13.1 SCOPE.

13.1.1 Purpose. This section establishes the method of specifying geometric characteristics of surface irregularities with respect to their height, width, and direction. It provides, through the use of symbols and numerical value classifications, a uniform system for accurately expressing the desired surface requirements (roughness, waviness, contact area, and lay) of solid materials on drawings. Surfaces normally excluded from these requirements are those which are controlled by their manufacturing process and are usually acceptable for most applications, i.e., textile, rubber, optical glass, plastics, felt, sheet metal, tubing, etc.

13.2 APPLICABLE DOCUMENTS. Note: DoD Policy Memo 05-3 "Elimination of Waivers to Cite Military Specifications and Standards in Solicitation and Contracts" has eliminated the need for waivers to use MIL-SPECS and MIL-STDS on DoD contracts. (See PREFACE 1, Section 2)

ASME Y14.100	Engineering Drawing Practices (Use in conjunction with ASME Y14.100.)
ASME B46.1	Surface Texture, Surface Roughness, Waviness and Lay
ASME Y14.36	Surface Texture Symbols
ISO 1302	Indication of Surface Texture in Technical Product Documentation

13.3 DEFINITIONS. Terms related to the surfaces of solid materials.

13.3.1 Surface. The surface of an object is the boundary which separates that object from another object, substance, or space and is produced by such means as abrading, casting, coating, cutting, etching, plastic deformation, sintering, wear, erosion, etc.

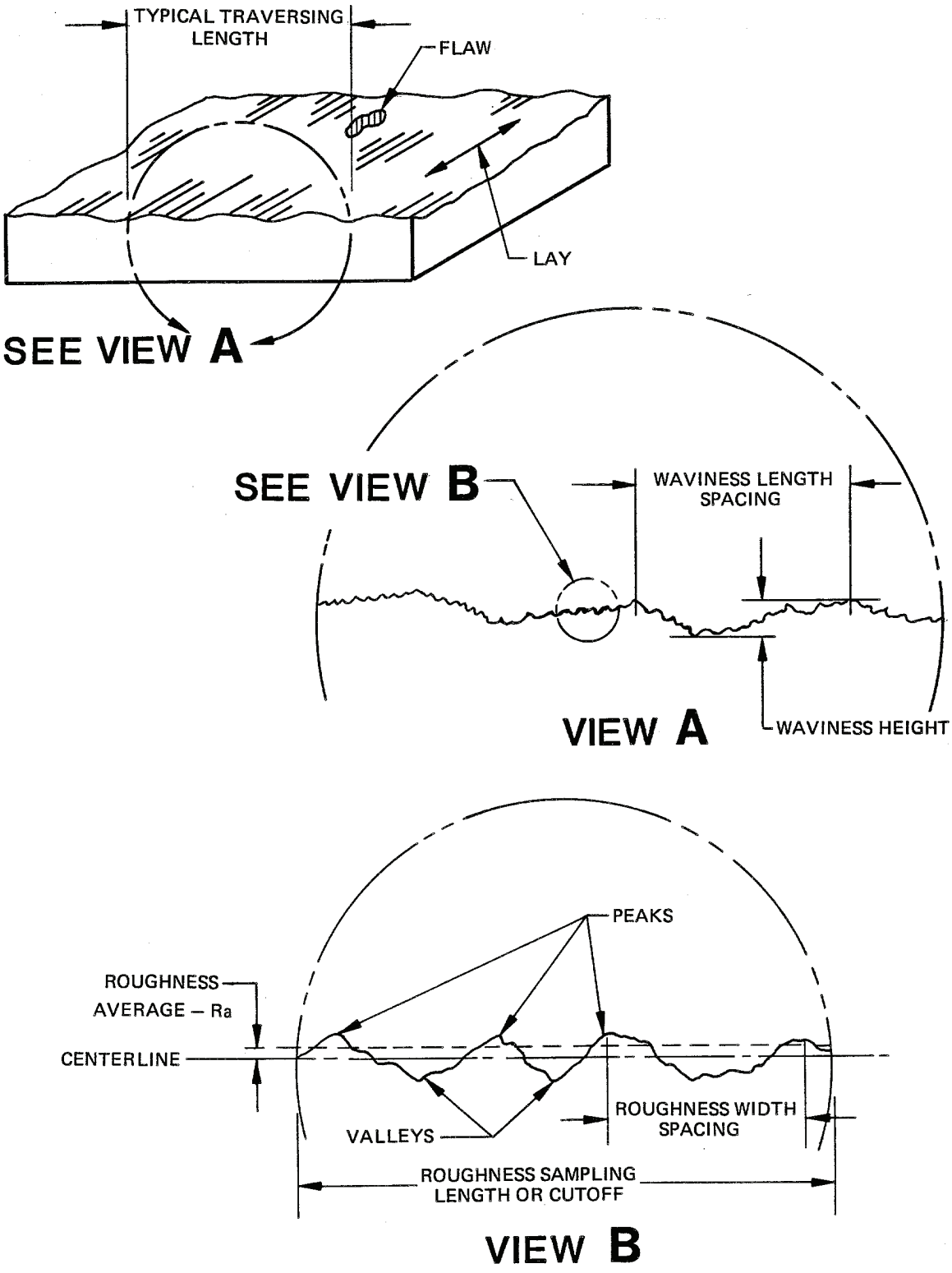
13.3.1.1 Measured Surface. The measured surface is a representation of the surface obtained by instrumentation.

13.3.1.2 Nominal Surface. The nominal surface is the intended surface contour, the shape and extent of which is usually shown and dimensioned on a drawing or descriptive specification.

13.3.2 Surface Texture. Surface texture is the repetitive or random deviations from the nominal surface which form the three-dimensional topography of the surface. Surface texture includes roughness, waviness, lay and flaws and may also be referred to as Surface Irregularities. FIGURE 13-1 is an example of a unidirectional lay surface.

