface shall meet the requirements of ANSI B46.1 as in Figures 9 and 10. The direction of stylus travel shall be in the direction which gives the maximum reading.

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7.4.1.1 Chisel Shaped Stylus - A chisel shaped stylus shall be used when chisel stylus is specified in the drawing callout as shown in Figure 8. The maximum width of the chisel stylus shall be 1.60 mm and the tip radius shall be 0.0125 mm, or the appropriate radius as listed in Figures 9 and 10.

7.4.1.2 Stylus For Measuring Waviness And / Or Profile Without Including Roughness - The stylus for tracing and analyzing waviness and / or profile, without tracing roughness, is allowed to be 0.5 mm or 0.75 mm radius if the roughness sampling length and cutoff λ_c (or L_c) is 0.8 mm or larger. (See Paragraph 3.12).

7.4.1.3 Assessment Length For Waviness - The assessment length for waviness should be at least equal to five roughness cutoffs, but preferably, it should equal ten roughness cutoffs or more to record enough waves for good statistics in calculating the waviness parameters.

7.4.2 Assessment Length - In product applications where the physical geometry of the part or surface does not allow for the full assessment length as specified in Figures 9 and 10 and no measurement parameters are specified on the drawing, use the longest assessment length (L_n) possible in Figures 9 and 10 and the corresponding measurement parameters.

7.4.3 Number Of Cutoffs - The default number of cutoffs used in the measurement of a surface is 5. In product applications where the physical geometry of the part or surface does not allow for 5 cutoffs, use the largest number of cutoffs possible and multiple measurements in different locations to achieve at least 5 cutoffs worth of evaluation length (See Paragraph 3.13).

7.4.4 Measuring Instrument - The measurement instrument shall meet the requirements of ANSI B46.1 and ISO 3274. There are two types of contact stylus instruments that are widely available and widely used in industry: skidded contact stylus instruments and skidless contact stylus instruments.

7.4.4.1 Skidless Contact Stylus Instruments - Skidless contact stylus instruments are surface texture measuring machines having only the stylus itself extending out of the probe body which then contacts the surface. They have a precision straight motion axis integrated in the probe head or probe drive unit that provides the reference straight motion that the surface location at any point in the surface trace is measured against. ISO 3274 arbitrator instruments in Paragraph 7.4 are such skidless contact stylus type.

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7.4.4.2 Skidded Contact Stylus Instruments - Skidded contact stylus instruments have a skid carrier around the stylus that holds a large radius skid which rides on the surface being measured, and the surface roughness trace location is measured relative to the location of this large radius skid. The skid is designed to mechanically filter out waviness and form error from the measurement. As a result, waviness or straightness or profile cannot be measured with such a skidded instrument. They are made to only measure roughness. Most market available skids on standard machines have the skid radius set to filter at $L_c = 0.8$ mm only, so they cannot properly measure any surface roughness that requires L_c not equal to 0.8 mm. If a skidded instrument is used for controlling roughness or for accepting or rejecting work pieces, it shall be demonstrated to correlate to a skidless instrument as described in Paragraph 7.4.4.1 for the surfaces being evaluated.

7.4.4.3 Non-Contact Measurements - Non-contact measurement methods are allowed to be used for reference only for surfaces with 2D roughness (R) parameters, unless they are correlated to stylus measurement methods. If they are not correlated to stylus measurement methods, they are not in compliance with measuring the surface per the drawing specification. If a non-contact roughness instrument is used for controlling roughness or for accepting or rejecting work pieces, it shall first be demonstrated to correlate to a skidless contact stylus instrument as described in Paragraph 7.4.4.1 for the surfaces being evaluated.

7.5 Calibration And Checking Of The Measuring Instrument - All surface texture measuring instruments require frequent calibrations and checks to provide reliable results. Calibration specimens are provided by the instrument maker and are generally in the form of step groove masters, circular groove masters. or sinusoidal master patches. For the step and circular groove masters (Type A1 and A2 Specimens in ANSI/ASME B46.1 and ISO 5436), the step or circular groove depth is measured and etched on the master by the supplier, so that a trace can be taken through the groove to see if the instrument provides the same depth as the supplier had. Any deviation is then adjusted out usually by the instrument's calibration software. For the sinusoidal master patch (Type C1 Specimen in ANSI/ASME B46.1 and ISO 5436), the R_a and/or the R_z for the sinusoidal patch is measured and etched on the master by the supplier, so that a trace can be taken across the sinusoidal profile to see if the instrument calculates the same R_a and/or R_z as the supplier measured. Any deviation is then adjusted out usually by the instrument's calibration software. A calibration check is when a measurement of a master patch is performed, when the resulting measurement value is expected to be sufficiently close to the patch value that no adjustment is required.

