



PISTON RINGS AND PISTONS—SAE J929a

SAE Standard

Report of Miscellaneous Division approved August 1916 and last revised by Engine Committee September 1976. Editorial change July 1977.

1. General—The following specifications are in general use and have been adopted as an SAE Standard. This standard is applicable to both conventional spark ignition, compression ignition engines, and compressors. It is intended to serve as a guide for new designs. Dimensions in this standard are expressed in inches.

It is recommended that cylinder diameter tolerance be specified as plus above the nominal diameter. Piston ring end clearance must be determined

from the minimum cylinder diameter. Piston ring and piston oversizes recommended for service installation are 0.020, 0.030, 0.040, and 0.060.

2. Material—Gray cast iron piston ring material is used for general automotive applications. Gray cast iron piston rings are made with a high carbon equivalent iron and with casting techniques that promote, in the small section castings, the most desirable graphite and matrix micro-structural conditions for wear resistance and adequate mechanical and physical properties. The

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TABLE 1—PIST N-RIN AND ROOVE WIDTHS UP T 8 DIA

Nominal Ring Width	Ring Widths ^a			Ring-Groove Widths									
	All Dia	Under 5 Dia	5 to 8 Dia	Compression-Ring Grooves				Ii-Ring Grooves ^b					
				Under 5 Dia		5 to 8 Dia, Inclusive		Under 5 Dia		5 to 8 Dia, Inclusive			
				Max	Min	Max	Min	Max	Min	Max	Min		
3/64	0.0470	0.0465	0.0460	0.0500	0.0490	—	—	—	—	—	—	—	—
1/16	0.0625	0.0620	0.0615	0.0655	0.0645	—	—	—	—	—	—	—	—
5/64	0.0780	0.0775	0.0770	0.0810	0.0800	—	—	—	—	—	—	—	—
3/32	0.0935	0.0930	0.0925	0.0965	0.0955	0.0970	0.0960	0.0960	0.0950	—	—	—	—
1/8	0.1240	0.1235	0.1230	0.1270	0.1260	0.1275	0.1265	0.1265	0.1255	—	—	—	—
5/32	0.1550	0.1545	0.1540	—	—	0.1585	0.1575	0.1575	0.1565	0.1580	0.1570	—	—
3/16	0.1865	0.1860	0.1855	—	—	0.1900	0.1890	0.1890	0.1880	0.1895	0.1885	—	—
1/4	0.2490	0.2485	0.2480	—	—	0.2525	0.2515	0.2515	0.2505	0.2520	0.2510	—	—

^a On side-coated compression rings subtract 0.0005 from minimum ring width. On side-coated oil rings add 0.0005 to maximum ring width.

^b On slotted grooves add 0.0005 to maximum groove width.

