METRIC AEROSPACE RECOMMENDED PRACTICE

MAP3439™ REV. A

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Superseding MAP3439

O-Ring Groove Design for Metric O-Ring Seals Used in Static Axial Compression Applications Specifically for Engine and Engine Control Systems

RATIONALE

This standard has been reformatted for ease of use, with no technical changes.

NOTE: This standard was transferred from the E-25 General Standards for Aerospace and Propulsion Systems Committee to the A-6C2 Seals Committee.

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1. SCOPE

This recommended practice provides the design criteria for static elastomeric O-ring seals used specifically in engine and engine control systems. It provides axial compression (face type) groove dimensions for aerospace metric O-ring sizes specified in MA2010. The conditions considered to formulate the design criteria are also described, e.g., seal squeeze and groove volume to accommodate O-ring swell.

NOTE: Tables of O-ring groove dimensions are included based on the design criteria specified herein. Dimensions in this document are in millimeters unless otherwise specified.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1231	Gland Design, Elastomeric O-Ring Seals, General Considerations
ARP1234	Static Axial O-Ring Seal Applications Without Anti-Extrusion Devices for Engine and Engine Control Systems
MA2010	Packing, Preformed - O-Ring Seal Standard Sizes and Size Codes, Metric

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ANSI B4.2	Preferred Metric Limits and Fits
ANSI Y14.36	Surface Texture Symbols

2.2 Symbols

Letter symbols used in this document are as follows:

d_1	O-ring inside diameter
d_2	O-ring cross-section diameter
d_7	Groove outside diameter, internal pressure
d_8	Groove inside diameter, external pressure
d_9	Plug diameter
d_{10}	Bore diameter, plug style
b	O-ring groove width
c	Diametral clearance between plug and bore

h	O-ring groove axial depth
h_{11}	Tolerance for d_8, See 3.6
H_{11}	Tolerance for d_7, See 3.6
max	Maximum
min	Minimum
r_1	Corner radius, the bottom of the groove
r_2	Edge radius, top of the groove
r_3	Fillet radius, plug style
tol	Tolerance
v_g	Volume of O-ring groove
v_o	Volume of O-ring in the free state (unsoaked and unstretched)

3. TECHNICAL REQUIREMENTS

3.1 General

The following static, radial squeeze, O-ring groove categories have been incorporated in this standard:

a. Rod mounted O-ring groove

b. Bore mounted O-ring groove

3.2 O-Rings

Figure 1 illustrates an O-ring and its dimensions; the inside diameters, cross-section diameters, and size codes are per MA2010.

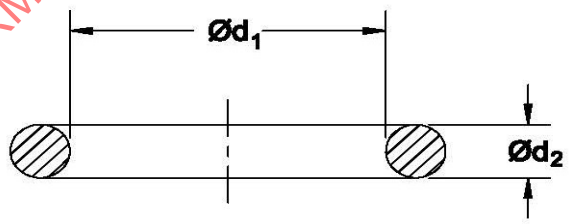

Figure 1 - O-ring dimensions

3.3 Typical Axial Compression (Face) Sealing

Figure 2 illustrates some typical axial compression O-ring sealing applications.

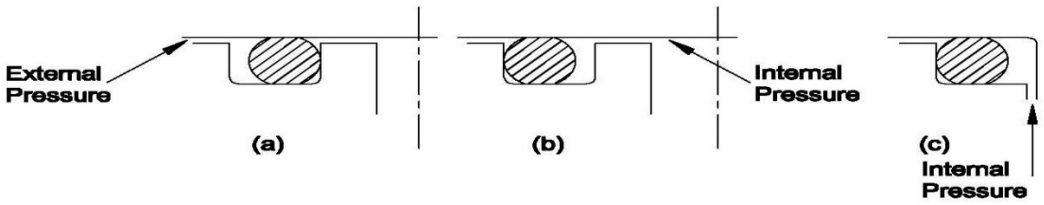

Figure 2 - O-ring face sealing application

3.4 Axial O-Ring Grooves

Figure 3 specifies the letter symbol dimensions for axial squeeze O-ring groove, internal pressure. Figure 4 specifies the letter symbol dimensions for axial squeeze O-ring groove, external pressure. The preferred configuration has a complete groove in one part, as in Figures 3 and 4, which minimizes the number of gaps through which the seal can extrude. The use of an O-ring groove with one wall missing should be used with a plug-style cover as in Figure 5 and is only applicable for internal applications.