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7.5.1 When To Calibrate - A calibration or calibration check shall be carried out at the beginning of a shift, or whenever the instrument is “bumped” or otherwise disturbed, whenever there is a large change in the instrument’s environment, at the beginning of measuring a significant number of work pieces that need to have their results compared to each other, and/or whenever the stylus is changed. Note that a calibration check can be typically carried out by an operator, where a full calibration may require support from a quality engineer or equivalent.

7.5.2 Stylus Check - Another necessary check is whether the stylus is intact or broken. Triangular profile master patches (Type B2 or C2 Specimens in ANSI/ASME B46.1 and ISO 5436) are provided to evaluate the integrity of the stylus. Once the instrument is properly calibrated, if the stylus is broken, it will measure the peak heights of the triangular profile fully, but it will not be able to reach the full bottom of the valleys. The resulting Ra or preferably Rz (Rz is more sensitive to stylus wear) will be reduced from the value measured and etched on the master by the supplier. Note that a stylus check with these specimens can be typically carried out by an operator. If this stylus check indicates the stylus may be worn or broken, then support from a quality engineer or equivalent may be required.

7.5.3 Alternatively, the stylus wear or breakage can also be confirmed using a 100x or better magnification microscope. A final optional method to check the stylus is the measurement of a sharp edge (Type B3 Specimen in ANSI/ASME B46.1 and ISO 5436) by tracing the stylus slowly over the edge. If the measurement produces a nicely rounded profile of about the radius of the stylus, then the tip is in good operating condition. The radius can be evaluated as described in references above. If the profile contains jagged or smooth worn flats, then the stylus is broken or worn and needs replacing. B3 type mounted razor blade artifacts that facilitate this type of stylus check are available from Rubert & Company (www.rubert.co.uk). If the stylus proves to be measurably worn or broken by any of these methods, it shall be replaced.

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8.0 TYPE 2 SURFACES

8.1 Designation - Surface roughness, R_a , and R_z are the only surface characteristics controlled by a Type 2 designation. The roughness requirement is designated by the letters F, H, K, or N on the drawing above the short leg of the symbol as shown in Figure 11. When one letter is present, it designates the maximum allowable average surface roughness (R_a) for that surface.

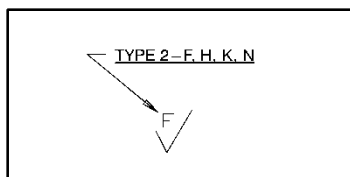


Figure 11 - Type 2 Example Designation

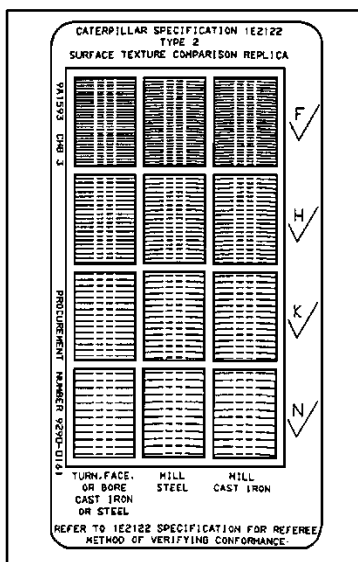


Figure 12 - Type 2 Surface Texture Comparison Replica

8.2 Comparison Replica - 9A1593 (Procurement Number 9290-0161) Type 2 surface texture comparison replica illustrated in Figure 12 is available from Illinois Valley Plastics (Supplier No.K9031S). Use of 9A1593 replica is for reference only. It cannot be used as the control for Type 2 surfaces. Control is by use of qualified surface instruments to ensure measured R_a values as shown in Figure 13. Suppliers and subsidiaries are to procure their supply from their Global Purchasing contact.

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8.3 Interpretation - The Type 2 letter designation shall be interpreted as shown in Figure 13.

