

INVOLUTE SPLINE GAGES (300° PRESSURE ANGLE)

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1. GENERAL:

1.1 INTRODUCTION: Only with perfect splines can the theoretical tooth thickness, dimensions (over pins or otherwise), gages, and the resultant fits be in complete agreement. In actual practice, the errors are relatively large and the discrepancies are troublesome. If tooth thickness on the shaft and space width in the hole are correct, then any errors of form or spacing will interfere unless the errors of both members match exactly, which is improbable. An imperfectly splined shaft, if snug in a ring gage, is necessarily undersize at all except the few points of contact; likewise an internal spline that fits its plug gage must be oversize at most points; the two parts then will almost certainly fit together looser than predicted by the gages. Note that, in general the actual fit will be tighter than predicted by measurements over pins, or by calipers, but looser than indicated by plug and ring gages; and the discrepancy will be of the same order of magnitude as the errors. For these reasons, the plug gages must be undersize and the ring gages fitted to representative master plugs in order to control parts more satisfactorily within specified dimensions. Note also that the plug and ring gages covered herein are not suitable for checking individual tooth or space dimensions. For that purpose special methods are necessary, usually involving direct measurements over pins, with calipers or by specialized apparatus. External spline elements are easier to produce, control and check than internal splines. For this reason, the "Go" and "Not Go" ring gages are customarily made to fit the master plug gages.

1.2 PRODUCTION GAGING: The gaging practice presented in this ARP 179 employing plug and ring gages is intended to find the greatest application to the gaging of splines in quantity production where the cost of the recommended gages can be justified. For suggestions regarding gaging on experimental parts or in small quantity manufacturing, see Section 7.

2. GAGE TOOTH NOMENCLATURE:

- 2.1 Figure 1 shows a tooth diagram of a ring gage. The various elements of the tooth are illustrated and defined.
- 2.2 Figure 2 shows a tooth diagram of a plug gage. The various elements of the tooth are illustrated and defined.

3. BASIC GAGE TOOTH PROPORTIONS:

- 3.1 Table 1 shows the basic gage tooth proportions. The "Go" gage must check the part to the true involute form diameter. If an involute clearance (see Figure 3) has been added (on an internal spline) or subtracted (on an external spline) the addendum of the "Go" gage must be increased by the same amount in order to check to the true involute form diameter of the part.
- 3.2 Figure 4 shows the relationship of the ring gage to the external spline it is to check.

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- 3.3 Figure 5 shows the relationship of the plug gage to the internal spline it is to check.
- 3.4 The true involute form diameter of the "Go" and "Not Go" ring gages is equal to the maximum outside diameter of the part to be checked. It is desirable, however, to have the true form diameter of the ring gages equal to the maximum outside diameter of the part plus an involute clearance in order to provide for permissible eccentricity of the outside diameter of the external spline. See Figure 3 on Page 8.
- 3.5 The true involute form diameter of the "Go" and "Not Go" plug gages is equal to the minimum inside diameter of the part to be checked. It is desirable, however, to have the true form diameter of the plug gages equal to the minimum inside diameter of the part minus an involute clearance in order to provide for permissible eccentricity of the inside diameter of the internal spline. See Figure 3 on Page 8.
- 3.6 The maximum inside diameter of the "Go" ring gage and the minimum outside diameter of the "Go" plug gage are the same as the true involute form diameter of the part to be checked, with involute clearance if desired.
- 3.7 A "Not Go" gage, to be effective, can check but one element. A "Not Go" gage made to check the chordal tooth thickness or chordal space at the pitch diameter is usually sufficient for practical purposes. In order that the "Not Go" gage may check at the pitch diameter, for practical purposes, a short addendum is provided so that the inside diameter of the "Not Go" ring gage is greater than the inside diameter of the "Go" ring gage, and the outside diameter of the "Not Go" plug gage is less than the outside diameter of the "Go" plug gage. The addendum of the "Not Go" gages shall be approximately $\frac{2}{3}$ of the addendum of the part. (See Figures 4 and 5).
- 3.8 The true involute form diameter of the master plug gage is equal to the minimum inside diameter of the ring gage minus an allowance required in the manufacturing of the ring gage.
- 3.9 The minimum outside diameter of the master plug gage used to check the "Go" and the "Not Go" ring gage is equal to the maximum outside diameter of the part. (Master plug gages may also be truncated to determine the wear of the ring gage.)
- 3.10 The amount of wear allowance shall be dependent on the tolerance of the part to be gaged. A wear allowance of .0003 has been incorporated in Tables 5 and 7.