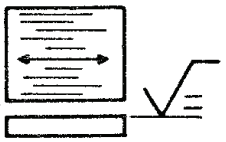
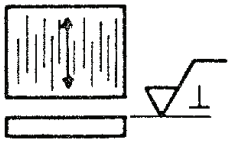
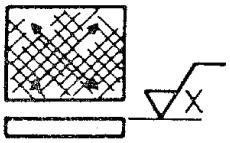
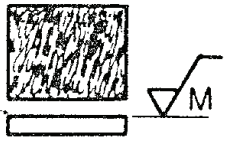
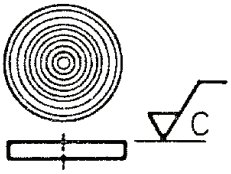
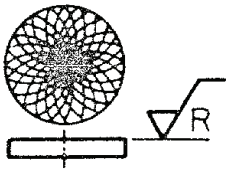
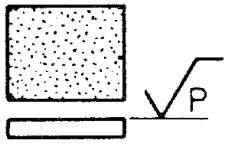
13.3.2.1 Roughness. Roughness is the surface feature of random and repetitively spaced minute or finer deviations from the "center line" having roughness height and width as included within a typical sampling length known as the Roughness-Width Cutoff. See FIGURE 13-1, VIEW B.

13.3.2.2 Waviness. Waviness is the surface feature of more widely spaced component of surface texture with characteristics deviating from the "center line" having waviness height and width with generally wider spacing than the roughness-width cutoff length. Roughness may be considered as superimposed on a "wavy" surface. See FIGURE 13-1, VIEW A. When a percentage of contact area is specified, the waviness height and width designations are not shown (See Surface Texture PARAGRAPH 13.3.2). Waviness may result from such factors as machine or work deflections, vibration, chatter, heat treatment or warping strains. Roughness may be considered superimposed on a "wavy" surface. See FIGURE 13-1, VIEW B.



SURFACE CHARACTERISTICS
FIGURE 13-1

13.3.2.3 Lay. Lay is the direction of the predominant surface pattern determined by the production method used (tool marks or grain). See FIGURES 13-2 and 13-7.

LAY SYM-BOL	MEANING	EXAMPLE SHOWING DIRECTION OF TOOL MARKS
=	Lay approximately parallel to the line representing the surface to which the symbol is applied.	
⊥	Lay approximately perpendicular to the line representing the surface to which the symbol is applied.	
X	Lay angular in both directions to line representing the surface to which the symbol is applied.	
M	Lay multidirectional.	
C	Lay approximately circular relative to the center of the surface to which the symbol is applied.	
R	Lay approximately radial relative to the center of the surface to which the symbol is applied.	
P*	Lay particulate, non-directional, or protuberant.	

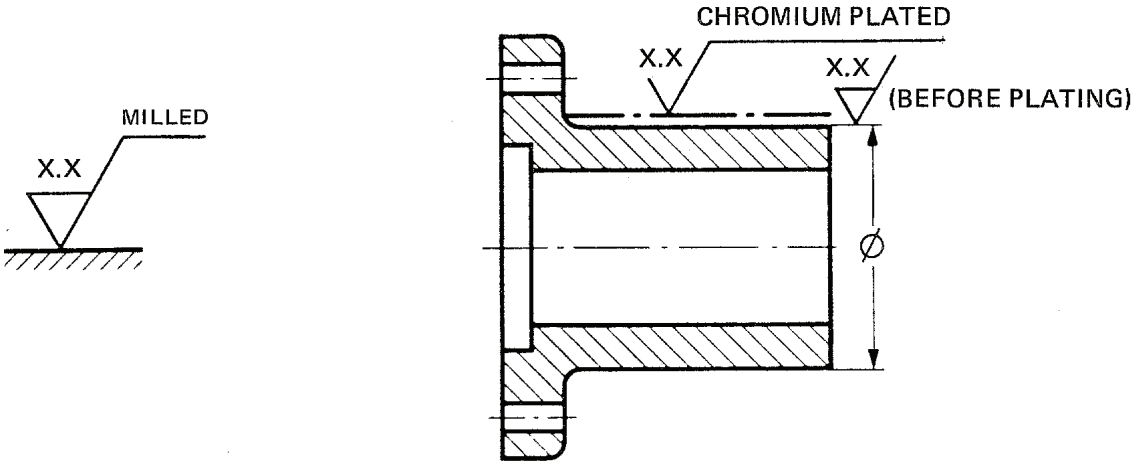
* The "P" symbol is not currently shown in ISO Standards. American National Standards Committee B46 (Surface Texture) has proposed its inclusion in ISO 1302 -"Methods of indicating surface texture on drawings."

LAY SYMBOLS

FIGURE 13-2

13.3.2.4 Indication Of Special Texture Characteristics. In certain circumstances, for functional reasons, it may be necessary to specify additional special requirements concerning surface texture.

EXAMPLES:



13.3.2.5 Flaws. Flaws are unintended surface imperfections occurring as a direct result of a manufacturing process. They include defects singularly or in-groups, such as cracks, blow holes, checks, ridges, scratches, gouges, nicks, cuts, punctures, dimples, chemical corrosion, etc. See FIGURE 13-1 and PARAGRAPH 13.5.6.

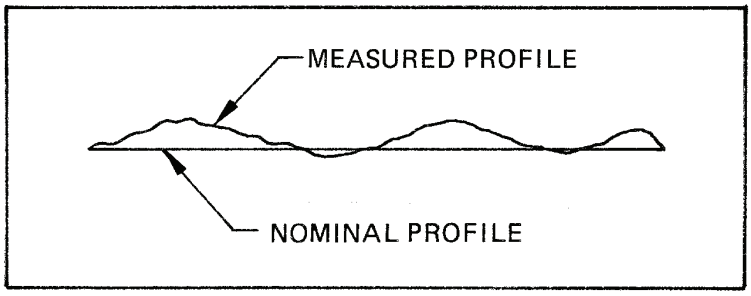
13.3.2.6 Error Of Form. The error of form is a deviation from the nominal surface which is not included in surface texture.

13.4 DEFINITIONS. (Terms related to the measurement of surface texture.)

13.4.1 Profile. The profile is the contour of a surface in a plane perpendicular to it, unless some other angle is specified.

13.4.1.1 Nominal Profile. The nominal profile is a profile of the nominal surface; it is the intended profile. See FIGURE 13.3.