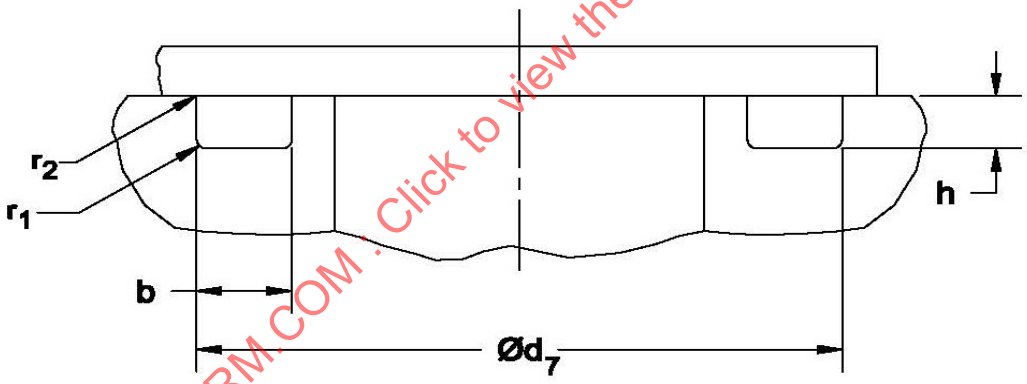

Figure 3 - Face seal groove dimensions, internal pressure

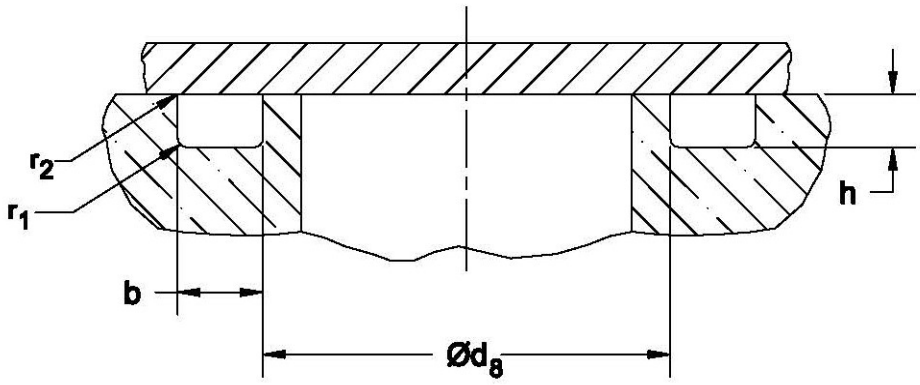

Figure 4 - Face seal groove dimensions, external pressure

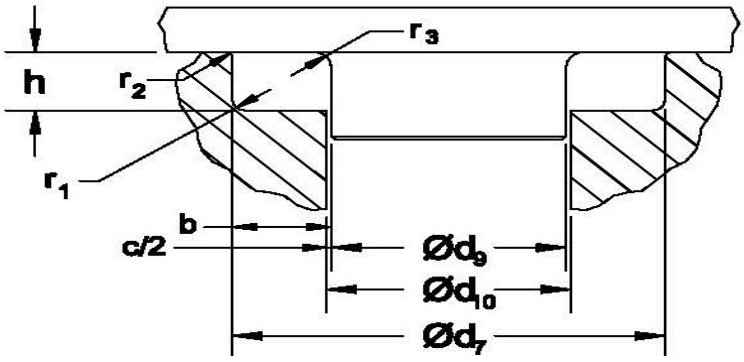

Figure 5 - Face seal groove dimensions, plug style, internal pressure applications only