4. TOLERANCES:

- 4.1 Table 2 shows the following tolerances for the plug gage:
- Chordal tooth thickness tolerance.
 - Involute tolerance.
 - Spacing tolerance between any 2 adjacent or non-adjacent teeth.
 - Total of twice the positive involute tolerance plus the spacing tolerance between any 2 adjacent or non-adjacent teeth.



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4.2 Table 3 shows the following tolerances for the ring gage:

- a. Involute tolerance.
- b. Spacing tolerance between any 2 adjacent or non-adjacent teeth.

4.3 Table 4 shows the following tolerances for the master plug gages:

- a. Chordal tooth thickness tolerance.
- b. Involute tolerance.
- c. Spacing tolerance between any 2 adjacent or non-adjacent teeth.
- d. Total of twice the positive involute tolerance plus the spacing tolerance between any 2 adjacent or non-adjacent teeth.

4.4.1 The chordal tooth thickness tolerance shown in Tables 2 and 4 applies to the chordal thickness specified in Tables 5, 6, 7 and 8.

4.4.2 The involute tolerance shown in Tables 2, 3 and 4 is the amount that the profile may deviate from the true involute form. All errors in profile in the direction of the tooth shall be called negative and all errors in profile in the direction of the space shall be called positive. (See Figures 6 and 7.)

4.4.3 Spacing tolerance between any two adjacent or non-adjacent teeth as shown in Tables 2, 3 and 4 denotes the maximum cumulative tooth to tooth spacing error. The tooth to tooth spacing error is the amount any tooth varies from the theoretical spacing in relation to an adjacent tooth.

4.4.4 Figures 8 and 9 tend to show that spacing errors, whether positive or negative, will have the same effect on the part to be checked. Figure 8 and 9 are sketches of a theoretical perfect part and a gage with a permissible error introduced to show the effect of this error on the part. In Figure 8, if one tooth of the gage has a negative error in spacing, the chordal space of the part will be increased by the amount of error in spacing as shown. All the chordal spaces of this part must be at least as large as the space mentioned above or the gage would fit in only one position. In Figure 9, one tooth of the gage has a positive error in spacing. If this positive error is equal to the negative error in Figure 8, it can easily be seen that a part checked by the gage in Figure 8 could also be checked by the gage in Figure 9.

4.4.5 In Figure 10 is shown a graphical record of the spacing errors. In the example plotted, the spacing error between any two teeth is equal to .0003.

4.4.6 The total of twice the positive involute tolerance plus the spacing tolerance between any 2 adjacent or non-adjacent teeth, as shown in Tables 2 and 4, is the maximum amount of interference error allowed not only by the accumulation of spacing and involute tolerances, but also for out of roundness and lack of parallelism. These latter errors, though not tabulated, will exist, but Column 5 of Tables 2 and 4 restricts the maximum effect on chordal thickness due to probable accumulated errors.

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5. DIMENSIONS FOR GAGES:

5.1 The plug gages shall be undersize as follows:

5.1.1 The chordal tooth thickness of the "Go" plug gage shall be equal to the minimum chordal space of the part to be checked minus the sum of the spacing error and twice the positive involute tolerance. To this value is then added a .0003 wear allowance. The chordal tooth thickness of the "Go" plug gage shall have a positive tolerance. See Tables 2 and 5.

5.1.2 The chordal tooth thickness of the "Go" plug gage shall be allowed to wear until the chordal tooth thickness of the gage is equal to the minimum chordal space of the part to be checked minus the sum of the spacing error and twice the positive involute tolerance. This allows the gage a wear allowance of .0003. See Table 5.

5.1.3 The chordal tooth thickness of the "Not Go" plug gage shall be equal to the maximum chordal space of the part to be checked minus the sum of the spacing error and twice the positive involute tolerance. See Tables 2 and 6. The chordal tooth thickness of the "Not Go" plug gage shall have a positive tolerance.