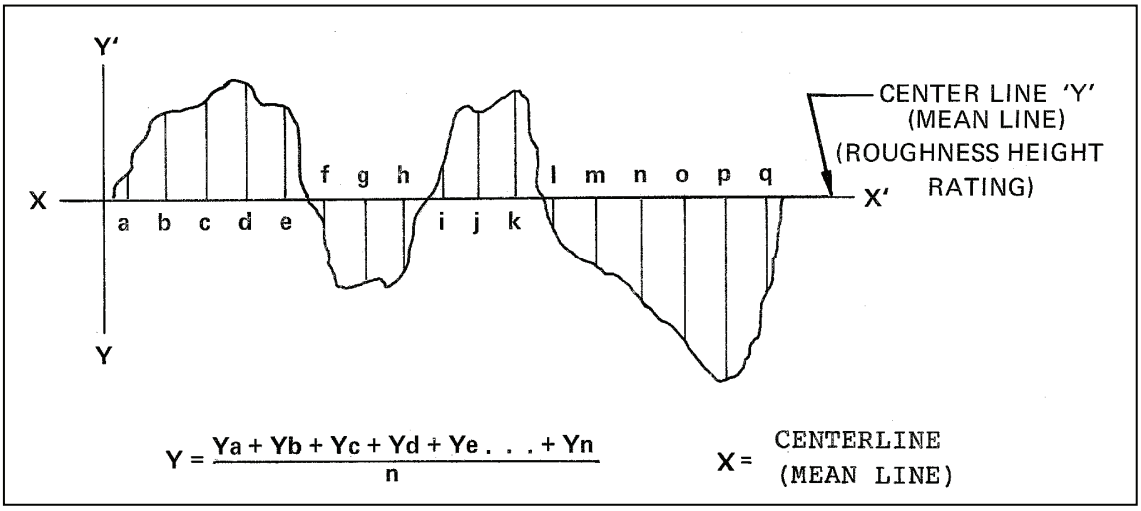
13.4.1.2 Measured Profile. The measured profile is a representation of the profile obtained by instrumental or other means. When the measured profile is a graphical representation, it will usually be distorted through the use of different vertical and horizontal magnifications but shall otherwise be as faithful to the profile as technically possible. See FIGURE 13-3.



MEASURED PROFILE
FIGURE 13-3

13.4.1.3 Modified Profile. The modified profile is a measured profile where filter mechanisms (including the instrument datum) are used to minimize certain surface texture characteristics and emphasize others.

13.4.2 Center Line (Mean Line). A mean line is a theoretical line parallel to the general surface profile at a mid-point between the high and low measurements of the surface features. See FIGURE 13-4.



SHORT SECTION OF HYPOTHETICAL PROFILE
DIVIDED INTO INCREMENTS
FIGURE 13-4

13.4.3 Peak. A peak is the point of maximum height on that portion of a profile which lies above the centerline and between two intersections of the profile and the centerline. See FIGURE 13-1, VIEW B.

13.4.4 Valley. A valley is the point of maximum depth on that portion of a profile which lies below the centerline and between two intersections of the profile and the centerline. See FIGURE 13-1, VIEW B.

13.4.5 Spacing. The spacing is the distance between specified points on the profile measured parallel to the nominal profile. See FIGURE 13-1.

13.4.5.1 Roughness Width Spacing. The roughness spacing is the average spacing between adjacent peaks of the measured profile within the roughness sampling length. See FIGURE 13-1, VIEW B and TABLE 13-2.

13.4.5.2 Waviness Spacing. The waviness spacing is the average spacing between adjacent peaks of the measured profile within the waviness sampling length. See FIGURE 13-1, VIEW A.

13.4.6 Sampling Length. The sampling length is the nominal spacing within which a surface characteristic is determined. See FIGURE 13-1.

13.4.6.1 Roughness Sampling Spacing. The roughness sampling spacing is the sampling length within which the roughness rating average is determined. This length is chosen, or specified, to separate the profile irregularities which are designated as roughness from those irregularities designated as waviness. See FIGURE 13-1, VIEW B.

13.4.6.2 Roughness Sampling Cutoff (Length). The Cutoff is the electrical response characteristic of the roughness-average measuring instrument which is selected to limit the spacing of surface irregularities to be included in assessing the roughness average. The Cutoff is rated in millimeters. See FIGURE 13-1, VIEW B. Standard Roughness -Width Cutoff Values are shown in TABLE 13-3.

13.4.6.3 Waviness Sampling Length. The waviness sampling length is the sampling length within which the waviness height is determined. See FIGURE 13-1, VIEW A.

13.4.7 Traversing Length. The traversing length is the length of profile which is traversed by the stylus to establish a representative measurement. See FIGURE 13-1.

13.4.8 Height. Height is considered to be those measurements of the profile in a direction normal to the nominal profile. See FIGURE 13-1, VIEWS A and B.

13.4.8.1 Roughness (Height) Average (Ra). Roughness average rating is the arithmetic average of the absolute values of the measured profile height deviations taken within the sampling length and measured from the graphical centerline. For graphical determinations of roughness average, the height deviations are measured normal to the chart center-line. See FIGURE 13-1, VIEW B. Roughness Average is expressed in micrometers. Standard values are shown in TABLE 13-1.

13.4.8.2 Waviness Height (W). The waviness height is the peak-to-valley height of the modified profile from which roughness and flaws have been removed by filtering, smoothing, or other means. The measurement is to be taken normal to the nominal profile within the limits of the waviness sampling length and expressed in millimeters. See FIGURE 13-1, VIEW A. Waviness Height standard values are shown in TABLE 13-4.

13.4.8.3 Peak-To Valley Height. The peak-to-valley height is the maximum excursion above the centerline plus the maximum excursion below the centerline within the sampling length. This value is typically 3 or more times the roughness average. See FIGURE 13-1, VIEW B.

13.4.9 Micrometer. A micrometer is one millionth of a meter (0.000001 meter). Thus 1.6 micrometers (1.6 or 1.6 m) equals 0.000016 meters.

13.4.10 *Microinch. A microinch is one millionth of an inch (.000001 inch). Thus 63 microinches (63 or 63 in.) equals .000063 inches.

Note: 1.6 micrometers is equivalent to 63 microinches

* Metrication values of ISO terminology and symbolism to U.S. usage was adopted 16 MAR 1978. This chapter will reflect the metric values and retain the inch values for reference only during the change-over period.

13.4.11 Contact Area. Contact area is a value expressed in percentages for the surface required to effect contact with its mating component surface. Unless otherwise specified, the contact area shall be distributed over the surface with approximate uniformity. See PARAGRAPH 13.6.7.

13.5 SURFACE TEXTURE CONTROL APPLIED TO DRAWINGS.

13.5.1 General Instructions. To ensure efficient and uniform drafting practices, the application of surface control requirements shall be made in the manner specified by this section.