CAT	TURNED BORED FACED			MILLED			MILLED CAST IRON		
	RANGE			RANGE			RANGE		
	Ra	Rz	Rsm*	Ra	Rz	Rsm*	Ra	Rz	Rsm*
GRADE	μm	μm	mm	μm	μm	mm	μm	μm	mm
F	< 3.5	<12	0.6	< 3.5	<10	0.7	< 3.5	<15	0.5
H	5.5	20	0.8	5.5	20	0.8	5.5	30	0.9
K	10	35	0.9	8.5	50	2.5	10	50	1.5
N	35	140	1.2	30	90	4.0	25	130	1.8
*Note:	Rsm values are not maximums, but are average values from the actual F, H, K, N, replica patches. They are meant for guiding the proper settings for measuring each patch for Ra and Rz values.								

Figure 13 - Measurement Specification And Interpretation For Type 2 Surfaces

8.3.1 Former Type 2 Roughness Designation D - Former designations for Type 2 surfaces included the Letter D, which is no longer in use. When the Letter D is designated (on older drawings) above the short leg of the symbol, the surface texture shall be interpreted as a Type 1 surface roughness with a Ra value of 2 μm and measured according to the requirements for Type 1 surfaces. (See Figures 9 and 10).

8.3.2 Two Type 2 Letters Specified - When two letters are present in the designation, they are the maximum and minimum roughness specified, the measured value shall be equal to one of the limits or between the two limits.

8.4 Minimum Surface Defect Quality Level For Type 2 Surfaces - Unless otherwise stated on the print or in other documentation the worst case flaw or defect quality level allowed on any Type 2 surface shall be that of 1E4334D (1E4436 Class C).

8.5 Measurement - The arbitrator method of measurement of Type 2 surfaces shall be contact stylus as per Paragraph 7.4, Paragraph 7.4.4.1, and ISO 3274, with the appropriate measurement parameters (transmission band, sampling length, and stylus size) as specified in Figure 14. Measurements shall be made in accordance with ISO 4288 and ISO 3274. None of these finishes are able to be evaluated using a hand or portable surface texture instrument unless it is a skidless instrument, is able to trace longer than 10 mm traces, and has the ability to use the appropriate cutoff settings.

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OBSERVED FEATURE SPACING	STYLUS TIP RADIUS	Ls	Lc	Ln
mm	μm	μm	mm	mm
Rsm < 1	5	8	2.5	12.5
Rsm ≥ 1	5 or 10	25	8	40

Figure 14 - Measurement Parameters for Type 2 Surfaces

8.5.1 Stylus - The stylus used to measure the surface shall meet the requirements of ANSI B46.1. The direction of stylus travel shall be in the direction which gives the maximum reading.

8.5.2 Assessment Length - In product applications where the physical geometry of the part or surface does not allow for the full assessment length as specified in Figure 14, use the largest number of cutoffs possible and multiple measurements in different locations to achieve at least 5 cutoffs worth of evaluation length (See Paragraph 3.13).

8.5.3 Measuring Instrument - The measurement instrument shall meet the requirements of ANSI/ASME B46.1 and ISO 3274. The instrument for these coarse surfaces shall be skidless according to Paragraph 7.4.4.1 or be shown to correlate to such a skidless instrument for the surfaces being evaluated.

8.5.4 Comparison Replica Inspection Method - Inspection by comparison to a Type 2 Surface Texture Replica has been replaced by skidless contact stylus measurement and shall not be used to determine conformance of parts. Comparison to a Type 2 Surface Texture Replica is to be used for reference only. 9A1593 (Procurement Number 9290-0161) surface texture replicas are available through shop tool cribs or from Cat Morton Parts. Suppliers and subsidiaries are to procure their supply from Global Purchasing - Indirect.

9.0 TYPE 3 (FLAME CUT) SURFACES

9.1 Designation - When the letter L, P, R, S, or T is designated on the drawing above the short leg of the symbol, the surface is identified as being produced by flame cutting or an alternate process. (See Figures 15, 16, and 17). The designated letter represents the roughest acceptable texture on the completed part that shall be equal to or smoother than the corresponding surface on the Type 3 replica shown in Figure 15.

9.2 Measurement - Comparison of the produced surface and the replica shall be by sight or touch. 9A9097 (Procurement Number 9290-0152) surface texture comparison replicas are available from Illinois Valley Plastics (Supplier No.K9031S). Suppliers and subsidiaries are to procure their supply from their Global Purchasing contact.