5.1.4 The following example shows the method of determining the chordal tooth thickness of a plug gage:

Spline - 16 teeth, 8/16 diametral pitch, fit .002 to .006 loose,
 chordal space .1960 - .1980, pitch diameter 2.0000

"Go" Plug Gage

Minimum chordal space of part		.1960
Spacing error (Table 2)	.0002	
Twice positive involute tolerance (Table 2)	<u>+.0002</u>	
	.0004	<u>-.0004</u>
		.1956
Wear allowance		<u>+.0003</u>
Minimum chordal tooth thickness of gage		.1959
Tooth thickness tolerance (Table 2)	<u>+.0002</u>	
Chordal tooth thickness of "Go" plug gage		.1959-.1961

The "Go" plug gage shall be allowed to wear to .1956

"Not Go" Plug Gage (See Table 6)

Maximum chordal space of part		.1980
		<u>-.0004</u>
Minimum chordal tooth thickness of gage		.1976
Tooth thickness tolerance (Table 2)	<u>+.0002</u>	
Chordal tooth thickness of "Not Go" plug gage		.1976-.1978

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5.2 The size of the ring gage shall be established as follows:

- 5.2.1 The "Go" ring gage shall be made to fit a master plug gage, the chordal tooth thickness of which shall be equal to the maximum chordal tooth thickness of the part to be checked minus .0003 (wear allowance) and minus .0002 (chordal space tolerance or fitting allowance for the "Go" ring gage). See Figure 11. The chordal tooth thickness of the master plug gage for the "Go" ring gage shall have a negative tolerance. See Table 4 and Figure 11.
- 5.2.2 The "Go" ring gage shall be allowed to wear until it fits a master plug gage, the chordal tooth thickness of which shall be equal to the maximum chordal tooth thickness of the part to be checked. The tolerance on this tooth thickness is negative, as stated above. See Figure 11.
- 5.2.3 The "Not Go" ring gage shall be made to fit a master plug gage, the chordal tooth thickness of which shall be equal to the minimum chordal tooth thickness of the part to be checked. The spacing tolerance or fitting allowance for the "Not Go" ring gage shall be +.0002. See Figure 12. The chordal tooth thickness of the master plug gage for the "Not Go" ring gage shall have a negative tolerance. See Table 4 and Figure 12.
- 5.2.4 The following example shows the method of determining the chordal space of a ring gage made to fit a master plug gage:

Spline - 16 Teeth, 8/16 diametral pitch, pitch diameter 2.0000
chordal tooth thickness .1920-.1940

"Go" Master Plug Gage

Maximum chordal tooth thickness of part	.1940
Wear allowance	-.0003
	<u>.1937</u>
Fitting allowance for the "Go" ring gage	-.0002
Maximum chordal tooth thickness of gage	<u>.1935</u>
Tooth thickness tolerance (Table 4)	-.0002
Chordal thickness of gage at Section B-B, Figure 11	.1933-.1935
Chordal thickness of gage at Section A-A	.1938-.1940

The "Go" ring gage shall be made to fit these master plug dimensions.

"Not Go" Master Plug Gage

Minimum chordal tooth thickness of part	.1920
Tooth thickness tolerance (Table 4)	-.0002
Chordal thickness of gage at Section D-D, Figure 12	.1918-.1920
Fitting allowance for the "Not Go" ring gage	.0002
Chordal thickness of gage at Section C-C, Figure 12	.1920-.1922

The "Not Go" ring gage shall be made to fit these master plug dimensions.

- 5.3 Tables 9 thru 22 give gage dimensions with tolerances as calculated from the basic gage tooth dimensions specified in Table 1.