13.5.2 Limitation. Where no surface control is specified, it is to be assumed that the surface produced by the manufacturing operation will be satisfactory. If a surface is to be controlled, the maximum acceptable value rating for the specific surface feature(s) should be indicated. Note that the surface symbol and value ratings do not control the geometric flatness of the surface. See SECTION 5, PARAGRAPH 5.14.1.

13.5.3 General Coverage. The surface control applying to all or most of the surfaces of the part is indicated in a general note similar to the following, as applicable:

UNLESS OTHERWISE SPECIFIED SURFACE ROUGHNESS XX

13.5.3.1 Control Of Surface Texture By Symbol. All surfaces of a part resulting from a shop operation and requiring control of surface texture are defined by the surface symbol in the general notes and/or on the field of drawing. The general application of the symbol does not affect surfaces specified on previous drawings, "stock" condition surfaces, or the surfaces resulting from a welding process.

13.5.4 Interpretation Reference. When an interpretation of surface symbols is required, the following general note, as applicable, may be included on the drawing as follows:

X. SURFACE TEXTURE PER ASME B46.1

13.5.5 Plated Or Coated Surfaces. Unless otherwise specified, surface texture designations apply to the completed surface. Drawings or specifications for plated or coated parts should definitely indicate whether the surface texture designations apply before plating (coating), apply after plating (coating), or apply before and after plating or coating.

13.5.6 Flaws. Unless otherwise specified, the effect of flaws is not included in the measurement of roughness height.

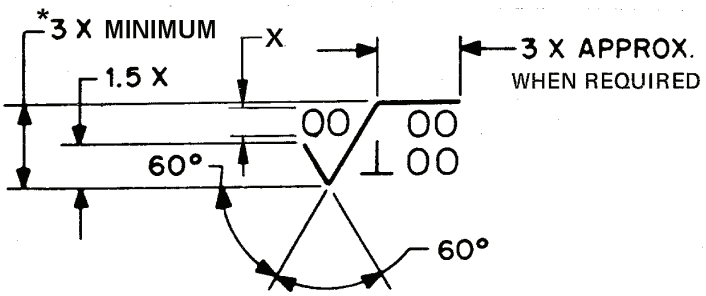
13.5.6.1 Control Of Flaws. When flaws are to be considered a characteristic of a surface, a note stating specific requirements should be included on the drawing.

EXAMPLE:

X. SURFACES INDICATED TO BE FREE FROM SCRATCHES, DENTS, STEPS OR FLAWS EXCEEDING XXX MICROMETERS IN DEPTH.

13.5.7 Surface Control Symbols. The surface control system used to designate the limits of surface features is a check mark with a horizontal top extension as shown in FIGURE 13-5. The long leg and extension are to the right as the drawing is read. The top extensions may be lengthened to the right as far as needed. The surface texture symbol is modified when necessary to require or prohibit removal of material. See FIGURES 13-6 and 13-7.

13.5.7.1 Size Of Lettering In Surface Texture Symbol. The lettering should be the same size as that of the drawing dimensions. The line weight should approximate that of the lettering.

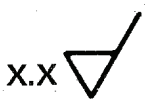
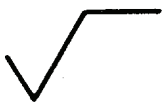


* DIMENSION IS INCREASED BY +1 FOR EACH LINE OF VALUES ADDED BELOW THE HORIZONTAL LINE.

LETTER HEIGHT = X	
DRAWING SIZE	
INCH	METRIC
17 X 22 AND SMALLER X = .125	420 X 594 AND SMALLER X = 3.5
LARGER THAN 17 X 22 X= .156	LARGER THAN 420 X 594 X = 3.5

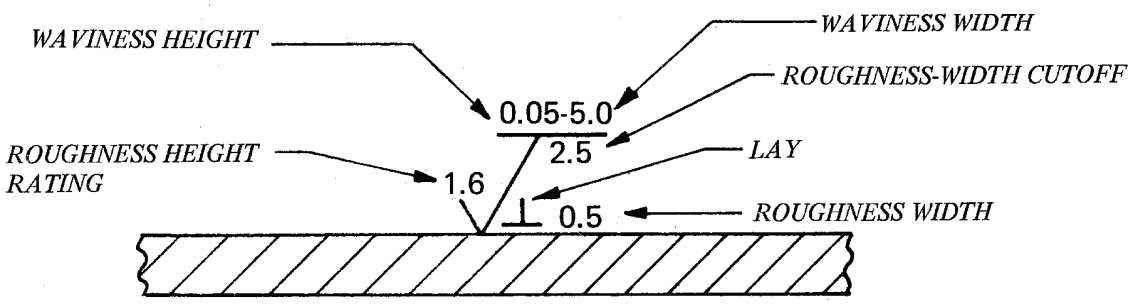
SURFACE TEXTURE CONTROL SYMBOL SIZE
FIGURE 13-5

13.5.7.2 Surface Texture Values Required Above Those Normally Produced. Where surface texture values other than roughness average are specified (above the normally produced surface texture), the symbol must be drawn with additional features to specify procedures and limits. See FIGURE 13-6.

PURPOSE	SYMBOL	COMMENT
BASIC SYMBOL: ROUGHNESS AVERAGE SPECIFIED		Where Roughness Height only is indicated, the surface may be produced by any method except when the bar " " or circle " " symbol is used.
REMOVAL OF MATERIAL REQD TO PRODUCE PART		Where Material Removal By Machining is Required. The horizontal bar indicates that material removal by machining is required to produce the surface and that material must be provided for that purpose.
REMOVAL OF MATERIAL REQD TO ACHIEVE FINISH		Where Material Removal Allowance. The number indicates the amount of stock to be removed by machining in millimetres (or inches). Tolerances may be added to the basic value shown or in a general note.
NO MATERIAL REMOVAL PERMITTED		Where Material Removal Is Prohibited. The circle in the vee indicates that the surface must be produced by processes such as casting, forging, hot finishing, cold finishing, die casting, powder metallurgy or injection molding without subsequent removal of material.
SPECIAL SURFACE CHARACTERISTICS INDICATED		Where Any Surface Characteristics Are Specified Above The Horizontal Line or to the Right of the Symbol. Surface may be produced by any method except when the bar or circle is specified.