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SURFACE TEXTURE

DATE
03 DEC 2015

CHG NO
21

NUMBER
1E2122

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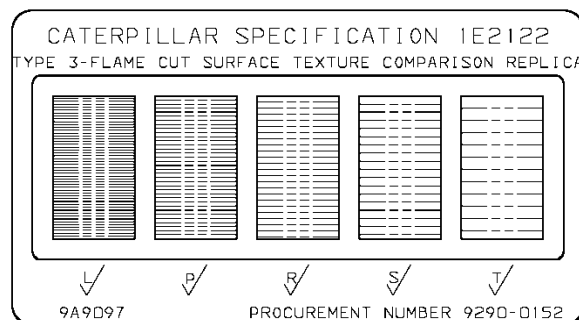


Figure 15 – Flame Cut Surface Texture Comparison Replica

GRADE	RANGE				SETTINGS
	Ra (μm)	Rz (μm)	Rsm* (mm)	STYLUS (μm)	
L	< 15	< 70	0.9	5	Lc = 2.5 mm, Ln = 12.5 mm
P	29	124	1.3	5 or 10	Lc = 8 mm, Ln = 40 mm
R	44	174	1.5	5 or 10	Lc = 8 mm, Ln = 40 mm
S	79	299	1.9	5 or 10	Lc = 8 mm, Ln = 40 mm
T	130	450	3.2	5 or 10	Lc = 8 mm, Ln = 40 mm
*Note:	Rsm values are not maximums, but are average values from the actual T, S, R, P, L, replica patches. They are meant for guiding the proper settings for measuring each patch for Ra and Rz values.				

Figure 16 – Values And Settings For Measuring Type 3 Finishes

9.2.1 Arbitration Of Type 3 Finishes In Case of Dispute - The arbitrator method of measurement of Type 3 surfaces shall be a skidless contact stylus type as per Paragraph 7.4.4.1, with the appropriate measurement parameters (transmission band, sampling length, and stylus size) as specified in Figure 16. Measurements shall be made in accordance with ISO 4288 and ISO 3274. None of these very coarse finishes are able to be evaluated using a hand or portable surface texture instrument unless it is skidless, are able to trace longer than 10 mm traces, has the range to measure the large surface excursions, and has the ability to use the appropriate cutoff settings.

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DRAWING CALLOUT	REQUIREMENTS			
	FLAME CUT	ALTERNATE PROCESS		
		STAMPED,BLANKED, SHEARED	NIBBLED	MACHINED
L✓	L✓	NOT ACCEPTABLE	NOT ACCEPTABLE	K✓
P✓	P✓	NOT ACCEPTABLE	NOT ACCEPTABLE	N✓
R✓	R✓	NOT ACCEPTABLE	NOT ACCEPTABLE	N✓
S✓	S✓	ACCEPTABLE	ACCEPTABLE IF 'BLENDED' SEE (2)	N✓
NONE	SEE (1) T✓	ACCEPTABLE	ACCEPTABLE	N✓

(1) **Machine Flame Cutting:** Grade T surface texture is the roughest acceptable texture where none is specified on drawings. Manufacturing and / or Quality Control shall apply surface texture grades which are more restrictive than required for engineering functional requirements, to maintain workmanship and appearance standards, or to accommodate processing requirements. For drawings released before January 1982, flame cut surface texture or special quality shall be controlled on a judgment basis by Manufacturing and Inspection Personnel. Before discontinuing this control, Manufacturing, Quality Control, or Purchasing shall request Engineering to review the requirements, and where required, to add the surface texture requirements to the drawing. For hand held torch cut surfaces where no surface texture is specified, surface texture rougher than Grade T (such as one produced by hand torch cutting) is acceptable, providing this finished surface is within specified dimensional tolerances, the surface is permanently hidden from view in any subsequent assembly, and a close fit with another part is not required.

(2) **Blend to be Acceptable:** The peaks of the Nibbled Scallop, and the top and bottom sharp edges shall be removed and blended to a Maximum Scallop depth of 0.025 mm.

Figure 17 - Type 3 Surfaces And Alternate Processes

9.3 Flaws In Type 3 Surfaces - (See Paragraph 3.19 for definition).

9.3.1 Grade T Surfaces - Flaws 1.5 mm or less depth or height, whose boundaries fall entirely within the tolerance zone of the flame cut surface, are acceptable.

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9.3.2 Grade L, P, R, Or S Surfaces - Flaws are not acceptable on the finished part.

9.3.3 All Surfaces - Flaws are not acceptable on the finished part if **FLAWS NOT PERMITTED** is noted on the drawing, or in instructions in the supply agreement or contract that is part of the purchase agreement of parts from a supplier.