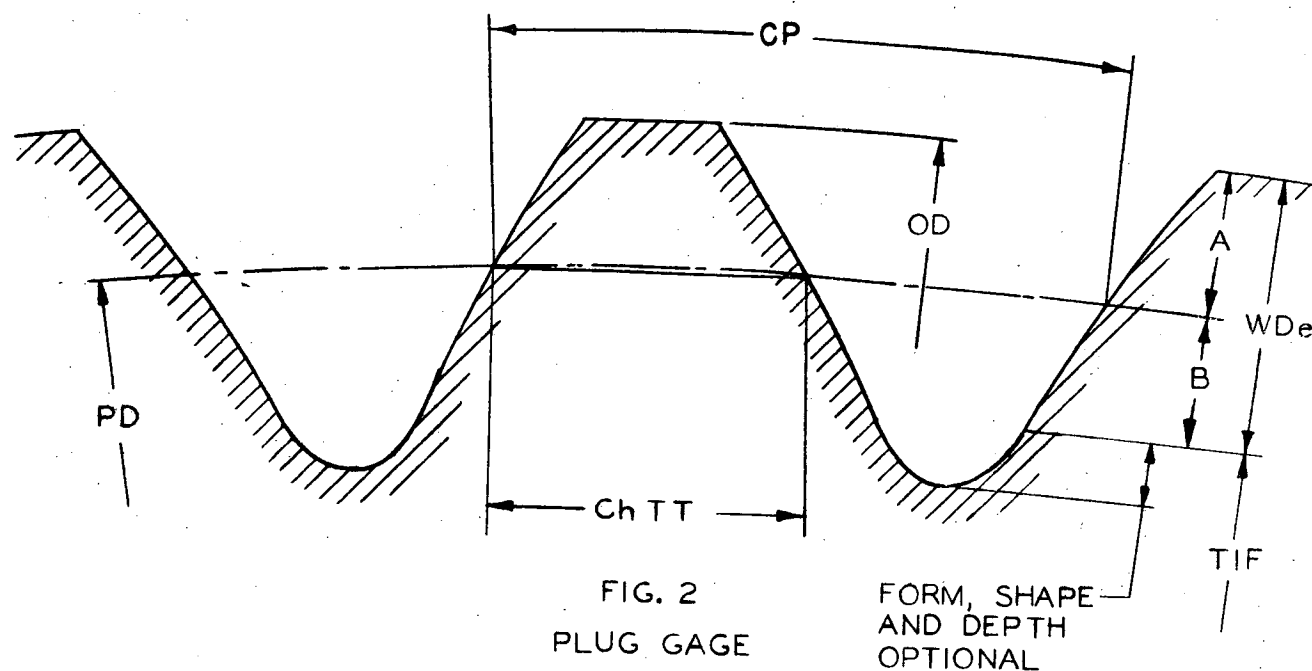
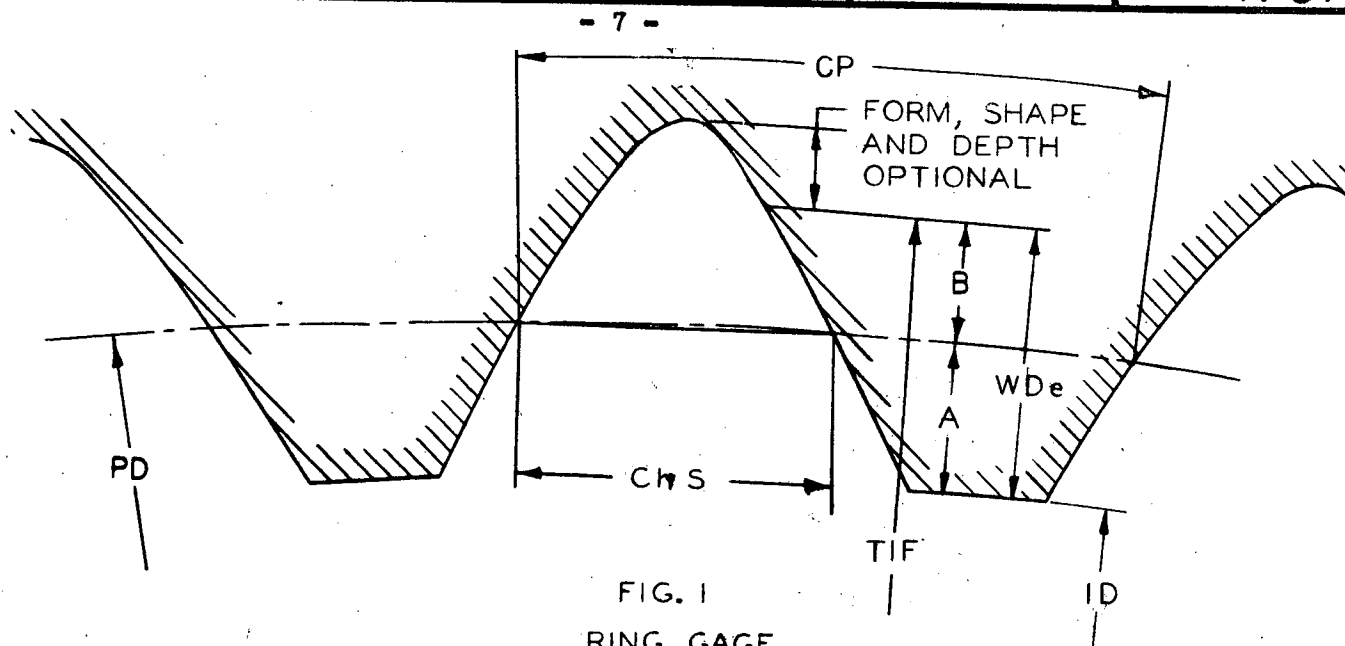
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6. TOLERANCES AND ALLOWANCES: The values listed in Tables 2, 3, 4, 5 and 6 are for average conditions and may be altered for very close or liberal part chordal tolerances.