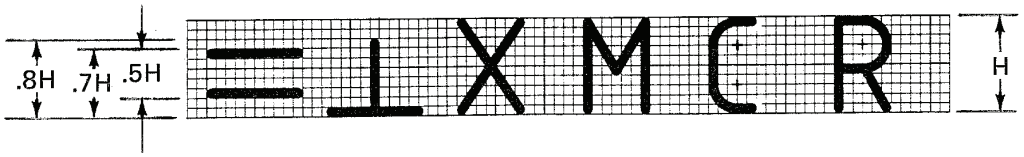
SURFACE TEXTURE SYMBOLS VARIATIONS
FIGURE 13-6

SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION
1.6	Roughness height rating is placed at the left of the long leg. The specification of only one rating shall indicate the maximum value and any lesser value shall be acceptable.	1.6 0.8 0.05-5.0 ⊥	Lay designation is indicated by the lay symbol placed at the right of the long leg.
1.6 0.8	The specification of maximum value and minimum value roughness height ratings indicates permissible range of value rating.	1.6 0.8 0.05-5.0 2.5 ⊥	Roughness-width cutoff rating is placed below the horizontal extension. When no value is shown, 0.80 is assumed.
1.6 0.8 0.05	Maximum waviness height rating is placed above the horizontal extension. Any lesser rating shall be acceptable.	1.6 0.8 0.05-5.0 2.5 ⊥ 0.5	Where required, maximum roughness width rating shall be placed at the right of the lay symbol. Any lesser rating shall be acceptable.
1.6 0.8 0.05-5.0	Maximum waviness width rating is placed above the horizontal extension and to the right of the waviness height rating. Any lesser rating shall be acceptable.	3.5 1.6	Material removal by machining is required to produce the surface. The basic amount of stock provided for material removal is specified at the left of the short leg of the symbol.
90%	Minimum requirements for contact or bearing area with a mating part or reference surface shall be indicated by a percentage value placed above the extension line as shown. Further requirements may be controlled by notes.	1.6	Removal of material is prohibited.



SURFACE TEXTURE CONTROL SYMBOLS
FIGURE 13-7

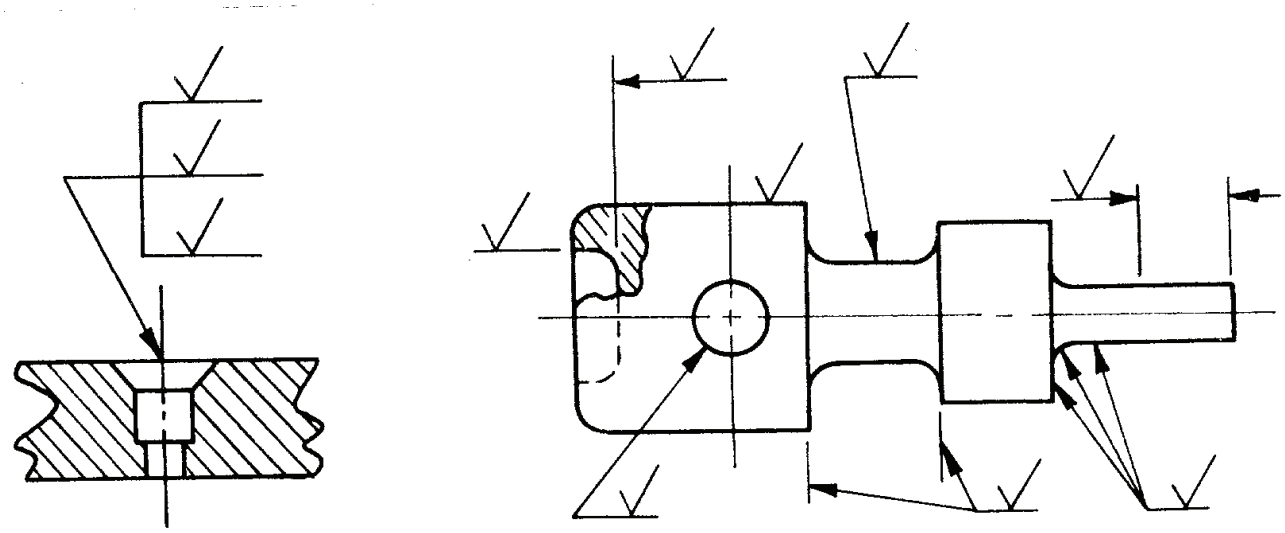
13.5.7.3 Surface Texture Control Related To Production Method. When the control of a surface texture is related to the production method used as the result of tool marks or grain, supplemental symbols are added to the Surface Control Symbols as described in FIGURE 13-2 and constructed as shown in FIGURE 13-8.



X = .125 or .156
(See FIGURE 13-5)
H = 1.5 X

LAY SYMBOL SIZE
FIGURE 13-8

13.5.8 Symbol Placement. Whenever practicable, the apex of the symbol is drawn touching the surface to be controlled. When this is not practical, the symbol may be placed with the apex touching an extension line from the surface to which it applies. Surface symbols are placed in a horizontal reading position. See FIGURE 13-9. Surface control indications for an individual surface are in one place only and not repeated in another view or section. Where the symbol is used with a dimension, it affects all surfaces defined by the dimension. Areas of transition, such as chamfers and fillets, conform with the roughest adjacent surface area unless otherwise indicated.



PLACEMENT OF SURFACE CONTROL SYMBOL
FIGURE 13-9

13.6 RECOMMENDED VALUE RATINGS.

13.6.1 General Considerations. Usually value ratings selected to qualify surface features will have an associated relationship and will not combine opposite extremes, such as a fine surface roughness height and a wide surface roughness width. Care should be exercised to insert numerical values in precise position as shown in FIGURE 13-5. The following ratings, when indicated with a surface symbol, represent the maximum condition acceptable and are the preferred or most common value used. Other values, not shown, between those indicated may be used as exceptions to the usual.