9.3.4 Flaw Repair Of Type 3 Surfaces - Gouge type flaws which fall entirely within the profile tolerance zone, and all protruding flaws are allowed to be repaired by grinding and blending with the adjacent flame cut surface (within the profile tolerance zone). If welding repair is permitted, such repair is allowed to be carried out according to Paragraph 9.3.6. If **WELD REPAIRS NOT PERMITTED** is noted on the drawing or in other instructions no such weld repair is allowed.

9.3.5 Surface Debris And / Or Deposits - Slag, loosely adhering oxide films, rust preventative films, and / or re-solidified deposits of metal melted during cutting shall be removed, for any surface texture measurement to be carried out, and when the flame cut surface is subject to any of the following conditions:

9.3.5.1 Visibly exposed on the machine.

9.3.5.2 Part of, or adjacent to a weld joint face in subsequent assembly.

9.3.5.3 Subsequently painted.

9.3.5.4 Subject to subsequent processing, such as heat treat.

9.3.6 Weld Repair Of Flaws

9.3.6.1 Weld repair of flaws shall be under the supervision of the Quality Control Department.

9.3.6.2 Weld repairs of surfaces which are heat treated after flame cutting shall be made prior to heat treating.

9.3.6.3 Where the part is heat treated after flame cutting, the filler metal shall have essentially the same heat treated properties as the base metal and the weld shall comply with 1E0099.

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10.0 TYPE 4 (MILL, CAST, OR FORGED) SURFACES

10.1 “CFS” and “HFS” designate “as produced” surfaces on bulk mill products such as steel, brass, aluminum, and copper procured in the shape of plate, sheet, bar, tubing, and rolled or extruded sections. The “as produced” mill surface is permitted on the surface of the completed part in accordance with the interpretations in Figure 18 and the requirements of 1E1821 and 1E2943.

	HFS - Hot Finished Surface: This Indicates that the surface “as produced” by a Hot Finishing or Hot Rolling Mill process is acceptable. Cold Finished, Cold Rolled, or Turned and Polished Surfaces are also permitted.
	SF - Scale Free: When SF follows the designation HFS , the Hot Finished HFS-SF Surface that remains on the completed part shall be free of scale. One way to fulfill this requirement is with a CFS Surface. For surfaces on existing drawings restricted by one of the former notes: “ HFS-SF Surface Texture 3.8” or HFS-SF Surface Texture 150”: This requirement is replaced and fulfilled by: —————→ Request Engineering to update drawings which have the former notes.
	P&O - Pickled and Oiled: When P&O follows the designation HFS , the Hot Finished Surface that remains on the completed part shall be free of scale. The P&O process shall be used for scale removal. One way to fulfill this requirement is with a CFS Surface.
	HFS ONLY: This Indicates that Machining is PROHIBITED and the Surface “as produced” by A Hot Finishing or Hot Rolling Mill process is required -- No Alternate Surface is Permitted.
	CFS – Cold Finished Surface: This indicates the surface “as produced” by one of the following drawings or Rolling Mill Processes is Acceptable: for Flat Stock-Cold Rolled, for Bar or Tube Stock-Cold Drawn, Cold Worked, Cold Reduced or Turned and Polished.
* A Number or Letter Designated above the short leg of the Symbol in conjunction with HFS or CFS permits any other process that has the ability to produce a surface texture within the specified value. The Number or Letter controls the alternate process only.	

Figure 18 - “CFS” And “HFS” Designations

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10.2 Cast-Forged Designations - The designations in Figure 19 dictate responsibility for producing a specific surface or feature. These designations replace the former practice of specifying casting or forging terms such as “coin”, “core”, or “punch”.

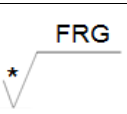
	This Indicates the surface shall be produced by the Foundry using a Casting process or a processing operation associated with the Foundry (such as a Drill, Grind, and Coin).
	This Indicates the surface shall be produced by the Forger using a Forging process or a processing operation associated with the Forge Shop (such as Trim, Punch, and Coin).
* When a Number or Letter is designated above the short leg of the Symbol, it controls the Roughness of the surface.	