TABLE 2—PISTON-RING RADIAL WALL THICKNESS^a AND GROOVE-ROOT DIAMETERS FOR REGULAR WALL RINGS

D Cylindr Dia	T Max Ring Radial Wall Thickness	Max Ring Groove-Root Dia		D Cylindr Dia	T Max Ring Radial Wall Thickness	Max Ring Groove-Root Dia		D Cylindr Dia	T Max Ring Radial Wall Thickness	Max Ring Groove-Root Dia		D Cylindr Dia	T Max Ring Radial Wall Thickness	Max Ring Groove-Root Dia	
		A Compression Rings	A Oil Rings			A Compression Rings	A Oil Rings			A Compression Rings	A Oil Rings			A Compression Rings	A Oil Rings
1	0.046	0.876	0.842	2-3/4	0.127	2.452	2.419	4-1/2	0.189	4.065	4.035	6-1/4	0.247	5.687	5.658
1-1/16	0.049	0.932	0.898	2-13/16	0.130	2.507	2.475	4-9/16	0.191	4.123	4.093	6-5/16	0.249	5.746	5.716
1-1/8	0.052	0.988	0.954	2-7/8	0.133	2.564	2.532	4-5/8	0.193	4.182	4.151	6-3/8	0.251	5.803	5.776
1-3/16	0.055	1.044	1.010	2-15/16	0.136	2.619	2.587	4-11/16	0.195	4.239	4.209	6-7/16	0.253	5.861	5.832
1-1/4	0.058	1.100	1.066	3	0.139	2.676	2.644	4-3/4	0.197	4.298	4.267	6-1/2	0.255	5.919	5.891
1-5/16	0.061	1.156	1.122	3-1/16	0.141	2.734	2.702	4-13/16	0.199	4.355	4.325	6-9/16	0.257	5.978	5.949
1-3/8	0.064	1.212	1.179	3-1/8	0.143	2.793	2.760	4-7/8	0.201	4.414	4.383	6-5/8	0.259	6.036	6.007
1-7/16	0.067	1.268	1.234	3-3/16	0.145	2.850	2.818	4-15/16	0.203	4.471	4.441	6-11/16	0.261	6.094	6.065
1-1/2	0.069	1.326	1.293	3-1/4	0.147	2.908	2.876	5	0.205	4.530	4.500	6-3/4	0.263	6.152	6.123
1-9/16	0.072	1.382	1.349	3-5/16	0.149	2.966	2.934	5-1/16	0.207	4.588	4.558	6-13/16	0.265	6.210	6.181
1-5/8	0.075	1.439	1.405	3-3/8	0.151	3.024	2.992	5-1/8	0.209	4.646	4.616	6-7/8	0.267	6.268	6.239
11/16	0.078	1.494	1.461	3-7/16	0.153	3.082	3.050	5-3/16	0.211	4.704	4.674	6-15/16	0.269	6.326	6.297
1-3/4	0.081	1.551	1.517	3-1/2	0.155	3.140	3.109	5-1/4	0.214	4.761	4.730	7	0.271	6.384	6.356
1-13/16	0.084	1.606	1.573	3-9/16	0.157	3.198	3.167	5-5/16	0.216	4.818	4.788	7-1/16	0.273	6.443	6.414
1-7/8	0.087	1.663	1.630	3-5/8	0.159	3.257	3.225	5-3/8	0.218	4.877	4.846	7-1/8	0.275	6.500	6.472
1-15/16	0.090	1.718	1.685	3-11/16	0.162	3.312	3.281	5-7/16	0.220	4.934	4.904	7-3/16	0.277	6.559	6.530
2	0.093	1.775	1.742	3-3/4	0.164	3.371	3.339	5-1/2	0.222	4.992	4.962	7-1/4	0.280	6.614	6.586
2-1/16	0.096	1.831	1.798	3-13/16	0.166	3.428	3.397	5-9/16	0.224	5.051	5.021	7-5/16	0.282	6.673	6.644
2-1/8	0.098	1.889	1.856	3-7/8	0.168	3.487	3.456	5-5/8	0.226	5.109	5.079	7-3/8	0.284	6.730	6.702
2-3/16	0.101	1.945	1.912	3-15/16	0.170	3.544	3.515	5-11/16	0.228	5.167	5.137	7-7/16	0.286	6.789	6.760
2-1/4	0.104	2.001	1.968	4	0.172	3.603	3.572	5-3/4	0.230	5.225	5.195	7-1/2	0.288	6.846	6.819
2-5/16	0.107	2.057	2.024	4-1/16	0.174	3.661	3.630	5-13/16	0.232	5.283	5.253	7-9/16	0.290	6.905	6.877
2-3/8	0.110	2.113	2.080	4-1/8	0.176	3.719	3.688	5-7/8	0.234	5.341	5.311	7-5/8	0.292	6.963	6.935
2-7/16	0.113	2.169	2.136	4-3/16	0.178	3.777	3.746	5-15/16	0.236	5.399	5.369	7-11/16	0.294	7.021	6.993
2-1/2	0.116	2.225	2.193	4-1/4	0.180	3.835	3.804	6	0.238	5.457	5.428	7-3/4	0.296	7.079	7.051
2-9/16	0.119	2.281	2.249	4-5/16	0.182	3.893	3.862	6-1/16	0.240	5.516	5.486	7-13/16	0.299	7.135	7.107
2-5/8	0.122	2.338	2.305	4-3/8	0.184	3.951	3.920	6-1/8	0.243	5.571	5.542	7-7/8	0.301	7.193	7.165
2-11/16	0.125	2.393	2.361	4-7/16	0.186	4.009	3.978	6-3/16	0.245	5.630	5.600	7-15/16	0.303	7.251	7.223
												8	0.305	7.309	7.282

^a Allowable tolerance on ring thickness is 0.010 up to 5-1/2 dia, and 0.015 over 5-1/2 dia.

chemical element ranges shown represent typical chemical compositions for gray cast iron piston rings.

2.1 Elements:

- Total Carbon: 3.50-3.95
- Silicon: 2.20-3.10
- Manganese: 0.40-0.80
- Phosphorus: 0.30-0.80
- Sulfur: 0.13 max

Alloying elements such as chromium, copper, molybdenum, vanadium, tin, etc. may be added to enhance the material properties or improve the material for special applications.

2.2 Hardness—Rockwell B 95-107.

2.3 Microstructure—Gray cast iron piston rings are made to present an abrasion resistant matrix combined with the best graphite attainable in gray iron for mechanical and physical properties.

The matrix is essentially completely pearlitic or sorbitic with a minimum of free ferrite and massive cementite. The phosphorus constituent, steadite, is uniformly distributed in nonmassive particles.

The graphite will consist principally of randomly oriented flakes that are described as AFS-ASTM type A or A-B combination. The graphite particles will normally be of AFS-ASTM sizes 4-8.

3. End Clearance—Recommended end clearances for rings are given in Table 4.

4. Piston Ring Radial Wall and Groove Root Diameter—Recommended ring radial walls are shown in Tables 2 and 3.

Groove root diameters (Tables 2 and 3 and illustrated in Fig. 4) were calculated from the following formulas, which allow for normal piston land clearances, 0.010 maximum radii at the root of the grooves and 0.005 TIR eccentricity of the groove root. Interpolate for sizes not tabulated.

Compression ring grooves:

$$A = D - (2T + 0.007D + 0.025)$$

Oil grooves—Single piece and spring loaded:

$$A = D - (2T + 0.006D + 0.060)$$

Circumferential expander and segment type oil rings:¹

- A = D - 0.400 shallow groove
- A = D - 0.420 intermediate groove
- A = D - 0.450 deep groove
- D = 3.5 to 5.0 in

¹ Selection of groove root diameter is dependent on expander/segment design. Because of varying designs, it may be necessary to depart from the suggested shallow, intermediate, and deep grooves to prevent production assembly problems.

TABLE 3—PISTON RING RADIAL WALL THICKNESS AND RING END CLEARANCES FOR INTERMEDIATE WALL COMPRESSION RINGS

D Cylinder Dia	T Max Ring Radial Wall Thickness +0.000/ -0.010	A Max Ring Groove-Root Dia (Com- pression Rings Only)	D Cylinder Dia	T Max Ring Radial Wall Thickness +0.000/ -0.010	A Max Ring Groove-Root Dia (Com- pression Rings Only)
3	0.141	2.672	4-1/4	0.198	3.799
3-1/16	0.144	2.729	4-5/16	0.201	3.856
3-1/8	0.147	2.784	4-3/8	0.204	3.911
3-3/16	0.150	2.841	4-7/16	0.207	3.968
3-1/4	0.153	2.896	4-1/2	0.209	4.025
3-5/16	0.156	2.953	4-9/16	0.212	4.082
3-3/8	0.158	3.010	4-5/8	0.215	4.137
3-7/16	0.161	3.067	4-11/16	0.218	4.194
3-1/2	0.164	3.122	4-3/4	0.221	4.249
3-9/16	0.167	3.179	4-13/16	0.224	4.306
3-5/8	0.170	3.235	4-7/8	0.227	4.362
3-11/16	0.173	3.291	4-15/16	0.229	4.420
3-3/4	0.175	3.349	5	0.232	4.476
3-13/16	0.178	3.405	5-1/16	0.235	4.533
3-7/8	0.181	3.461	5-1/8	0.238	4.588
3-15/16	0.184	3.517	5-3/16	0.241	4.645
4	0.187	3.573	5-1/4	0.244	4.700
4-1/16	0.190	3.630	5-5/16	0.246	4.759
4-1/8	0.192	3.687	5-3/8	0.249	4.814
4-3/16	0.195	3.744	5-7/16	0.252	4.871
			5-1/2	0.255	4.926

* Maximum thickness is dia/22 +0.005.