13.6.2 Roughness Height Values. In Micrometers. See PARAGRAPH 13.4.8.1 and TABLE 13-1.

MICROMETERS, μm (MICROINCHES, μin)*

μm	μin	μm	μin	μm	μin	μm	μin
0.012	(.5)	0.25	(10)	1.25	(50)	**6.3**	**(250)**
0.025	(1)	0.32	(13)	**1.6**	**(63)**	8.0	(320)
0.050	**(2)**	**0.40**	**(16)**	2.0	(80)	10.0	(400)
0.075	(3)	0.50	(20)	2.5	(100)	**12.5**	**(500)**
0.100	**(4)**	0.63	(25)	**3.2**	**(125)**	15.0	(600)
0.125	(5)	**0.80**	**(32)**	4.0	(160)	20.0	(800)
0.15	(6)	1.00	(40)	5.0	(200)	25.0	(1000)
0.20	**(8)**						

*Boldface values preferred

ROUGHNESS AVERAGE RATING VALUES
TABLE 13-1

13.6.3 Roughness Width Values. In Millimeters. See PARAGRAPH 13.4.5.1 and TABLE 13-2.

ROUGHNESS WIDTH VALUES	
Minimum	**Maximum**
0.12	0.50

ROUGHNESS AVERAGE RATING VALUES
TABLE 13-2

13.6.4 Roughness Width Cutoff. In Millimeters. When no value is specified, the value 0.80 is assumed. See PARAGRAPH 13.4.6.2 and TABLE 13-3.

VALUES MILLIMETERS, mm (INCHES, in.)*

mm	in.	mm	in.	mm	in.
0.08	(.003)	**0.80**	**(.030)**	8.0	(.300)
0.25	(.010)	2.50	(.100)	25.0	(1.000)

*Boldface values preferred

STANDARD ROUGHNESS - WIDTH CUTOFF
TABLE 13-3

13.6.5 Waviness Height Values. In Millimeters. See PARAGRAPH 13.4.8.2 and TABLE 13-4.

MILLIMETERS, mm (INCHES , in.)*

mm	in.	mm	in.	mm	in.
0.0005	**(.00002)**	0.008	(.0003)	**0.12**	**(.005)**
0.0008	(.00003)	**0.012**	**(.0005)**	0.20	(.008)
0.0012	**(.00005)**	0.020	(.0008)	**0.25**	**(.010)**
0.0020	(.00008)	**0.025**	**(.0010)**	0.38	(.015)
0.0025	**(.00010)**	**0.05**	**(.002)**	**0.50**	**(.020)**
0.005	**(.0002)**	0.08	(.003)	0.80	(.030)

*Boldface values preferred

WAVINESS HEIGHT VALUES
TABLE 13-4

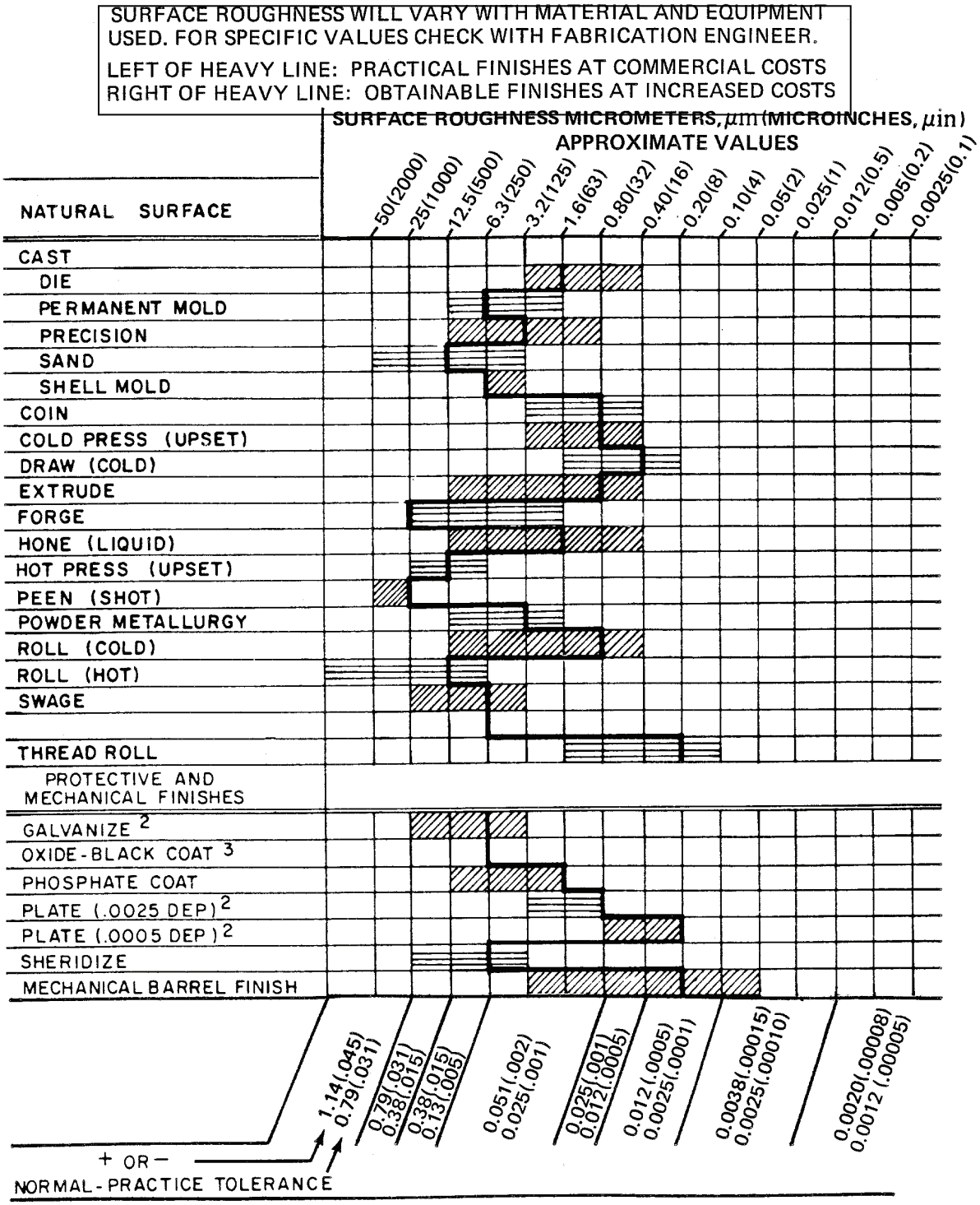
13.6.6 Waviness Width Values. In Millimeters. Waviness height and waviness width values are separated by a dash, no standard values are established. See PARAGRAPH 13.4.8.2 and 13.4.6.3 respectively.

13.6.7 Contact Area. A representation of the measured surface obtained by instrumentation or other means.

Percentage (approximate).
90% 75% 50%

13.7 RECOMMENDED RATINGS FOR STANDARD PROCESSES.

13.7.1 The ratings listed in TABLE 13-5 represent the acceptable surface qualities resulting from standard commercial manufacturing processes.