Figure 19 - Cast - Forged Surfaces

10.3 Minimum Surface Defect Quality Level For Type 4 Surfaces - Unless otherwise stated on the drawing or in other documentation, the worst case flaw or defect quality level allowed on any Type 4 surface shall be as per Paragraph 8.4 of 1E2679 for cast steel surfaces, and Paragraph 6.7 of 1E2680 for cast iron surfaces. For forged steel surfaces, the worst case flaw or defect quality level allowed shall be as per Article 11 Paragraph 14.3 of 1E0100.

11.0 SUPPLEMENTAL CONTROLS RELATED TO PROCESSING

11.1 Surface Lay - Lay is the direction of the predominate pattern of the surface texture. It is designated by geometric symbols or letters which are located to the right of the long leg of the surface texture symbol. Specific processing controls shall also be added as shown in Figures 20 and 21. Conformance shall be determined by visual inspection.

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SYMBOL	INTERPRETATION	EXAMPLE	SYMBOL	INTERPRETATION	EXAMPLE
	LAY APPROXIMATELY PARALLEL TO THE LINE REPRESENTING THE SURFACE TO WHICH THE SYMBOL IS APPLIED. (FORMERLY)			LAY APPROXIMATELY CIRCULAR RELATIVE TO THE CENTER OF THE SURFACE TO WHICH THE SYMBOL IS APPLIED.	
	LAY APPROXIMATELY PERPENDICULAR TO THE LINE REPRESENTING THE SURFACE TO WHICH THE SYMBOL IS APPLIED.			LAY APPROXIMATELY RADIAL RELATIVE TO THE CENTER OF THE SURFACE TO WHICH THE SYMBOL IS APPLIED.	
	LAY ANGULAR IN BOTH DIRECTIONS TO THE LINE REPRESENTING THE SURFACE TO WHICH THE SYMBOL IS APPLIED.			LAY NON-DIRECTIONAL, PITTED, OR PROTUBERANT	
	LAY MULTIDIRECTIONAL.				

Figure 20 - Lay Symbols

LAY SYMBOL	INTERPRETATION
	LAY MAY BE FURTHER RESTRICTED BY USE OF TERMS SUCH AS HONE, LAP, POLISH, ETC., WHICH SPECIFY THE FINAL METHOD OF PROCESSING.
	THE TERM "NO LEAD" FOLLOWING THE LAY DESIGNATION PROHIBITS LEAD DUE TO MACHINE FEEDS. PROCESSES SUCH AS PLUNGE GRINDING MUST BE USED TO FULFILL THIS REQUIREMENT.
	A SPECIFIC LEAD IS REQUIRED WHICH SHALL BE SPECIFIED UNDER THE SURFACE TEXTURE SYMBOL, OR IN A NOTE. (REFER TO 1E4074)

Figure 21 - Additional Lay Symbols

11.2 Machining Requirements - Machining required, machine allowance, machining prohibited, and control of tool drag are to be interpreted as shown in Figure 22.

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SYMBOL	INTERPRETATION
	MACHINING REQUIRED. The Horizontal Bar indicates that Machining is Required to Produce the Surface and that Material shall be provided for that purpose.
	BASIC MACHINE ALLOWANCE. The Number indicates the Basic amount of Stock Required for Machining.
	INFINITE MACHINE ALLOWANCE. The Infinity Symbol used with a Hole Callout indicates that the Feature (Hole) is to be Machined from Solid Material.
	MACHINING PROHIBITED. The Circle in the Vee indicates that the surface shall be produced without the removal of material by processes such as Cast, Forge, Hot and Cold Finished, Die Cast, Powdered Metallurgy or Injection Molded.
	CROSSED OUT V PROHIBITS TOOL DRAG. Marks and / or Grooves (Spiral or Straight Dragout). Such as caused by Dragging a Cutting Tool on a Finished Surface. Processing shall provide methods to prevent Tool Drag. (See Paragraph 5.7).

Figure 22 - Supplemental Symbols

11.3 Surface Lay For Plastic Parts - Specific patterns and roughnesses used for plastic parts are interpreted in Figure 23. Patterns are produced in the mold as indicated. Mold surfaces reproduce the pattern on the part surfaces. Surface definition is variable, depending on plastic type and color, fillers employed, and processing conditions. Conformance is assessed by visual inspection and comparison with comparison plaques from the sources in Paragraph 11.3.3.