TABLE 4—RING END CLEARANCES, in

Cylinder Diameter	End Clearance	Cylinder Diameter	End Clearance
1 to 1-31/32 inclusive	0.005 to 0.013	4 to 4-31/32 inclusive	0.013 to 0.023
2 to 2-31/32 inclusive	0.007 to 0.017	5 to 6-31/32 inclusive	0.017 to 0.032
3 to 3-31/32 inclusive	0.010 to 0.020	7 to 8 inclusive	0.023 to 0.040

* Compressor and sealing rings, depending upon the particular application, require special end clearances and tolerances.

TABLE 5—DIMENSIONS OF KEYSTONE RINGS (FIG. 1)

Nominal Ring Width	Min Groove and Max Ring Width, W
3/32	0.0935
1/8	0.1240
5/32	0.1550
3/16	0.1865
1/4	0.2490
5/16	0.3115
3/8	0.3740

TABLE 6—GROOVE DIMENSIONS

Nominal Groove Widths	3/32		1/8		5/32		Width Change Factor	Typical Mean Side Clearance	
	0.0935		0.1240		0.1550				
Min Groove Widths W at D _L	0.0935		0.1240		0.1550		D _x		
Nominal Angle Suggested Tol. +0 minutes/-15 minutes	P _d	D _L - D _p (min)	P _d	D _L - D _p (min)	P _d	D _L - D _p (min)			
Full Keystone	8 deg	0.0800	0.117	0.1100	0.093	0.1400	0.077	0.0143	0.0046
	15 deg	0.0700	0.108	0.1000	0.079	0.1300	0.055	0.0076	0.0070
	20 deg	0.0600	0.128	0.0900	0.098	0.1200	0.071	0.0057	0.0086
Half Keystone	7 1/2 deg	0.0800	0.128	0.1100	0.104	0.1400	0.087	0.0152	0.0044
	10 deg	0.0750	0.134	0.1050	0.108	0.1400	0.023	0.0113	0.0053

Note: Symbols in this Table are shown in Fig. 1.

TABLE 7—DIMENSIONAL X MAX VALUES FOR FRONT EDGE BEARING RINGS

Nominal Ring Widths	3/32		1/8		5/32		Width Change Factor
	0.0935		0.1240		0.1550		
Max Ring OD Width Equals Min Groove Width at D _L	0.0935		0.1240		0.1550		X _r
Nominal Angle +24 minutes -0 minutes	W _x	X max / X min	W _x	X max / X min	W _x	X max / X min	
Full Keystone	8 deg	0.0800	0.0919	0.1100	0.0953	0.1400	0.1021
	15 deg	0.0700	0.0812	0.1000	0.0846	0.1300	0.0914
	20 deg	0.0600	0.0869	0.0900	0.0888	0.1200	0.0925
Half Keystone	7 1/2 deg	0.0800	0.0812	0.1100	0.0831	0.1400	0.0868
	10 deg	0.0750	0.0931	0.1050	0.0945	0.1400	0.0973
			0.0888	0.0971	0.0930		

Note—Symbols in this Table are shown in Fig. 1.

For all ring grooves:

$$B = A - 0.010$$

Where:

- A = High limit for groove root diameter
- B = Low limit for groove root diameter
- D = Nominal cylinder diameter
- T = Maximum ring radial wall thickness

5. Rectangular Piston Ring and Groove Width—Recommended piston groove widths and ring widths are shown in Table 1. When deviations from Table 1 are made, they should be in the piston groove specification and not in the ring specification.