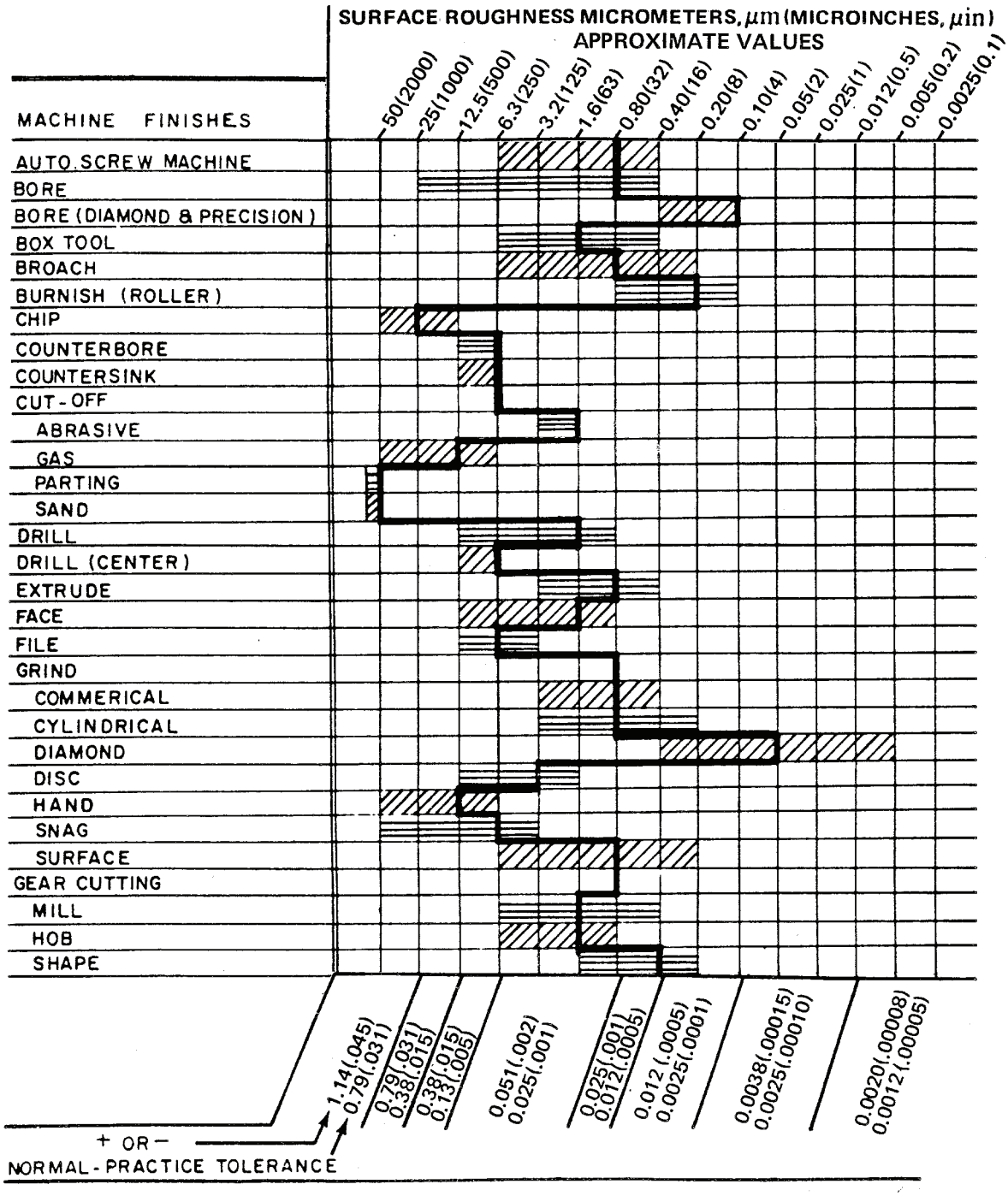
1) DEPENDENT ON PREVIOUS FINISHES, GRIT & GRADE OF ABRASIVE.
2) ROUGHNESS INCREASES WITH THICKNESS OF DEPOSIT.
3) SURFACE ON WHICH APPLIED DOES NOT CHANGE.

SURFACE TEXTURE VS. PROCESS

TABLE 13-5 Continued next page

SURFACE ROUGHNESS WILL VARY WITH MATERIAL AND EQUIPMENT USED. FOR SPECIFIC VALUES CHECK WITH FABRICATION ENGINEER.