11.3.1 Instrument Roughness Measurements - The Society of the Plastics Industry states that their plaque is not intended for surface texture measurement to determine Ra for example. Yet, if it is desired to measure the SPI plaque, mold, or component surfaces using a roughness measuring instrument, all SPI surface indications except D3 shall be measured with a 2 μ m stylus, short cutoff L_s = 2.5 μ m, and assessment length L_n = 4.0 mm. For A1, A2, A3, B1 surfaces, the cutoff L_c = 0.25 mm. For B2, B3, C1, C2, C3, D1, D2 surfaces, the cutoff L_c = 0.8 mm. The D3 surface shall be measured using a 5 μ m stylus, short cutoff L_s = 8 μ m, assessment length L_n = 12.5 mm, and cutoff L_c = 2.5 mm. The E10 shot blasted surface shall be measured with a 5 μ m or 10 μ m stylus, with short cutoff L_s = 25 μ m, assessment length L_n = 40 mm, cutoff L_c = 8 mm.

11.3.2 Multiple Approved Source Requirement - For surface designations where more than one source and/or specification is approved, only one specification shall be selected and used in cases where multiple parts will be assembled in proximity to each other on the same application.

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CAT LAY SYMBOL	OLD SPI	NEW SPI	GENERATION PROCESS REQUIREMENTS
E1	#1	A1	#3 Diamond
E1.5		A2	#6 Diamond Buff
E2			Etched - Approved Surfaces: Mold-Tech MT-11540, MT-11530, MT-11520 and Akron E-922, E-923, E-40. (Note: Not For New Designs.)
E2.5			Etched - Approved Surfaces: Mold-Tech MT-11020, Akron E-999, (for reference, both have 0.0381 mm texture depth).
E2.8			Etched – Approved Surfaces: Mold-Tech MT-11030, Akron E-999, (for reference, both have 0.0508 mm texture depth).
E3			Etched – Approved Surfaces: Akron A-226, Mold-Tech MT-11265, (for reference both have 0.127 mm texture depth). (Note: Not For New Designs. Former approved surfaces: Uniroyal 68RE40, Rawal MT-980)
E3.5			Etched – Approved Surfaces: Mold-Tech MT-11080 and Akron E-193, (for reference, both have 0.0508 mm texture depth).
E4			Etched – Approved Surface: Mold-Tech MT-1046. (Note: Not For New Designs)
E4.5			Etched – Approved Surface: Mold-Tech MT-6952 (Custom HEX pattern for Caterpillar).
E5	#2	A3	#15 Diamond Buff
E5.5		B1	600 Grit Paper
E5.8		B2	400 Grit Paper
E6	#3	B3	320 Grit Paper
E6.5		C1	600 Stone
E7	#4	C2	400 Stone
E7.5		C3	320 Stone
E8	#5	D1	Dry Blast Glass Bead #11
E8.5		D2	Dry Blast #240 Oxide
E9	#6	D3	Dry Blast #24 Oxide
E10			Etched/shot blasted - Tenibac-Graphicon Plaque #4 sample 18 or Shot blasted-356 aluminum mold (ASTM SG1) blasted to depth of 0.07 to 0.11 mm with 330 steel shot.

Figure 23 - Lay Symbols - Plastic Parts

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11.3.3 Etched Surface Plaque Providers And Society Of Plastics Industry, Inc. (SPI)

Mold-Tech IL
279 East Lies Rd.
Carol Stream, IL 60188

Tenibac – Graphion, Inc
35155 Automation Dr.
Villa Park, Clinton Township, MI 48045

The Akron Metal Etching Co.
463 Locust St.
Akron, OH 44307

SPI Mold Finish Guide, The Society of the Plastics Industry, Inc.
3150 Des Plaines Ave.
Des Plaines, IL 60018

12.0 REFERENCES

Abbreviations	1E0011
Caterpillar Specifications	1E0099, 1E0100, 1E1821, 1E2679, 1E2680, 1E2943, 1E4074, 1E4334A, 1E4334B, 1E4334C, 1E4334D, 1E4436.
Caterpillar Part Numbers	9A1593 (Procurement Number 9290-0161) Surface Texture Comparison Replica, available from Illinois Valley Plastics (Supplier No.K9031S). 9A9097 (Procurement Number 9290-0152) Surface Texture Comparison Replica, available from Illinois Valley Plastics (Supplier No.K9031S).
ANSI	Y14.36, B46.1
ISO	1302, 3274, 4287, 4288, 5436, 8785, 11562, 13565.
Automotive Industry Action Group	Advanced Product Quality Planning and Control Plan Manual
Automotive Industry Action Group	Purchased Part Approval Process Manual

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