6. Keystone Piston Ring and Groove—Keystone rings are used to reduce ring sticking because of carbon and ash deposits on the rings and pistons. Side clearance, fit, and side seating geometry are generally affected by thermal and pressure deformation in the piston and also by piston cocking. The designer should take into consideration these variables to ensure that the ring will not stand *Proud* and carry piston side thrust loads or have insufficient or excessive side clearance. Typical mean cold side clearances are shown in Table 6. The approximate mean ring side clearance can be calculated by using the formula shown in Fig. 3. If it is found that the side clearance departs from the typical limits the design should be changed accordingly. Excessive side clearance can

cause ring breakage, scuffing, and groove wear. Insufficient side clearance can result in ring pinching and sticking. The following figures and tables are intended to serve as a guide; and if deviations are required, it is suggested that the formulae and definition in Figs. 1 and 3 should be utilized. In all cases of groove and ring dimensioning shown in Tables 6 and 7, the following tolerances are used:

SUGGESTED TOLERANCES

Groove angle (ϕ)	+0 -15 minutes	Groove Width	+0.0010 -0.000
Ring Side Angle (ϕ_b or ϕ_t)	± 12 minutes	Ring Width	+0.000 -0.0015

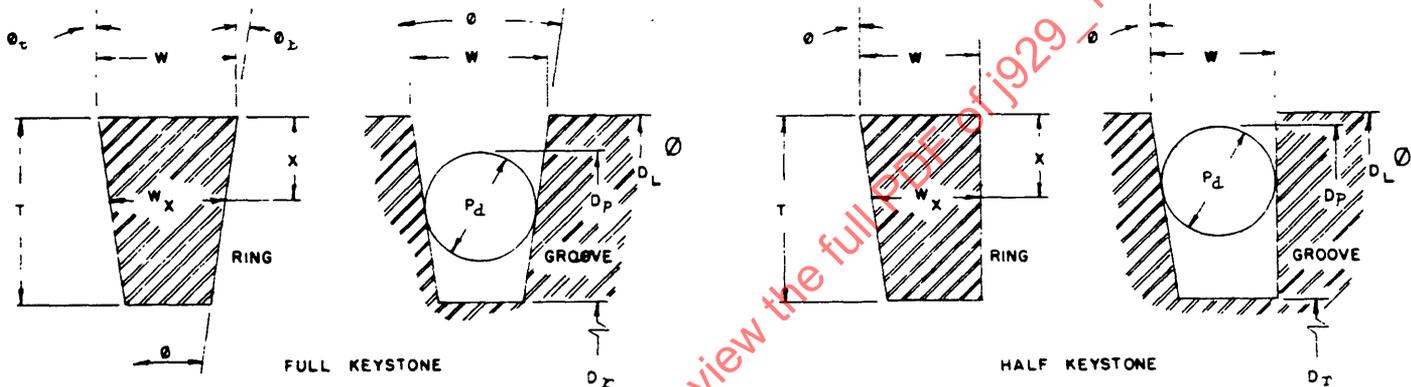
Ring Included Angle (ϕ) ± 12 minutes

Note—The tolerance of ring included angle (ϕ) may vary with ring cross section and engine design.

A description of terms and the necessary formula for ring and groove calculations is given in Fig. 1.

A description of types of fits utilized in Keystone set-up is given in Fig. 2.

6.1 Calculation of Keystone Piston Grooves—Table 6 depicts the groove dimensioning necessary to describe a Keystone groove. Where grooves are required which are not described, they can be calculated using the formula



DEFINITIONS:

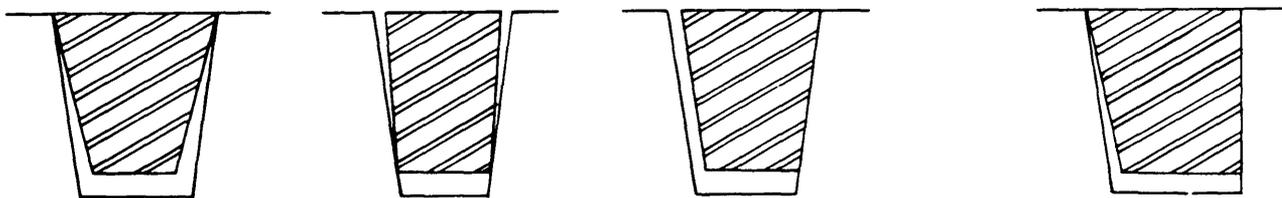
- ϕD_L = Diameter at which zero side clearance is present when ring face is flush with land diameter
- D_p = Max diameter over gage pins
- D_r = Groove root diameter
See Tables 2 or 3 as applicable
 D_r min = D_r max - 0.020
- D_x = Change in D_p for each 0.001 change in groove width
- ϕ = included angle
- ϕ_b = Bottom side angle of ring
- D_c = Nominal cylinder diameter
- ϕ_t = Top side angle of ring
- P_d = Diameter of gage pin or ball
- T = Max radial ring wall thickness
- ϕW = Min groove width at D_L ; max ring width at ring OD assuming zero side clearance
- X_r = Change in X for each 0.0015 change in ring width
- W_x = Gage width of ring
- X = Gage distance from ring OD
- X_{max} = Gage distance for max width ring
- X_{min} = Gage distance for min width ring
- D_p = Nominal diameter over gage pins

$$W = \left\{ \frac{P_d(\cos \phi_t + \cos \phi_b)}{2} \right\} + \left\{ \frac{\tan \phi_t [P_d(\sin \phi_t + 1) + (D_L - D_p)]}{2} \right\} + \left\{ \frac{\tan \phi_b [P_d(\sin \phi_b + 1) + (D_L - D_p)]}{2} \right\}$$

$$X = \frac{W - W_x}{2 \left(\frac{\tan \phi}{2} \right)} \quad \text{Full Keystone (Symmetrical Rings only)}$$

$$X = \frac{W - W_x}{\tan \phi} \quad \text{Half Keystone}$$

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 ϕ FIG. 1—KEYSTONE RING GROOVE DEFINITIONS AND FORMULAE



FRONT EDGE BEARING

Both nominal groove angles are less than nominal ring angles

BACK EDGE BEARING

Both nominal ring angles are less than nominal groove angles

FLUSH BEARING

Both nominal ring angles are equal to nominal groove angles

FRONT EDGE BEARING (HALF KEYSTONE)

Nominal groove angle is less than nominal ring angle

ϕ FIG. 2—KEYSTONE RING FIT TYPES

shown in Fig. 1. Piston Land Diameter (D_L) is determined by engine design and is a function of variables such as cylinder diameter, piston alloy, operating temperature, and land position and will determine operating groove to ring side clearance. After Piston Land Diameter (D_L) has been determined, use of the tables will produce ring and groove specifications having zero side clearance with the ring flush with the Piston Land Diameter (D_L).

Typical Example:

Given: Specify a groove for a $\frac{1}{8}$ in full Keystone 15 deg ring for a cylinder of 5.000. The designer has also determined that the minimum groove OD width of 0.1240 for $\frac{1}{8}$ in rings should be at a minimum D_L of 4.960. (This will also be the diameter at which zero side clearance is present when the ring face is flush to D_L).

To Find: The groove angle (ϕ), diameter of gage ball (P_d), diameter over gage pin (D_p), and groove root diameter (D_r).

1. Groove angle (ϕ); 15 deg +0 minutes/-15 minutes (Table 6)
2. Diameter of gage pin (P_d): 0.1000 (Table 6)
3. Maximum diameter over gage pin (D_p): This is calculated using the value of $D_L - D_p$ from Table 6 (0.079) and the given D_L of 4.960.

$$4.960 - 0.079 = 4.881 (D_p \text{ max})$$

The minimum value of D_p is dependent on the desired width tolerance (See Step 5).

4. Groove root diameter (D_r):

$D_r \text{ max}$ —See Table 2 or 3 as applicable

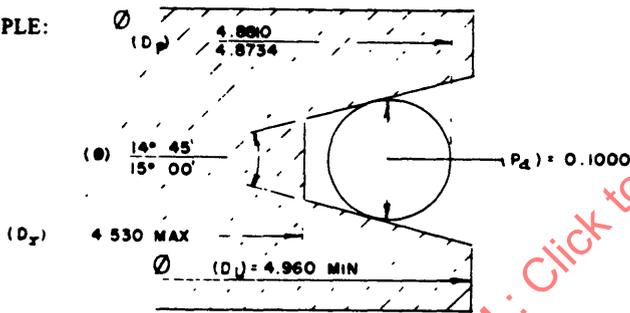
$D_r \text{ min} = D_r \text{ max} - 0.020$