7. GAGING SMALL QUANTITIES:

- 7.1 For experimental parts or small quantity manufacturing, the cost or time for obtaining complete plug and ring gages may be unjustifiable. It is likely to be of undiminished importance that the desired spline fit be obtained but it may be possible to sacrifice a certain amount of interchangeability. Gaging in some accurate manner is therefore still a necessity. Measurements over pins or with calipers are inconvenient and can give the difficulties from localized tight fitting referred to in 1.1. Two alternatives are often practiced. Since the external spline can be made and checked (with pins or otherwise) more easily, the external spline is finished first and then used as a plug gage for gaging the internal splines in the mating part. A second procedure is to cut a minimum number of gages from soft steel and to use these in an unhardened condition for the few parts required. Where a magnifying comparator is available, it may also provide a convenient way of checking small numbers of spline parts.
- 7.2 For gaging moderate quantities, it is possible to use "Go" spline plug and ring gages only, and to control the "Not Go" limits either by pin measurements or backlash checks with the "Go" spline gages.

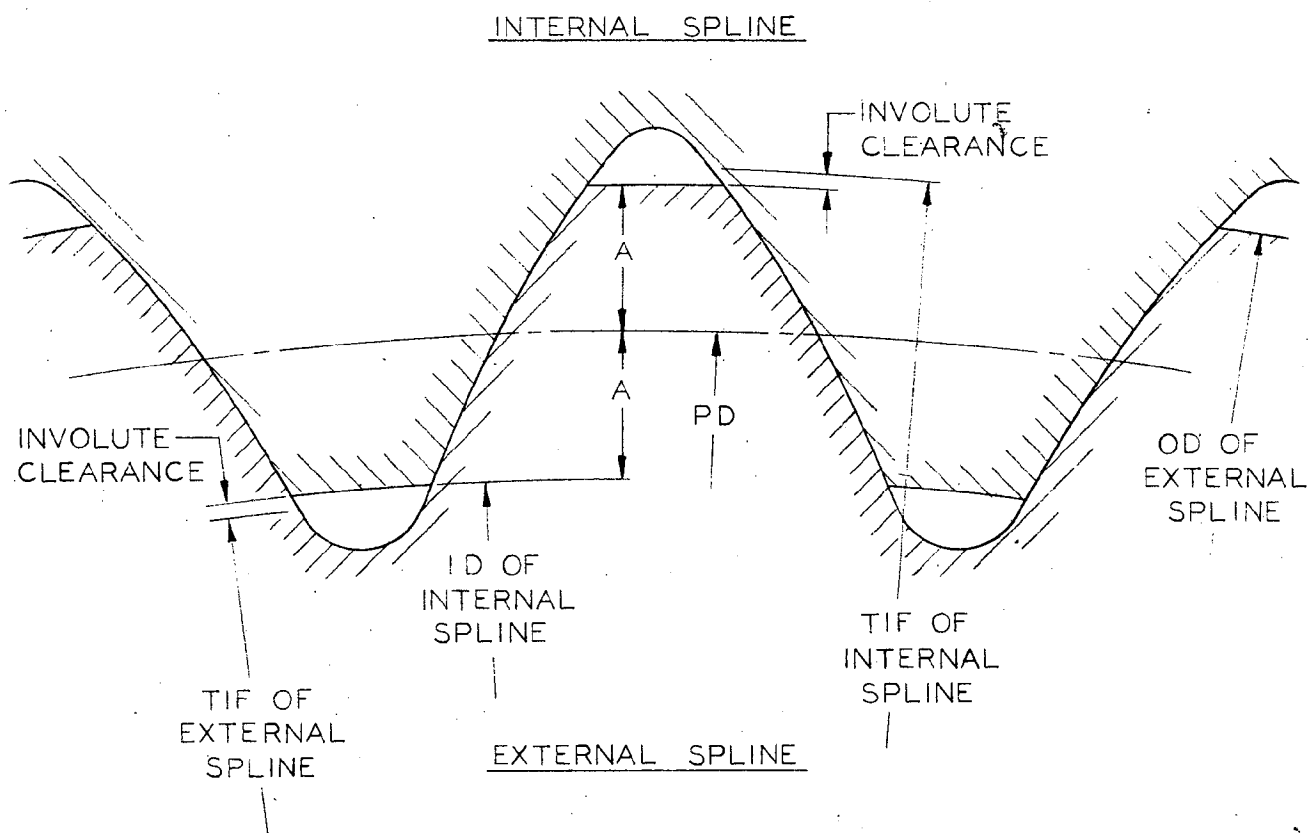


A = ADDENDUM
 B = ADDENDUM OF PART
 CP = CIRCULAR PITCH
 ChS = CHORDAL SPACE (RING)
 ChTT = CHORDAL TOOTH THICKNESS
 (PLUG)
 TIF = TRUE INVOLUTE FORM DIAMETER

WDe = WORKING DEPTH
 OD = OUTSIDE DIAMETER
 ID = INSIDE DIAMETER
 PD = PITCH DIAMETER

GAGE NOMENCLATURE