3.5 Surface Roughness

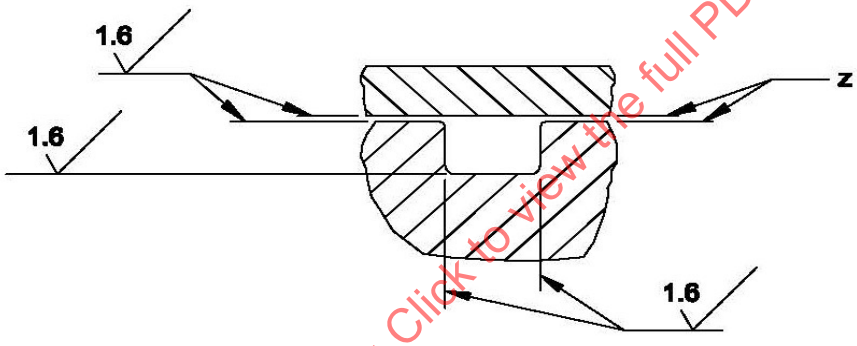

Figure 6 - Face seal groove, surface roughness requirements

3.6 Corner and Edge Radii and Fillet Radius

The corner radius (r_1) and edge radius (r_2) of the O-ring groove, and the fillet radius of the plug style O-ring gland shall be as specified in Table 1.

Table 1 - Groove corner and edge radii and fillet radius of plug style

d2 nom	r1 (corner)	r2 (edge)	r3 (fillet)
1.80	0.3-0.5	0.1-0.3	0.4-0.6
2.65	0.3-0.5	0.1-0.3	0.6-0.9
3.55	0.4-0.8	0.1-0.3	0.7-1.0
5.30	0.4-0.8	0.1-0.3	1.2-1.5
7.00	0.8-1.2	0.1-0.3	1.2-1.5

NOTE: Dimensions are in millimeters.

3.7 Groove Diameter Tolerance

The tolerance for O-ring groove diameter d_7 is H_{11} and for d_8 is h_{11} per ANSI B4.2.

3.8 Dimensions of Axial Groove

3.8.1 Groove Widths, b

The groove widths, b, are specified in Table 2. Tolerance is 0 to +0.25. The values were calculated and averaged to provide a groove volume not less than 115% of the max O-ring volume, and for most groove sizes the volume is 130% or more.

Table 2 - Groove widths, b

d2 nom	1.80	2.65	3.55	5.30	7.00
b	3.00	4.10	5.20	7.30	9.20

NOTE: Dimensions are in millimeters.

3.8.2 Groove Depths, h

The groove depths, h, are specified in Table 3. Tolerance is 0 to +0.10. The values were calculated to provide a nominal percent squeeze as in Table 4.

Table 3 - Groove depths, h

d2 nom	1.80	2.65	3.55	5.30	7.00
h	1.28	1.96	2.75	4.30	5.90

NOTE: Dimensions are in millimeters.

3.8.3 Derivation of Groove Dimensions

3.8.3.1 Diameters, d7 and d8

These diameters are such that the seals will be in contact with the groove wall away from the pressure side of the seal. Thus, the diameters are based on the following equations:

$$d_7 \text{ min} = d_1 \text{ nom} + 2d_2 \text{ nom (internal pressure)}$$
$$d_7 \text{ max} = d_7 \text{ min} + H_{11} \quad \text{(Eq. 1A)}$$

$$d_8 \text{ min} = d_1 \text{ nom (external pressure)}$$
$$d_8 \text{ max} = d_8 \text{ min} + h_{11} \quad \text{(Eq. 1B)}$$

3.8.3.2 Depth, h

The depth, h, is based on providing a nominal squeeze as specified in Table 4.

Table 4 - O-ring seal squeeze

d2 nom	Nom Squeeze % of d2 nom
1.80	26
2.65	24
3.55	21
5.30	18
7.00	15

NOTE: d2 nom in millimeters.

Thus, the depth is based on the following equations:

$$h\ nom = d_2\ nom - (d_2\ nom \times \%\ squeeze / 100)$$
$$h\ min = h\ nom - 0.05$$
$$h\ max = h\ nom + 0.05 \quad \text{(Eq. 2)}$$

The resulting limits for depth h and percentage squeeze are specified in Table 5.

Table 5 - Depth h and % squeeze

d2 nom	1.80	2.65	3.55	5.30	7.00
Depth, h	1.28- 1.38	1.96- 2.06	2.75- 2.85	4.30- 4.40	5.90- 6.00
% Squeeze	31.9 -19.8	28.5 -19.5	24.7 -17.4	20.8 -14.9	17.5 -12.4

NOTE: d2 nom in millimeters.

3.8.3.3 Width, b, Internal Pressure

To make allowances for O-ring seal swell by absorption of some amount of fluid that is in contact with the seal, the minimum volume of the O-ring groove was equated to 130% of the maximum O-ring volume in the unsoaked condition. Thus, the following equation is established:

$$v_g\ min = 1.3v_o\ max \quad \text{(Eq. 3)}$$

The volume of the maximum O-ring seal (unsoaked) is as follows:

$$v_o\ max = 2.4674\ (d_2\ max)^2(d_1\ max + d_2\ max) \quad \text{(Eq. 3A)}$$

The volume of the minimum O-ring groove is as follows:

$$v_g\ min = [h\ min \bullet b\ min - 0.4292(r_1\ max)^2](d_7\ min - b\ min)\pi \quad \text{(Eq. 3B)}$$

NOTE: Equation 3B applies to Figure 3 axial groove, internal pressure. The plug style, internal pressure groove in Figure 5 requires Equation 3B to be modified to take into effect the fillet radius r_3 max. However, it is not considered that this fillet radius will affect the groove volume in any significant way; thus, Equation 3B will be used to solve for b min.

Hence,

$$v_g\ min - 1.3v_o\ max = 0 \quad \text{(Eq. 3C)}$$

Let $Ar_1 = 0.4292(r_1\ max)^2$ and substituting Ar_1 in Equation 6.

Entering the results in Equation 7 for v_g min, the following results:

$$(h\ min \bullet b\ min - Ar_1)(d_7\ min - b\ min) - (1.3v_o\ max/\pi) = 0 \quad \text{(Eq. 4)}$$

Multiplying factors, Equation 8 becomes the following equation in quadratic form:

$$(b\ min)^2 - [d_7\ min + (Ar_1/h\ min)]\ b\ min + [(Ar_1 \bullet d_7\ min)/h\ min] \quad \text{(Eq. 5)}$$

Therefore, the root of Equation 9 becomes:

$$b\ min = 0.5d_7\ min + (Ar_1/2h\ min) - \{[0.5d_7\ min - (Ar_1/2h\ min)]^2 - (Ar_1 \bullet d_7\ min/h\ min) - (1.3v_o\ max/\pi h\ min)\}^{1/2} \quad \text{(Eq. 6)}$$

The groove width, b min, was calculated for a representative number of O-ring sizes of each cross-section O-ring and averaged to provide groove volumes that were not less than 115% of the max O-ring volume. Most groove sizes having widths as in 3.8.1 have groove volumes that are about 130% of the max O-ring volume.

3.8.3.4 Width, b, External Pressure

The equation for minimum groove volume is as follows:

$$v_g \text{ min} = [h \text{ min} \bullet b \text{ min} - 0.4292(r_1 \text{ max})^2](d_8 \text{ min} + b \text{ min})\pi \quad \text{(Eq. 7)}$$

In a similar manner as in 3.8.3.3, the equation for b min becomes:

$$b \text{ min} = -0.5d_8 \text{ min} + (Ar_1/2h \text{ min}) + \{[0.5d_8 \text{ min} - (Ar_1/2h \text{ min})]^2 + (Ar_1 d_8 \text{ min}/h \text{ min}) + (1.3v_o \text{ max}/\pi h \text{ min})\}^{1/2} \quad \text{(Eq. 8)}$$

The average calculated values for b min will be slightly less than those for internal pressure because the mid groove diameter (d8 min + b min) is greater than (d7 min - b min). For standardization, the groove widths computed for internal pressure are given under 3.8.1, Table 2, were adopted for the external pressure sealing grooves.

3.8.4 O-Ring Size Ranges

The O-ring sizes selected for use as axial compression (face) seals are shown in Table 6. Internal pressure groove dimensions are not provided for the smaller O-ring sizes in MA2010 because the O-ring groove inside diameter is too small to provide a practical bore size.

Table 6 - O-ring size code range

d2 nom	Internal Pressure	External Pressure
1.80	A0075-A1250	A0035-A1250
2.65	B0090-B2500	B0045-B2500
3.55	C0140-C3550	C0140-C3550
5.30	D0375-D2000	D0375-D2000
7.00	E1090-E4000	E1090-E4000

NOTE: d2 nom in millimeters.

3.8.5 Plug Style, Internal Pressure, Plug Diameter

The plug diameter, d9, is based on Equation 9:

$$d_9 \text{ min} = d_7 \text{ min} - 2b \text{ max}$$
$$d_9 \text{ max} = d_9 \text{ min} + \text{tol}$$

d_9 tol = 0.08 for size codes up to A0125
= 0.10 for size codes A0132 and up
= 0.13 for d_2 nom = 2.65
= 0.15 for d_2 nom = 3.55 and 5.30
= 0.20 for d_2 nom = 7.00 (Eq. 9)

3.8.6 Plug Style, Internal Pressure, Bore Dia

The bore diameter, d10, is based on Equation 10:

$$d_{10} \text{ max} = d_9 \text{ min} + c \text{ max}$$
$$d_{10} \text{ min} = d_{10} \text{ max} - \text{tol} \quad \text{(Eq. 10)}$$

d_{10} tolerance is the same as the d_9 tolerance. c max diametral clearance, see Table 7.

3.8.7 Clearances

Surfaces labeled “Z” in Figure 6 should be maintained as flat as possible, consistent with manufacturing requirements. In addition, the strength of the mating parts shall be sufficient to minimize distortion of the parts during operation. Distortion and lack of flatness can cause O-ring seal extrusion into the resulting gap between surfaces.

3.8.7.1 Plug-to-Bore Diametral Clearances

The plug-to-bore diametral clearances shown in Figure 5 must be held to a minimum to prevent seal damage in case of pressure reversal during operation. The maximum diametral clearance is specified in Table 7.

Table 7 - Plug style, diametral clearance

MA2010 O-Ring Size Code	d_2 nom	Diametral Clearance c max
A0075-A0125	1.80	0.20
A0132-A1250	1.80	0.25
B0090-B2500	2.65	0.31
C0140-C3550	3.55	0.40
D0375-D2000	5.30	0.46
E1090-E4000	7.00	0.61

NOTE: d2 nom in millimeters.

3.8.8 Groove Dimensions

Tables 8 through 12 provide dimensions for each size groove applicable to Figures 3 and 4 internal and external axial squeeze grooves. The groove dimensions for the plug-style groove are not listed in these tables; therefore, the dimensions will require the use of Equations 9 and 10.

Table 8 - O-ring seal axial (face) groove dimensions for d_2 nom = 1.80 mm

Groove Depth h = 1.28 - 1.38
Groove Width b = 3.00 - 3.25
Corner Radius r_1= 0.3 - 0.5
Edge Radius r_2 = 0.1 - 0.3
(Dimensions in millimeters)

O-Ring MA2010		Internal Pressure	External Pressure	O-Ring MA2010		Internal Pressure	External Pressure
Size Code	d1 nom	d7	d8	Size Code	d1 nom	d7	d8
A0035	3.55	---	3.55- 3.63	A0250	25.00	28.60- 28.73	25.00- 25.13
A0037	3.75	---	3.75- 3.83	A0258	25.80	29.40- 29.53	25.80- 25.93
A0040	4.00	---	4.00- 4.08	A0265	26.50	30.10- 30.26	26.50- 26.63
A0045	4.50	---	4.50- 4.58	A0280	28.00	31.60- 31.76	28.00- 28.13
A0048	4.87	---	4.87- 4.95	A0300	30.00	33.60- 33.76	30.00- 30.16
A0050	5.00	---	5.00- 5.08	A0315	31.50	35.10- 35.26	31.50- 31.66
A0051	5.15	---	5.15- 5.23	A0325	32.50	36.10- 36.26	32.50- 32.66
A0053	5.30	---	5.30- 5.38	A0335	33.50	37.10- 37.26	33.50- 33.66
A0056	5.60	---	5.60- 5.68	A0345	34.50	38.10- 38.26	34.50- 34.66
A0060	6.00	---	6.00- 6.09	A0355	35.50	39.10- 39.26	35.50- 35.66
A0063	6.30	---	6.30- 6.39	A0365	36.50	40.10- 40.26	36.50- 36.66
A0067	6.70	---	6.70- 6.79	A0375	37.50	41.10- 41.26	37.50- 37.66
A0069	6.90	---	6.90- 6.99	A0387	38.70	42.30- 42.46	38.70- 38.86
A0071	7.10	---	7.10- 7.19	A0400	40.00	43.60- 43.76	40.00- 40.16
A0075	7.50	11.10-11.21	7.50- 7.59	A0412	41.20	44.80- 44.96	41.20- 41.36
A0080	8.00	11.60-11.71	8.00- 8.09	A0425	42.50	46.10- 46.26	42.50- 42.66
A0085	8.50	12.10-12.21	8.50- 8.59	A0437	43.70	47.30- 47.46	43.70- 43.86
A0087	8.75	12.35-12.46	8.75- 8.84	A0450	45.00	48.60- 48.76	45.00- 45.16
A0090	9.00	12.60-12.71	9.00- 9.09	A0475	47.50	51.10- 51.29	47.50- 47.66
A0095	9.50	13.10-13.21	9.50- 9.59	A0500	50.00	53.60- 53.79	50.00- 50.19
A0100	10.00	13.60-13.71	10.00-10.09	A0530	53.00	56.60- 56.79	53.00- 53.19
A0106	10.60	14.20-14.31	10.60-10.71	A0560	56.00	59.60- 59.79	56.00- 56.19
A0112	11.20	14.80-14.91	11.20-11.31	A0600	60.00	63.60- 63.79	60.00- 60.19
A0118	11.80	15.40-15.51	11.80-11.91	A0630	63.00	66.60- 66.79	63.00- 63.19
A0125	12.50	16.10-16.21	12.50-12.61	A0670	67.00	70.60- 70.79	67.00- 67.19
A0132	13.20	16.80-16.91	13.20-13.31	A0710	71.00	74.60- 74.79	71.00- 71.19
A0140	14.00	17.60-17.71	14.00-14.11	A0750	75.00	78.60- 78.79	75.00- 75.19
A0150	15.00	18.60-18.73	15.00-15.11	A0800	80.00	83.60- 83.82	80.00- 80.22
A0160	16.00	19.60-19.73	16.00-16.11	A0850	85.00	88.60- 88.82	85.00- 85.22
A0170	17.00	20.60-20.73	17.00-17.11	A0900	90.00	93.60- 93.82	90.00- 90.22
A0180	18.00	21.60-21.73	18.00-18.13	A0950	95.00	98.60- 98.82	95.00- 95.22
A0190	19.00	22.60-22.73	19.00-19.13	A1000	100.00	103.60-103.82	100.00-100.22
A0200	20.00	23.60-23.73	20.00-20.13	A1060	106.00	109.60-109.82	106.00-106.22
A0212	21.20	24.80-24.93	21.20-21.33	A1120	112.00	115.60-115.82	112.00-112.22
A0224	22.40	26.00-26.13	22.40-22.53	A1180	118.00	121.60-121.85	118.00-118.22
A0236	23.60	27.20-27.33	23.60-23.73	A1250	125.00	128.60-128.85	125.00-125.25

Table 9 - O-ring seal axial (face) groove dimensions for d_2 nom = 2.65 mm

Groove Depth h = 1.96 - 2.06
Groove Width b = 4.10 - 4.35
Corner Radius r_1= 0.3 - 0.5
Edge Radius r_2 = 0.1 - 0.3
(Dimensions in millimeters)