$D_r \text{ max} = 4.530$ (From Table 2)

5. Groove width tolerance: The width change factor D_x shown in Table 6 is 0.0076 change in diameter over pins for each 0.001 of groove width change.

$$D_p \text{ min} = D_p \text{ max} - 0.0076 = 4.8810 - 0.0076 = 4.8734$$

EXAMPLE:



6.2 Calculation of Keystone Piston Rings—After grooves have been specified, it is first necessary to determine the type of fit desired as shown in Fig. 2, which establishes ring side angles. By using the proper formula, ring gage dimensions are then determined for the standard gage widths shown in Table 7. Table 7 in addition to showing the recommended standard gage widths also shows calculated ring gage dimensions ($X \text{ max}$ and $X \text{ min}$) for front edge bearing rings.

Calculation of X dimensions:

1. Front edge bearing rings
Full Keystone (Symmetrical Rings only)

$$X_{\text{max}} = \frac{W - W_x}{2 \left(\tan \frac{\phi_{\text{max}}}{2} \right)}$$

Half Keystone

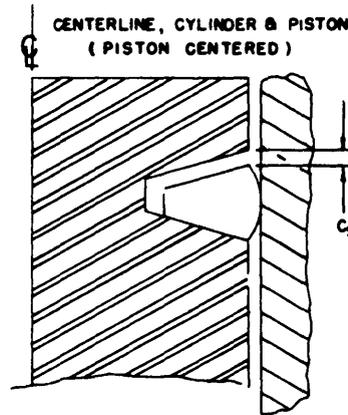
$$X_{\text{max}} = \frac{W - W_x}{\tan \phi_{\text{max ring side angle}}}$$

2. Back edge bearing rings
Full Keystone (Symmetrical Rings only)

$$X_{\text{max}} = \frac{W - 2(T) = \left[\tan \frac{\phi_{\text{max groove}}}{2} - \tan \left(\frac{\phi_{\text{min ring}}}{2} \right) \right] - W_x}{2 \left[\tan \left(\frac{\phi_{\text{min ring}}}{2} \right) \right]}$$

$X \text{ min}$ —Values of $X \text{ min}$ are calculated using the following formula:

$$X \text{ min} = X \text{ max} - X_r \text{ (See Table 7 for } X_r \text{)}$$



C_s = Approx. Mean Ring Side Clearance

$$\phi C_s = 0.0015 + (D_c - D_L) \left(\tan \frac{\phi}{2} \right)$$

FIG. 3—KEYSTONE RING SIDE CLEARANCE

3. Flush bearing rings—Perform $X \text{ max}$ calculations for back edge bearing and for front edge bearing rings (full Keystone only). Use the lower value of the two for flush bearing rings.

Typical Example:

Given: A 5.000 x $\frac{1}{8}$ in full Keystone Ring of front edge bearing to fit the groove example given previously. The minimum groove width (W) of 0.124 at D_L was previously determined.

To Find: The ring angles (ϕ), gage distance (X), gage width (W_x), and ring wall (T).

1. Ring Angles: In the case of front edge bearing the side angles of the ring are equal to and greater than the groove side angle. The maximum groove angle of 15 deg gives a 7 deg 30 min maximum on each side. The ring bottom side angle will be 7 deg 30 min minimum plus 24 min. Ring included angle will be 15 deg 0 min minimum plus 24 min.

2. Gage width (W_x)—(Directly from Table 7) 0.1000.

3. Gage distance $X \text{ max}$ —This value is calculated using the formulae shown with the included angles, and gage widths previously determined. Table 7 shows precalculated $X \text{ max}$ values for front edge bearing rings and the answer (0.0888) can be selected from Table 7.

4. Gage distance $X \text{ min}$ —This value is dependent on the required width tolerance (in this case the designer has selected 0.0015). Therefore the width change factor (X_r) can be used directly.

5. Radial Thickness (T)—Table 1 (0.205)