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THIS FIGURE ILLUSTRATES DATA PERTINENT TO INVOLUTE CLEARANCE ON SPLINES. WHEN PARTS ARE MADE WITH THIS CLEARANCE, THE ADDENDUM OF THE "GO" GAGES MUST BE INCREASED BY THE AMOUNT OF THIS CLEARANCE.

FIG. 3

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TABLE 1
BASIC GAGE TOOTH PROPORTIONS

DIAMETRAL PITCH	CIRCULAR PITCH	TYPE GAGE	ADDENDUM OF GAGE EXCEPT MASTER PLUG GAGE	ADDENDUM OF PART AND MASTER PLUG GAGE	WORKING DEPTH
2.5/5	1.2566	GO NOT GO	.2000 .1333	.2000 .2000	.4000 .3333
3/6	1.0472	GO NOT GO	.1667 .1111	.1667 .1667	.3333 .2778
4/8	.7854	GO NOT GO	.1250 .0833	.1250 .1250	.2500 .2083
5/10	.6283	GO NOT GO	.1000 .0667	.1000 .1000	.2000 .1667
6/12	.5236	GO NOT GO	.0833 .0556	.0833 .0833	.1667 .1389
8/16	.3927	GO NOT GO	.0625 .0417	.0625 .0625	.1250 .1042
10/20	.3142	GO NOT GO	.0500 .0333	.0500 .0500	.1000 .0833
12/24	.2618	GO NOT GO	.0417 .0278	.0417 .0417	.0833 .0694
16/32	.1963	GO NOT GO	.0312 .0208	.0312 .0312	.0625 .0521
20/40	.1571	GO NOT GO	.0250 .0167	.0250 .0250	.0500 .0417
24/48	.1309	GO NOT GO	.0208 .0139	.0208 .0208	.0417 .0347
32/64	.0982	GO NOT GO	.0156 .0104	.0156 .0156	.0312 .0260
40/80	.0785	GO NOT GO	.0125 .0083	.0125 .0125	.0250 .0208
48/96	.0654	GO NOT GO	.0104 .0069	.0104 .0104	.0208 .0174

The "GO" Gage must check the part to the true involute form diameter. The addendum of the "GO" Gages and subsequently the working depth, must be increased when involute clearances are required on the part, in order to check to the true involute form diameter.



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