O-Ring MA2010		Internal Pressure	External Pressure	O-Ring MA2010		Internal Pressure	External Pressure
Size Code	d_1 nom	d_7	d_8	Size Code	d_1 nom	d_7	d_8
B0045	4.50	---	4.50- 4.58	B0450	45.00	50.30- 50.49	45.00- 45.16
B0053	5.30	---	5.30- 5.38	B0462	46.20	51.50- 51.69	46.20- 46.36
B0060	6.00	---	6.00- 6.09	B0475	47.50	52.80- 52.99	47.50- 47.66
B0069	6.90	---	6.90- 6.99	B0487	48.70	54.00- 54.19	48.70- 48.86
B0080	8.00	---	8.00- 8.09	B0500	50.00	55.30- 55.49	50.00- 50.19
B0090	9.00	14.30-14.41	9.00- 9.09	B0515	51.50	56.80- 56.99	51.50- 51.69
B0095	9.50	14.80-14.91	9.50- 9.59	B0530	53.50	58.30- 58.49	53.00- 53.19
B0100	10.00	15.30-15.41	10.00-10.11	B0545	54.50	59.80- 59.99	54.50- 54.69
B0106	10.60	15.90-16.01	10.60-10.71	B0560	56.00	61.30- 61.49	56.00- 56.19
B0112	11.20	16.50-16.61	11.20-11.31	B0580	58.00	63.30- 63.49	58.00- 58.19
B0118	11.80	17.10-17.21	11.80-11.91	B0600	60.00	65.30- 65.49	60.00- 60.19
B0125	12.50	17.80-17.91	12.50-12.61	B0615	61.50	66.80- 66.99	61.50- 61.69
B0132	13.20	18.50-18.63	13.20-13.31	B0630	63.00	68.30- 68.49	63.00- 63.19
B0140	14.00	19.30-19.43	14.00-14.11	B0650	65.00	70.30- 70.49	65.00- 65.19
B0150	15.00	20.30-20.43	15.00-15.11	B0670	67.00	72.30- 72.49	67.00- 67.19
B0160	16.00	21.30-21.43	16.00-16.11	B0690	69.00	74.30- 74.49	69.00- 69.19
B0170	17.00	22.30-22.43	17.00-17.11	B0710	71.00	76.30- 76.49	71.00- 71.19
B0180	18.00	23.30-23.43	18.00-18.13	B0730	73.00	78.30- 78.49	73.00- 73.19
B0190	19.00	24.30-24.43	19.00-19.13	B0750	75.00	80.30- 80.52	75.00- 75.19
B0200	20.00	25.30-25.43	20.00-20.13	B0800	80.00	85.30- 85.52	80.00- 80.19
B0212	21.20	26.50-26.63	21.20-21.33	B0850	85.00	90.30- 90.52	85.00- 85.22
B0224	22.40	27.70-27.83	22.40-22.53	B0900	90.00	95.30- 95.52	90.00- 90.22
B0236	23.60	28.90-29.03	23.60-23.73	B0950	95.00	100.30-100.52	95.00- 95.22
B0250	25.00	30.30-30.46	25.00-25.13	B1000	100.00	105.30-105.52	100.00-100.22
B0258	25.80	31.10-31.26	25.80-25.93	B1060	106.00	111.30-111.52	106.00-106.22
B0265	26.50	31.80-31.96	26.50-26.63	B1120	112.00	117.30-117.52	112.00-112.22
B0280	28.00	33.30-33.46	28.00-28.13	B1180	118.00	123.30-123.55	118.00-118.22
B0300	30.00	35.30-35.46	30.00-30.16	B1250	125.00	130.30-130.55	125.00-125.25
B0315	31.50	36.80-36.96	31.50-31.66	B1320	132.00	137.30-137.55	132.00-132.25
B0325	32.50	37.80-37.96	32.50-32.66	B1400	140.00	145.30-145.55	140.00-140.25
B0335	33.50	38.80-38.96	33.50-33.66	B1500	150.00	155.30-155.55	150.00-150.25
B0345	34.50	39.80-39.96	34.50-34.66	B1600	160.00	165.30-165.55	160.00-160.25
B0355	35.50	40.80-40.96	35.50-35.66	B1700	170.00	175.30-175.55	170.00-170.25
B0365	36.50	41.80-41.96	36.50-36.66	B1800	180.00	185.30-185.59	180.00-180.29
B0375	37.50	42.80-42.96	37.50-37.66	B1900	190.00	195.30-195.59	190.00-190.29
B0387	38.70	44.00-44.16	38.70-38.86	B2000	200.00	205.30-205.59	200.00-200.29
B0400	40.70	45.30-45.46	40.00-40.16	B2120	212.00	217.30-217.59	212.00-212.29
B0412	41.20	46.50-46.66	41.20-41.36	B2240	224.00	229.30-229.59	224.00-224.29
B0425	42.50	47.80-47.96	42.50-42.66	B2360	236.00	241.30-241.59	236.00-236.29
B0437	43.70	49.00-49.16	43.70-43.86	B2500	250.00	255.30-255.62	250.00-250.32