LEFT OF HEAVY LINE: PRACTICAL FINISHES AT COMMERCIAL COSTS
RIGHT OF HEAVY LINE: OBTAINABLE FINISHES AT INCREASED COSTS



SURFACE TEXTURE Vs. PROCESS

TABLE 13-5 Continued next page

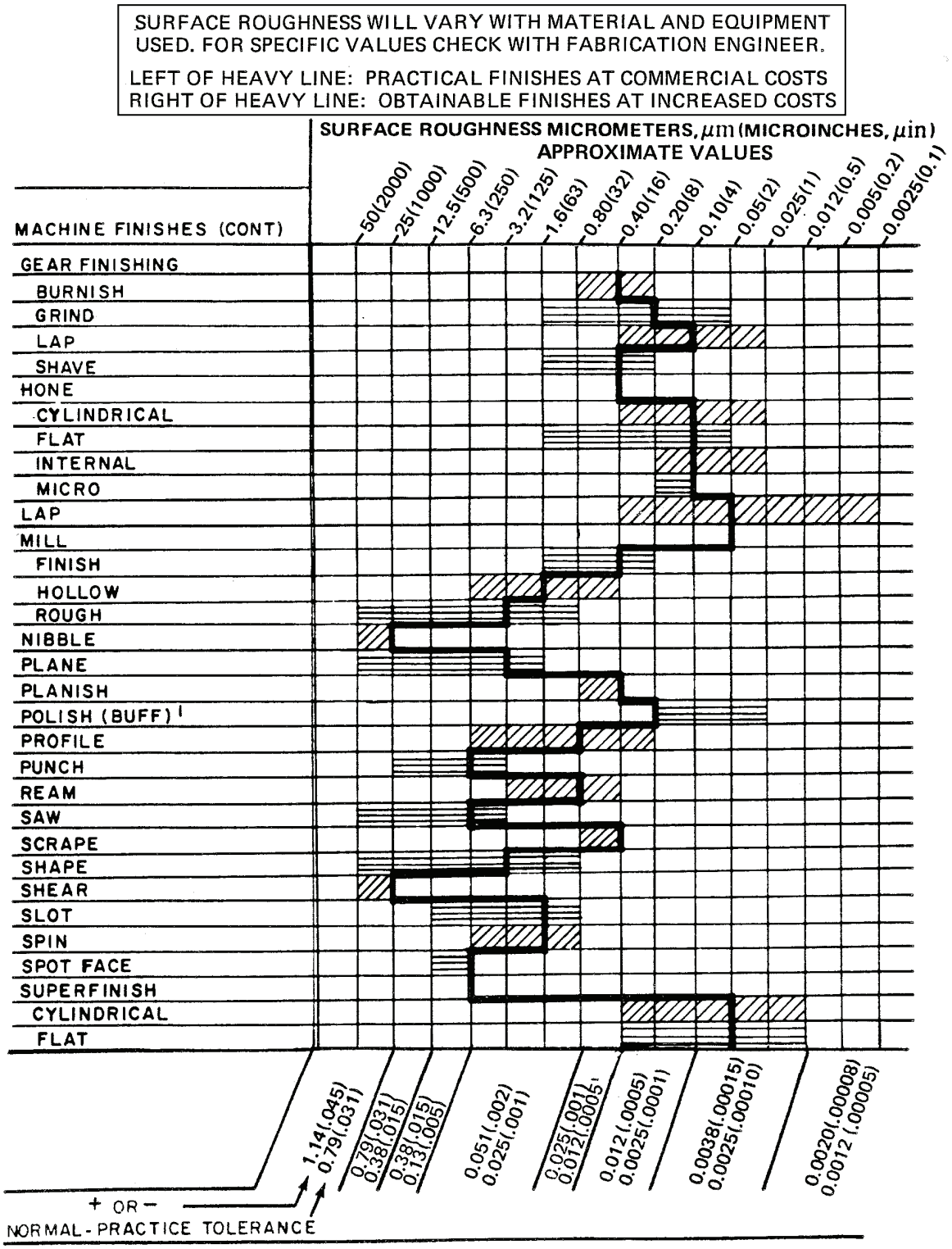


TABLE 13-5 Continued next page

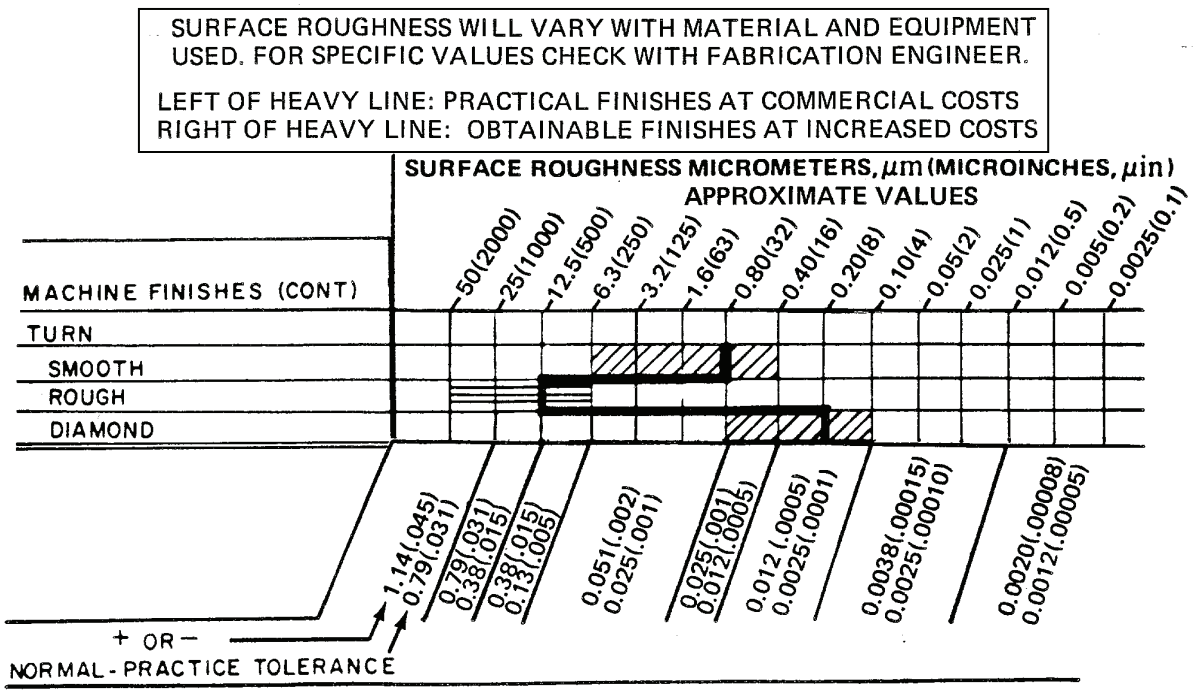

SURFACE ROUGHNESS WILL VARY WITH MATERIAL AND EQUIPMENT USED. FOR SPECIFIC VALUES CHECK WITH FABRICATION ENGINEER.
LEFT OF HEAVY LINE: PRACTICAL FINISHES AT COMMERCIAL COSTS
RIGHT OF HEAVY LINE: OBTAINABLE FINISHES AT INCREASED COSTS
SURFACE ROUGHNESS MICROMETERS, μm (MICROINCHES, μin)
APPROXIMATE VALUES
50(2000)
25(1000)
12.5(500)
6.3(250)
3.2(125)
1.6(63)
0.80(32)
0.40(16)
0.20(8)
0.10(4)
0.05(2)
0.025(1)
0.012(0.5)
0.005(0.2)
0.0025(0.1)
MACHINE FINISHES (CONT)
TURN
SMOOTH
ROUGH
DIAMOND
1.14(.045)
0.79(.031)
0.79(.031)
0.38(.015)
0.38(.015)
0.13(.005)
0.051(.002)
0.025(.001)
0.025(.001)
0.012(.0005)
0.012(.0005)
0.0025(.0001)
0.0038(.00015)
0.0025(.00010)
0.0020(.00008)
0.0012(.00005)
+ OR −
NORMAL-PRACTICE TOLERANCE

TABLE 13-5

NOTES: