DESIGN MANUAL

Bellofram®
DIAPHRAGM DIVISION
A HIGHER SEALING

belloframdiaphragm.com

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TABLE OF CONTENTS

"C" STYLE
Preconvoluted diaphragm. Convolution is molded into "as installed" shape.

CLASS
Description of the molded configuration of the diaphragm and its flange.

CONVOLUTION WIDTH C
The radial clearance between the cylinder wall and piston wall of the hardware.

CYLINDER BORE, D_C
Inside diameter of the cylinder into which the diaphragm will fit and function. *Note: this pertains to the hardware not the diaphragm.*

EFFECTIVE AREA, AE
Defined by a diameter halfway between the hardware cylinder bore and piston diameters. It may be calculated by this formula:

$$A_E = .7854 \left(D_C - \frac{D_C - D_P}{2}\right)^2$$

Effective area does not change regardless of stroke position as long as the diaphragm remains in a 180˚ convolution.

FLANGE
Outer portion of the diaphragm retained, supported or clamped by the hardware.

FLANGE CORNER RADIUS
The blend radius between the sidewall and flange of the diaphragm.

FLASH
A fine line of material projecting from the edge of a diaphragm, formed by the parting line or other openings in the mold. Cannot be completely removed by trimming.

HEAD
Area of the diaphragm retained against the piston head.

HEAD CORNER RADIUS
Blend radius between the head and sidewall of the diaphragm.

HEIGHT / STROKE LIMITS
Height of diaphragm necessary to obtain a particular stroke. Formulas for determining this relationship are as follows:

For "Top Hat" style diaphragms required height:

$$H = S_M + 2R_P + 1.56C + W_F + Z$$

For "C" Style Diaphragms:

Required Height: $K = 1/2\ (S_M + C + 2R_P + 2W_F)$

K – Height Of "C" Style BRD

S_M – Maximum Half Stroke; S_A Up Stroke; S_B Down Stroke

Z – Safety Factor Constant

W_F – Flange Thickness

H – Height Of "Top Hat" Style BRD

C – Convolution Width

R_P – piston corner radius

R_L – Cylinder Corner Radius

Cylinder Bore	.33/.99	1.00/2.50	2.51/4.00	4.01/8.00
Z	.060	.100	.120	.140

HEIGHT, H AND K
Height of the diaphragm (H for "Top Hat" or K for "C" style), is measured from bottom of flange to top of head (or convolution in "C" style). Height is measured from top of bead to top of head on class 1A & 1B type of diaphragms (does not include height of bead).

IDENTIFICATION
Diaphragms are identified by a Bellofram **ABC (Approximate Bellofram Code) part number.**

Example: **ABC# 4 – 200 – (181) – 100 – C B J – 1**
(4 = 1, 200 = 2, (181) = 3, 100 = 4, C = 5, B = 6, J = 7, 1 = 8)

1. Class of diaphragm
2. Cylinder bore (D_C) = 2.000 Dia.
3. Piston diameter (D_P) = 1.812" Dia.
   (Used only when non-standard DP is required and always placed in parentheses)
4. Height, H (or K in "C" style) 1.00"
5. Bellofram's designation for sidewall thickness
   (May also be a group of numbers)
6. Bellofram's designation for fabric. (May also be group of numbers or if no fabric put a dash in parentheses)
7. Bellofram's designation for elastomer. (May also be group of numbers)
8. -1 Designates that the diaphragm has special trim

PISTON DIAMETER D_P
Measured diametrically across the piston head.
Note: this pertains to the hardware, not the diaphragm.

PRESSURE DROP ACROSS DIAPHRAGM
The rolling diaphragm is designed to have the higher pressure acting on the Elastomer side, the pressure on the fabric side should always be less under all conditions of operations.

SIDEWALL THICKNESS, W_{SW}
Portion of the diaphragm between the head and flange, or between the head and beaded area.

STROKE
- **Neutral plane position (Fig. 5)** – The stroke capability of a diaphragm is usually calculated or specified using "neutral position" (neutral plane) as a basis. It is defined as that point in the stroke where the piston head is in the same plane as the clamping flange of the cylinder.
- **Half stroke (Fig. 6/Fig. 7)** – Many designs involve stroking the piston and diaphragm in only one direction from the neutral plane. "Halfstroke" is the term used to designate the stroke capability of the diaphragm under this condition. The half-stroke is designated as S_B if it strokes below neutral plane.
  (Fig. 7) – If a bonnet is used, the piston and diaphragm are allowed to stroke above the neutral plane, also. This portion of the diaphragm stroke capability is designated as S_A stroke above neutral plane.
- **Full stroke (Total Stroke)** – the full stroke capability of the diaphragm is the sum of the half strokes ($S_A + S_B = S_T$). S_T designates the total stroke.

TOP HAT
Diaphragm molded in familiar "hat" shape that is formed into a rolling convolution when assembled into the hardware

TRIM
Head and flange contour and perforations, made according to customer's design requirements or Bellofram standards (if not specified by customer).

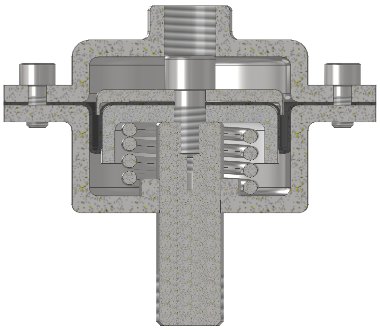


Fig. 5: Neutral Plane Position

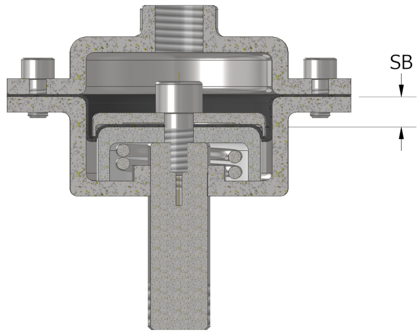


Fig. 6: Down-Stroke Position

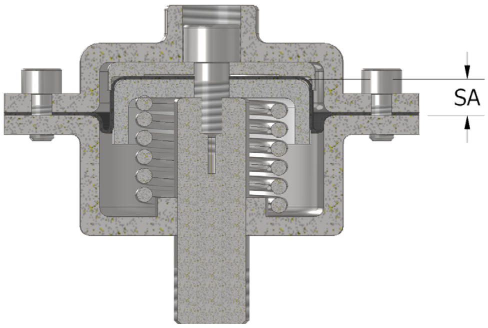
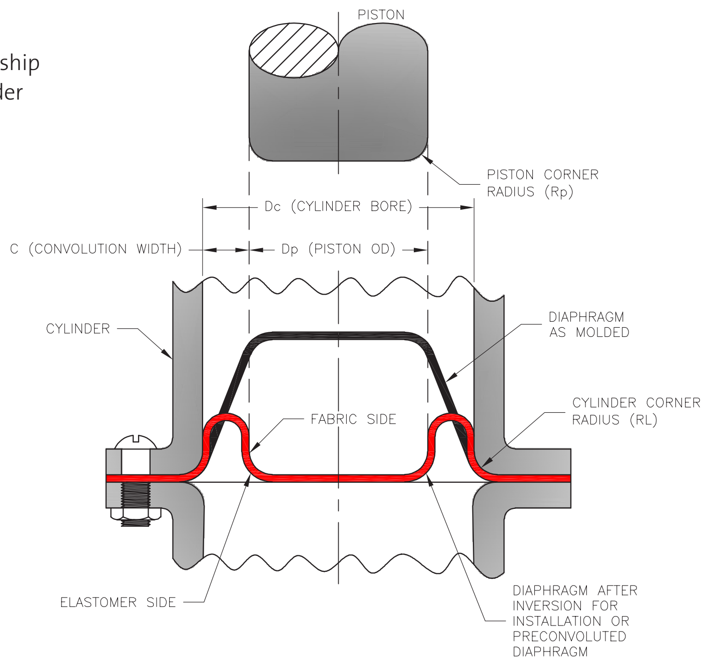


Fig. 7: Up-Stroke Position

Fig. 8: Dimensional Relationship of Diaphragm / Cylinder



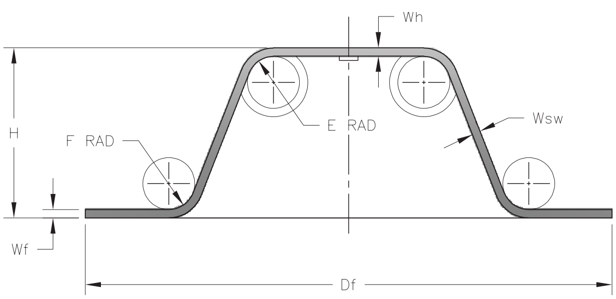


Fig. 9: Top Hat Diaphragm

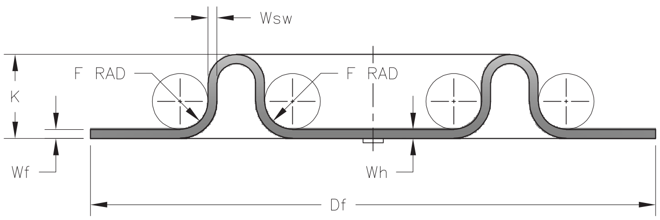


Fig. 10: Preconvoluted Diaphragm

E - HEAD CORNER RADIUS
F - FLANGE CORNER RADIUS
H - HEIGHT OF TOP HAT INCLUDING FLANGE THICKNESS
K - HEIGHT OF PRECONVOLUTION INCLUDING FLANGE THICKNESS

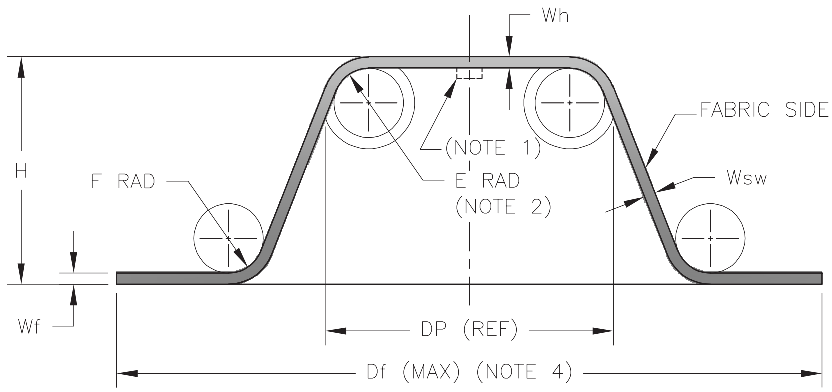
D_F - FLANGE DIAMETER
W_F - FLANGE THICKNESS
W_H - HEAD THICKNESS
W_{SW} - SIDEWALL THICKNESS

CLASS 4 DIAPHRAGMS

The Class 4 diaphragm is the most common type of rolling diaphragm. This type of diaphragm has a flat flange, which is designed to act as a gasket between hardware with flat mating surfaces. The flat gasket design keeps the fabric reinforcement layer tightly clamped between the mating surfaces, enabling the diaphragm to seal against high pressures. The flange can be trimmed with slots and/or bolt holes to match almost any hardware configuration. The amount of clamping pressure necessary to achieve a good seal is generally on the order of 1000 psi, but this can vary by application. Class 4 diaphragms are molded into a top-hat shape, which allows for long stroke lengths. In order to form the rolling convolution, this type of diaphragm must be inverted prior to installation. It is recommended to use a curved lip retainer plate to keep the head corner of the diaphragm in contact with the piston and prevent re-inversion during operation.

Dimensions and Tolerances

Diaphragms are shown in the “as molded” configurations. The diaphragm must be inverted prior to installation.



D_C	.25-.99	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
H	As required to yield design stroke (See standard size tables & Note 3)				
D_C / Dp	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"				
W_H & W_F	.020 ± .005	.020 ± .005	.030 ± .005	.035 ± .005	.045 ± .007
W_{SW}	.015 ± .003 (Code "B")	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
E	3/32 R	1/8 R	5/32 R	1/4 R	1/4 R
F	1/32 R	1/16 R	3/32 R	1/8 R	1/8 R
D_F	D_C + 3/4" See Note 4	D_C + 1" See Note 4	D_C + 1 1/2" See Note 4	D_C + 2" See Note 4	D_C + 2" See Note 4

NOTES

1. Stock diaphragms are supplied with a button on the pressure side 1/8" diameter x 3/32" high on bore sizes 1" and over.
2. This radius is not the piston radius since the head corner will be inverted at assembly.
3. Height should not exceed the bore (D_C). Tolerance on height to be no less than ±.015" or greater than ±.015" per inch of height.
4. Trim tolerances.
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00”	**±.010”**
1.01 - 3.01”	**±.015”**
over 3.01”	**±.020”**

5. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

Class 4 - Standard Sizes

Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
.37	.25	.31	B	.07	.060	.09
.50	.37	.37	B	.15	.062	.15
.62	.50	.50	B	.24	.062	.28
.75	.62	.62	B	.36	.065	.39
.75	.62	.62	.020	.36	.065	.39
.87	.75	.75	B	.51	.060	.53
1.00	.81	.44	C	.64	.095	.06
1.00	.81	.62	C	.64	.095	.24
1.00	.81	.81	C	.64	.095	.43
1.00	.81	1.00	C	.64	.095	.62
1.12	.94	.44	C	.83	.090	.07
1.12	.94	.69	C	.83	.090	.32
1.12	.94	.94	C	.83	.090	.57
1.12	.94	1.12	C	.83	.090	.75
1.25	1.06	.50	C	1.04	.095	.12
1.25	1.06	.75	C	1.04	.095	.37
1.25	1.06	1.00	C	1.04	.095	.62
1.25	1.06	1.25	C	1.04	.095	.87
1.37	1.19	.44	C	1.28	.090	.07
1.37	1.19	.56	C	1.28	.090	.19
1.37	1.19	.87	C	1.28	.090	.50
1.37	1.19	1.12	C	1.28	.090	.75
1.37	1.19	1.37	C	1.28	.090	1.00
1.50	1.31	.44	C	1.55	.095	.06
1.50	1.31	.62	C	1.55	.095	.24
1.50	1.31	.94	C	1.55	.095	.56
1.50	1.31	1.50	C	1.55	.095	1.12
1.62	1.44	.44	C	1.83	.090	.07
1.62	1.44	.69	C	1.83	.090	.32
1.62	1.44	1.00	C	1.83	.090	.63
1.62	1.44	1.37	C	1.83	.090	1.00
1.62	1.44	1.62	C	1.83	.090	1.25
1.75	1.56	.44	C	2.15	.095	.06
1.75	1.56	.75	C	2.15	.095	.37
1.75	1.56	1.06	C	2.15	.095	.68
1.75	1.56	1.44	C	2.15	.095	1.06
1.75	1.56	1.75	C	2.15	.095	1.37
2.00	1.81	.44	C	2.85	.095	.06
2.00	1.81	.81	C	2.85	.095	.43
2.00	1.81	1.25	C	2.85	.095	.87
2.00	1.81	1.62	C	2.85	.095	1.24
2.00	1.81	2.00	C	2.85	.095	1.62
2.25	2.06	.62	C	3.64	.095	.24
2.25	2.06	.94	C	3.64	.095	.56
2.25	2.06	1.37	C	3.64	.095	.99
2.25	2.06	1.81	C	3.64	.095	1.42

Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

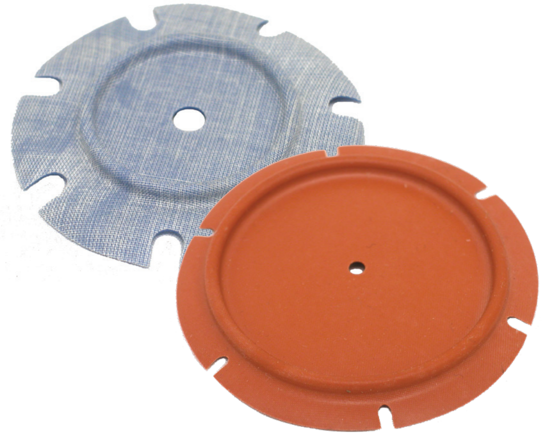
Class 4 - Standard Sizes Continued

Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
2.25	2.06	2.25	C	3.64	.095	1.87
2.50	2.31	.62	C	4.54	.095	.24
2.50	2.31	1.06	C	4.54	.095	.68
2.50	2.31	1.50	C	4.54	.095	1.12
2.50	2.31	2.00	C	4.54	.095	1.62
2.50	2.31	2.50	C	4.54	.095	2.12
2.75	2.44	1.12	D	5.28	.155	.57
2.75	2.44	1.62	D	5.28	.155	1.07
2.75	2.44	2.25	D	5.28	.155	1.70
2.75	2.44	2.75	D	5.28	.155	2.20
3.00	2.69	1.19	D	6.35	.155	.64
3.00	2.69	1.75	D	6.35	.155	1.20
3.00	2.69	2.37	D	6.35	.155	1.82
3.00	2.69	3.00	D	6.35	.155	2.45
3.25	2.94	1.94	D	7.52	.155	1.39
3.25	2.94	3.25	D	7.52	.155	2.70
3.50	3.19	1.00	D	8.78	.155	.45
3.50	3.19	2.12	D	8.78	.155	1.57
3.50	3.19	3.50	D	8.78	.155	2.95
3.75	3.44	1.00	D	10.15	.155	.45
3.75	3.44	2.25	D	10.15	.155	1.70
3.75	3.44	3.75	D	10.15	.155	3.20
4.00	3.69	1.00	D	11.61	.155	.45
4.00	3.69	2.44	D	11.61	.155	1.89
4.00	3.69	4.00	D	11.61	.155	3.45
4.50	4.00	1.00	F	14.18	.250	.22
4.50	4.00	2.75	F	14.18	.250	1.97
4.50	4.00	4.50	F	14.18	.250	3.72
5.00	4.50	1.00	F	17.72	.250	.22
5.00	4.50	3.00	F	17.72	.250	2.22
5.00	4.50	5.00	F	17.72	.250	4.22
5.50	5.00	1.12	F	21.64	.250	.34
5.50	5.00	3.37	F	21.64	.250	2.59
6.00	5.50	1.25	F	25.96	.250	.47
6.00	5.50	3.62	F	25.96	.250	2.84
6.00	5.50	6.00	F	25.96	.250	5.22
12.00	11.25	6.00	H	106.13	.375*	5.02

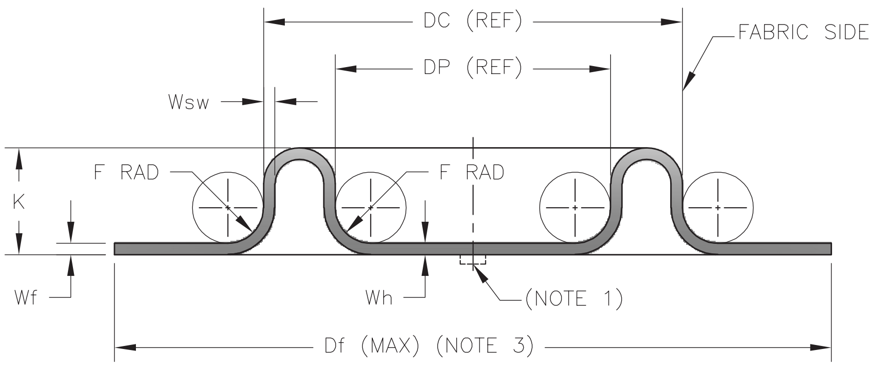
Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

CLASS 4C DIAPHRAGMS

The Class 4C diaphragm is similar to the Class 4, except the rolling convolution is molded in. The preconvoluted design simplifies the installation process, as the diaphragm does not need to be inverted prior to installation. A simple flat retainer plate can be used to fasten the diaphragm to the piston. Preconvoluted diaphragms are limited to short stroke lengths, since deep-molded convolutions are impractical to manufacture.



Dimensions and Tolerances



D_C	.26-.99	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
H	As required to yield design stroke (See standard size tables & Note 2)				
D_C	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"				
D_P					
W_H & W_F	.020 ± .003	.020 ± .004	.030 ± .004	.035 ± .005	.045 ± .007
W_{SW}	.015 ± .003 (Code "B")	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
F	1/32 R	1/16 R	3/32 R	1/8 R	1/8 R
D_F	D_C + 3/4" See Note 3	D_C + 1" See Note 3	D_C + 1 1/2" See Note 3	D_C + 2" See Note 3	D_C + 2" See Note 3

NOTES

1. Stock diaphragms are supplied with a button on the pressure side 1/8" diameter x 3/32" high on bore sizes 1" and over.
2. Trim tolerances.
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00”	**±.010”**
1.01 - 3.00”	**±.015”**
over 3.01”	**±.020”**

3. Height tolerances is ±.015
4. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

Class 4C - Standard Sizes

Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
.37	.25	.10	B	.07	.060	.07
.50	.37	.10	B	.14	.065	.07
.62	.50	.10	B	.24	.060	.07
.75	.62	.10	B	.36	.065	.07
.87	.75	.10	B	.51	.060	.07
1.00	.81	.15	C	.64	.095	.08
1.12	.94	.15	C	.83	.060	.08
1.25	1.06	.15	C	1.04	.095	.08
1.37	1.19	.15	C	1.28	.090	.08
1.50	1.31	.15	C	1.55	.095	.08
1.62	1.44	.15	C	1.83	.090	.08
1.75	1.56	.15	C	2.15	.095	.08
2.00	1.81	.15	C	2.85	.095	.08
2.25	2.06	.15	C	3.64	.095	.08
2.50	2.31	.15	C	4.54	.095	.08
2.75	2.44	.25	D	5.28	.155	.15
3.00	2.69	.25	D	6.35	.155	.15
3.25	2.94	.25	D	7.52	.155	.15
3.50	3.19	.25	D	8.78	.155	.15
3.75	3.44	.25	D	11.15	.155	.15
4.00	3.69	.25	D	11.61	.155	.15
4.25	3.75	.37	F	12.56	.250	.24
4.50	4.00	.37	F	14.18	.250	.24
5.00	4.50	.37	F	17.72	.250	.24
5.50	5.00	.37	F	21.64	.250	.24
5.75	5.25	.37	F	23.75	.250	.24
6.00	5.50	.37	F	25.96	.250	.24
6.50	6.00	.37	F	30.67	.250	.24
7.00	6.50	.37	F	35.78	.250	.24
7.50	7.00	.37	F	41.28	.250	.24
8.00	7.50	.37	F	47.17	.250	.24

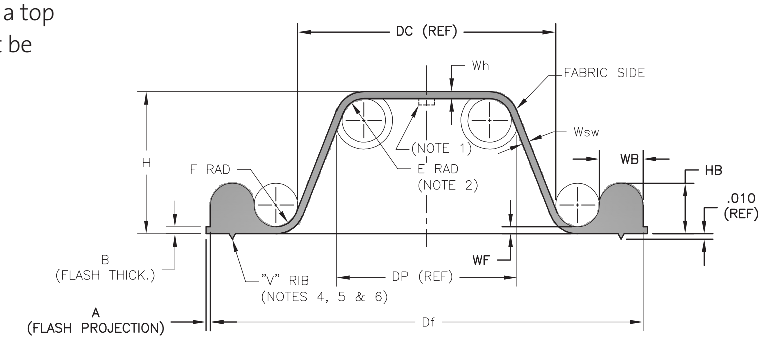
Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

CLASS 3 DIAPHRAGMS

The Class 3 diaphragm has a "D" shaped bead around its circumference, which seals the outer diameter of the diaphragm by axial compression, much like an O-ring. This type of diaphragm allows for simple, economical hardware design, as well as simple installation processes. This type of design is generally not recommended in applications where differential pressures exceed 150 psi, since large sidewall stresses can cause the bead to lose some of its effectiveness. Class 3 diaphragms are molded into a top hat shape, which allows for long stroke lengths. The diaphragm must be inverted prior to installation in order to form the rolling convolution, and a curved lip retainer plate is recommended.

Dimensions and Tolerances

Diaphragms are shown in the "as molded" configurations. The diaphragm must be inverted prior to installation.



D_C	.37-.99	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
H	As required to yield design stroke (See standard size tables & Note 3)				
D_C	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"				
Dp					
W_H & W_F	.020 ± .005	.020 ± .005	.030 ± .005	.035 ± .005	.045 ± .007
W_{SW}	.015 ± .003 (Code "B")	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
A	.025 Max.	.025 Max	.035 Max.	.040 Max	.056 Max
B	.025 Max.	.025 Max	.035 Max.	.040 Max	.056 Max
E	3/32 R	1/8 R	5/32 R	1/4 R	1/4 R
F	1/32 R	1/16 R	3/32 R	1/8 R	1/8 R
D_F	D_C + 5/16"	D_C + 1/2"	D_C + 3/4"	D_C + 1"	D_C + 1"
W_B	.094 ± .003	.125 ± .003	.187 ± .003	.250 ± .003	.250 ± .004
H_B	.095 ± .004	.135 ± .004	.200 ± .005	.270 ± .007	.270 ± .008

NOTES

1. Stock diaphragms are supplied with a button on the pressure side 1/8" diameter x 3/32" high on bore sizes 1" and over.
2. This radius is not the piston radius since the head corner will be inverted at assembly.
3. Height should not exceed the bore (D_C). Tolerance on height to be no less than ±.015" or greater than ±.015" per inch of height.
4. This "V" rib is for diaphragm processing only. It may not appear on all diaphragms. It is not functional and need not be completely filled. Rib is normally on rubber side of diaphragm.
5. Two "V" ribs may be used on beads that are .25 or larger in width.
6. Number, size, spacing and location of "V" ribs may be modified to suit specific beads, or may be left off altogether.
7. Trim tolerances.
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00"	**±.010"**
1.01 - 3.00"	**±.015"**
over 3.00"	**±.020"**

8. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

Class 3 - Standard Sizes

Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
.37	.25	.31	B	.07	.060	.09
.50	.37	.38	B	.14	.065	.15
.62	.50	.50	B	.24	.060	.28
.75	.62	.62	B	.36	.065	.39
.87	.75	.75	B	.51	.060	.53
1.00	.81	.44	C	.64	.095	.06
1.00	.81	.62	C	.64	.095	.24
1.00	.81	.81	C	.64	.095	.43
1.00	.81	1.00	C	.64	.095	.62
1.12	.94	.44	C	.83	.090	.07
1.12	.94	.69	C	.83	.090	.32
1.12	.94	.84	C	.83	.090	.57
1.12	.94	1.12	C	.83	.090	.75
1.25	1.06	.50	C	1.04	.095	.12
1.25	1.06	.75	C	1.04	.095	.37
1.25	1.06	1.00	C	1.04	.095	.62
1.25	1.06	1.25	C	1.04	.095	.87
1.37	1.19	.44	C	1.28	.090	.07
1.37	1.19	.56	C	1.28	.090	.19
1.37	1.19	.87	C	1.28	.090	.50
1.37	1.19	1.12	C	1.28	.090	.75
1.37	1.19	1.37	C	1.28	.090	1.00
1.50	1.31	.44	C	1.55	.095	.06
1.50	1.31	.62	C	1.55	.095	.24
1.50	1.31	.94	C	1.55	.095	.56
1.50	1.31	1.50	C	1.55	.095	1.12
1.62	1.44	.44	C	1.83	.090	.07
1.62	1.44	.69	C	1.83	.090	.32
1.62	1.44	1.00	C	1.83	.090	.63
1.62	1.44	1.37	C	1.83	.090	1.00
1.62	1.44	1.62	C	1.83	.090	1.25
1.75	1.56	.44	C	2.15	.095	.06
1.75	1.56	.75	C	2.15	.095	.37
1.75	1.56	1.06	C	2.15	.095	.68
1.75	1.56	1.44	C	2.15	.095	1.06
1.75	1.56	1.75	C	2.15	.095	1.37
2.00	1.81	.44	C	2.85	.095	.06
2.00	1.81	.81	C	2.85	.095	.43
2.00	1.81	1.25	C	2.85	.095	.87
2.00	1.81	1.62	C	2.85	.095	1.24
2.00	1.81	2.00	C	2.85	.095	1.62
2.25	2.06	.62	C	3.64	.095	.24
2.25	2.06	.94	C	3.64	.095	.56
2.25	2.06	1.37	C	3.64	.095	.99
2.25	2.06	1.81	C	3.64	.095	1.43
2.25	2.06	2.25	C	3.64	.095	1.87

Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

Class 3 - Standard Sizes

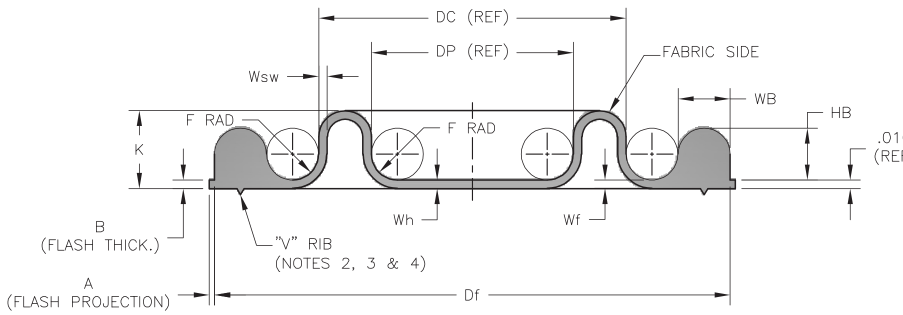
Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
2.50	2.31	1.06	C	4.54	.095	.68
2.50	2.31	2.00	C	4.54	.095	1.62
2.50	2.31	2.50	C	4.54	.095	2.12
2.75	2.44	1.12	D	5.28	.155	.57
2.75	2.44	1.62	D	5.28	.155	1.07
2.75	2.44	2.25	D	5.28	.155	1.70
2.75	2.44	2.75	D	5.28	.155	2.20
3.00	2.69	1.19	D	6.35	.155	.64
3.00	2.69	1.75	D	6.35	.155	1.20
3.00	2.69	2.37	D	6.35	.155	1.82
3.00	2.69	3.00	D	6.35	.155	2.45
3.25	2.94	1.94	D	7.52	.155	1.39
3.50	3.19	1.00	D	8.78	.155	.45
3.50	3.19	2.12	D	8.78	.155	1.57
3.50	3.19	3.50	D	8.78	.155	2.95
3.75	3.44	1.00	D	10.15	.155	.45
3.75	3.44	2.25	D	10.15	.155	1.70
3.75	3.44	3.75	D	10.15	.155	3.20
4.00	3.69	1.00	D	11.61	.155	.45
4.00	3.69	2.44	D	11.61	.155	1.89
4.00	3.69	4.00	D	11.61	.155	3.45
4.50	4.00	1.00	F	14.18	.250	.22
4.50	4.00	2.75	F	14.18	.250	1.97
4.50	4.00	4.50	F	14.18	.250	3.72
5.00	4.50	1.00	F	17.72	.250	.22
5.00	4.50	3.00	F	17.72	.250	2.22
5.00	4.50	5.00	F	17.72	.250	4.22
5.50	5.00	1.12	F	21.64	.250	.34
5.50	5.00	3.37	F	21.64	.250	2.59
5.50	5.00	5.50	F	21.64	.250	4.72
6.00	5.50	1.25	F	25.96	.250	.47
6.00	5.50	3.62	F	25.96	.250	2.84

Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

CLASS 3C DIAPHRAGMS

The Class 3C diaphragm is a preconvoluted version of the Class 3. Just like the Class 3, the Class 3C has a “D” shaped bead around its circumference, which is sealed by axial compression. The same recommendation of a maximum differential pressure of 150 psi also applies to this design. Since this type of diaphragm is preconvoluted, it does not need to be inverted prior to installation, and a flat retainer plate can be used.

Dimensions and Tolerances



D_C	.37-.99	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
K	As required to yield design stroke (See standard size tables & Note 1)				
D_C	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"				
Dp					
W_H & W_F	.020 ± .003	.020 ± .004	.030 ± .004	.035 ± .005	.045 ± .007
W_{SW}	.015 ± .003 (Code "B")	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
A	.025 Max.	.025 Max	.035 Max.	.040 Max	.056 Max
B	.025 Max.	.025 Max	.035 Max.	.040 Max	.056 Max
F	1/32 R	1/16 R	3/32 R	1/8 R	1/8 R
D_F	D_C + 5/16"	D_C + 1/2"	D_C + 3/4"	D_C + 1"	D_C + 1"
W_B	.093 ± .003	.125 ± .003	.187 ± .003	.250 ± .003	.250 ± .004
H_B	.094 ± .004	.135 ± .004	.200 ± .005	.270 ± .006	.270 ± .008

NOTES

1. Height tolerances is ±.015”
2. This “V” rib is for diaphragm processing only and it may not appear on all diaphragms. It is not functional and need not be completely filled. Rib is normally on rubber side of diaphragm.
3. Two “V” ribs may be used on beads that are .25 or larger in width.
4. Number, size, spacing and location of “V” ribs may be modified to suit specific beads, or may be left off altogether.
5. Trim tolerances.
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00”	**±.010”**
1.01 - 3.00”	**±.015”**
over 3.01”	**±.020”**

6. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

Class 3C - Standard Sizes

Cylinder Bore D_C	Piston Diameter Dp	Height K	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
.37	.25	.12	B	.07	.062	.11
.69	.32	.21	.014	.19	.183*	.17
.91	.72	.15	.015	.52	.095*	.14
1.00	.75	.16	C	.60	.125*	.07
1.12	.93	.15	C	.83	.094	.08
1.37	1.18	.15	C	1.28	.094	.08
1.50	1.31	.15	C	1.55	.094	.08
1.75	1.56	.15	C	2.15	.094	.08
1.18	1.00	.15	C	.93	.094	.08
2.00	1.81	.15	C	2.85	.094	.08
2.25	2.06	.15	C	3.65	.094	.20
2.37	2.18	.15	C	4.07	.091	.08
2.50	2.31	.15	C	4.54	.095	.08
3.00	2.69	.25	D	6.35	.155	.15
4.25	3.75	.37	F	12.56	.250	.24
6.00	5.50	.37	.035	25.96	.250	.24
6.75	6.25	.38	F	33.18	.250	.26
7.50	7.00	.38	F	41.28	.250	.24
8.00	7.50	.37	.035	47.17	.250	.24

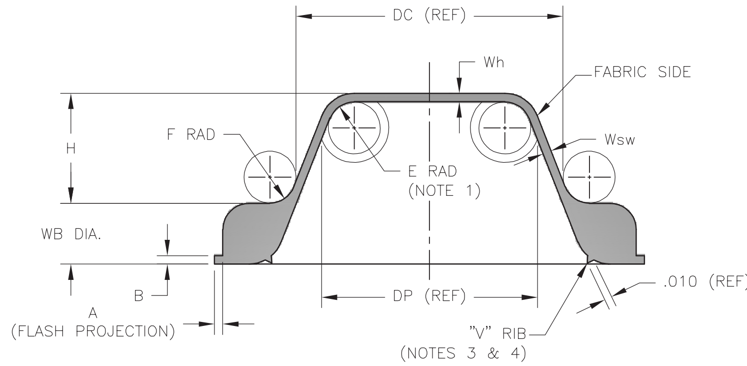
Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

CLASS 1A DIAPHRAGMS

The Class 1A diaphragm has an O-ring type bead around the base of its sidewall, which allows for low-profile hardware design. This diaphragm is a top hat design, which allows for long stroke lengths. The head corner must be inverted prior to installation, and it is recommended to use a curved lip retainer plate. The same recommendation of a maximum differential pressure of 150 psi also applies to this design.

Dimensions and Tolerances

Diaphragms are shown in the "as molded" configurations. The diaphragm must be inverted prior to installation.



D_C	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
H	As required to yield design stroke (See standard size tables & Note 2)			
D_C	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"			
Dp				
W_H	.020 ± .005	.030 ± .005	.035 ± .005	.045 ± .007
W_{SW}	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
A	.025 Max.	.035 Max	.040 Max.	.056 Max
B	.025 Max.	.035 Max	.040 Max.	.056 Max
E	1/16 R	3/32 R	1/8 R	1/8 R
F	1/32 R	3/64 R	1/16 R	1/16 R
W_B Dia.	.121 ± .005	.151 ± .005	.242 ± .010	.242 ± .010

NOTES

1. This radius is not the piston radius since the head corner will be inverted at assembly
2. Height should not exceed the bore (D_C). Tolerance on height to be no less than ±.015" per inch of height.
3. This "V" rib is for diaphragm processing only. It may not appear on all diaphragms. It is not functional and need not be completely filled. Rib is normally on rubber side of diaphragm.
4. Number, size, spacing and location of "V" ribs may be modified to suit specific beads, or may be left off altogether.
5. Trim tolerances.
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00"	**±.010"**
1.01 - 3.00"	**±.015"**
over 3.01"	**±.020"**

6. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

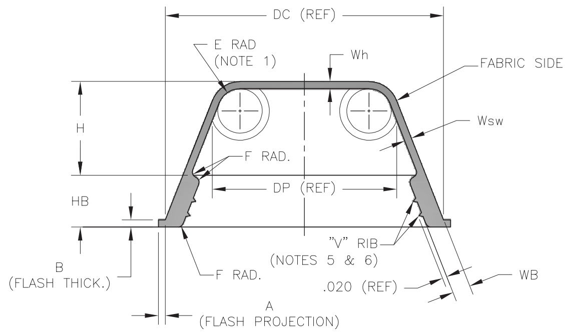
Class 1A - Standard Sizes

Cylinder Bore D_C	Piston Diameter Dp	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
1.00	.81	.62	C	.64	.094	.24
1.68	1.50	.75	C	1.99	.093	.38
1.75	1.53	.44	.017	2.11	.110*	.01
2.00	1.81	1.03	C	2.85	.094	.53
3.51	3.05	3.51	.025	8.44	.230*	2.87
3.75	3.43	2.25	D	10.14	.156	1.69
4.50	4.00	5.25	.034	14.18	.250	4.22
5.25	4.75	3.18	.034	19.63	.250	2.34
5.50	5.00	5.50	F	21.64	.250	4.47
6.25	5.75	5.25	F	28.27	.250	4.22

Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

CLASS 1B DIAPHRAGMS

The Class 1B diaphragm has a rectangular bead around the bottom inner edge of its sidewall. This type of bead is designed to be clamped inside the cylinder bore, allowing for an absolute minimum hardware footprint. Since the clamping hardware is located inside the cylinder bore, this design is generally limited to a half-stroke in the Sb direction. This design must be inverted prior to assembly, and a curved lip retainer plate is recommended. The same recommendation of a maximum differential pressure of 150 psi also applies to this design.



Dimensions and Tolerances

Diaphragms are shown in the "as molded" configurations. The diaphragm must be inverted prior to installation.

D_C	1.00-2.50	2.51-4.00	4.01-8.00	8.01 and up
H	As required to yield design stroke (See standard size tables & Note 2)			
D_C	Tolerances on D_C and Dp are ± .010" per inch of diameter but the tolerance will be no less than ± .010" or greater than ± .060"			
Dp				
W_H	.020 ± .005	.030 ± .005	.035 ± .005	.045 ± .007
W_{SW}	.017 ± .003 (Code "C")	.024 ± .004 (Code "D")	.035 ± .005 (Code "F")	.045 ± .007 (Code "H")
A	.025 Max.	.035 Max	.040 Max.	.056 Max
B	.025 Max.	.035 Max	.040 Max.	.056 Max
E	1/16 R	3/32 R	1/8 R	1/8 R
F	1/32 R	3/64 R	1/16 R	1/16 R
W_B	.080 ± .003	.100 ± .003 See note #3	.120 ± .003 See note #3	.160 ± .003 See note #3
H_B	.150 ± .005	.200 ± .005	.260 ± .005	.300 ± .005

NOTES

1. This radius is not the piston radius since the head corner will be inverted at assembly
2. Height should not exceed the bore (D_C). Tolerance on height to be no less than ±.015" per inch of height.
3. This tolerance does not include sidewall variation
4. Trim tolerances
   Hole Diameter OD Trim

Diameter	*Tolerances*
0 - 1.00"	**±.010"**
1.01 - 3.00"	**±.015"**
over 3.01"	**±.020"**

5. This "V" rib is for diaphragm processing only. It may not appear on all diaphragms. It is not functional and need not be completely filled. Rib is normally on rubber side of diaphragm.
6. Number, size, spacing and location of "V" ribs may be modified to suit specific beads, or may be left off altogether.
7. Dimensions and tolerances pertain to Bellofram Rolling Diaphragms as manufactured and not to dimensions and tolerances of mating parts.

Class 1B - Standard Sizes

Cylinder Bore D_C	Piston Diameter D_p	Height H	Sidewall Thickness W_{SW}	Effective Pressure Area AE $(in)^2$	Convolution C	Maximum Half Stroke S_A/S_B
3.00	2.68	1.19	D	6.35	.156	.63
3.06	2.57	3.32	.035	6.22	.245*	2.34
3.62	3.12	3.31	.035	8.94	.250*	2.33
3.62	3.12	3.87	.035	8.94	.250*	2.89
4.15	3.65	1.95	.035	11.94	.250	.95
4.15	3.65	3.19	.035	11.94	.250	2.19
4.75	4.25	3.68	.035	15.90	.250	2.55
4.75	4.25	5.21	.035	15.90	.250	4.08
6.50	6.00	4.34	.040	30.67	.250	3.01
6.50	6.00	7.35	.040	30.67	.250	6.02
7.00	6.50	4.81	.040	35.78	.250	3.48
7.00	6.50	7.36	.040	35.78	.250	6.05

Side Wall Thickness B = approx. .015 C = approx. .017
D = approx. .024 F = approx. .035 H = approx. .045

HARDWARE DESIGN

General

The Bellofram Rolling Diaphragm rolls back and forth from the piston to the cylinder wall. This unique seal employs very simple hardware design that is easy to develop and economical to fabricate.

Cylinder Bore D_C	Convolution Width C	Piston Skirt Length	Cap* Length	Rp	**R_F
0.37-0.99	.0625	$\frac{H + S_A}{2}$	Stroke in S_A Direction	.0312	.0312
1.00-2.50	.0937	$\frac{H + S_A}{2}$	Stroke in S_A Direction	.0625	.0625
2.51-4.00	.1562	$\frac{H + S_A}{2}$	Stroke in S_A Direction	.0937	.0937
4.01-8.00	.250	$\frac{H + S_A}{2}$	Stroke in S_A Direction	.125	.125

NOTES: *Plus diaphragm head & retainer thickness **On hardware
Chart refers to Fig. 17.

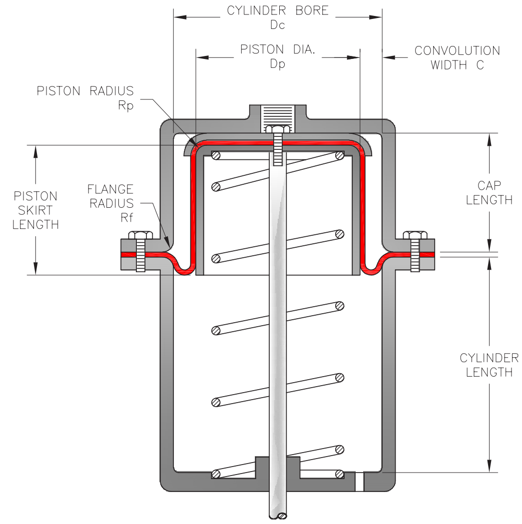


Fig. 17: Hardware Dimensions

Hardware Finish

One advantage of utilizing Bellofram Rolling Diaphragms is that hardware smoothness is not critical and, therefore, there is no need for expensive, finely machined surfaces. A surface finish of 63 microinches is sufficient for most applications.

Curved Lip Retainer Plates

The head corners of some classes of diaphragms require inversion during assembly to form the convolution. Therefore, it is quite possible, in some installations and under certain operating conditions, that the diaphragm will try to re-invert to its original "as-molded" position, thus causing sidewall "scrubbing". This condition is illustrated in Fig. 18. To eliminate this effect, curved lip retainer plates, as shown in Fig. 20, are recommended to hold the inverted head corner of the rolling diaphragm in intimate contact with the piston head corner. The use of retainer plate in the original piston assembly is highly recommended, since it greatly reduces the possibility of incorrect reassembly of the rolling diaphragm. A recommended curved lip retainer plate design is described below.

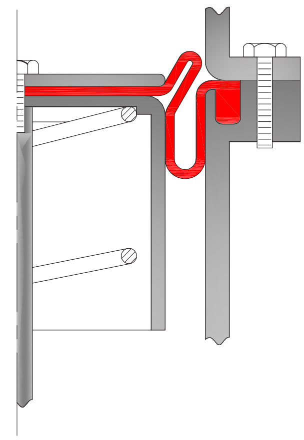
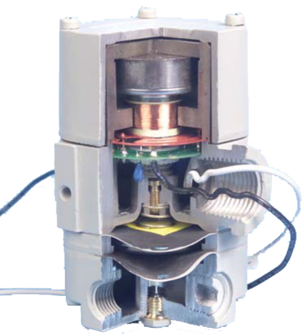


Fig. 18: Diaphragm inversion resulting from lack of curved retainer plate.

Cylinder Bore D_C	A	B	C	D	E	F	G
0.37-0.99	$Dp+2W_{SW}$	Not required	.015	1/16	1/8	Not required	.025
1.00-2.50	$Dp+2W_{SW}$	.7 Dp	.025	3/32	3/16	.010	.030
2.51-4.00	$Dp+2W_{SW}$	.7 Dp	.030	7/64	7/32	.015	.040
4.01-8.00	$Dp+2W_{SW}$	.7 Dp	.030	1/8	1/4	.015	.060

NOTES: **Dp**=piston skirt outside diameter, **W_{SW}**=Max. sidewall thickness of BRD
Chart refers to Fig. 19 and Fig. 20.



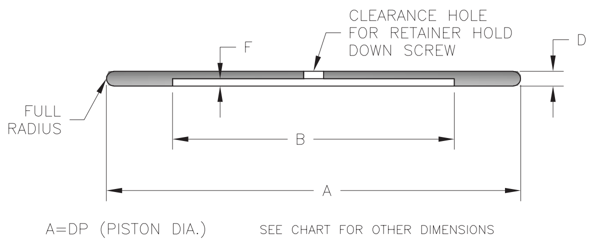


Fig. 19: Flat washer type retainer for Classes 3C and 4C (Pre-convoluted Diaphragms).

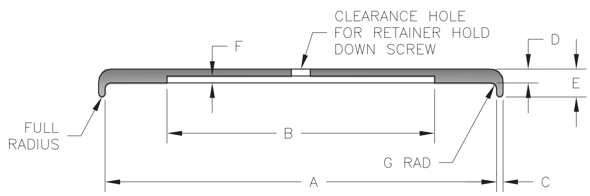


Fig. 20: Curved lip retainer for Classes 3, 4, 1A and 1B ("Top-Hat" Diaphragms).

CLASS 4 & 4C DIAPHRAGMS

Diaphragm Flange Retention Methods

Crimp Ring (Fig. 21) — This type of flange retention employs a separate metal crimp ring which is assembled to the actuator with properly designed crimp tools and lends itself to low cost, high volume manufacturing. Crimp rings are made of thin ductile material so that the forces required to form the lip will not result in overstressing the diaphragm flange.

Swaged Lip (Fig. 22) — This is similar to the crimp ring except that the retaining lip is an integral part of either the bonnet or cylinder. Again the crimp lip should be thin and ductile for proper flange assembly and retention. The swaged lip provides a minimum outside diameter for a flat flange, yet lends itself to low cost, high volume production.

Bolted Flange (Fig. 23) — The most common method of flange retention is the bolted flange design. The perforations should be at least 15% larger than the OD of the flange bolts or studs. A sufficient number of bolts or studs should be used to eliminate any serious distortion or bowing of the flange between the bolts. This provides a pressure- tight seal that prevents flange pull-out of the diaphragm from between the bolts.

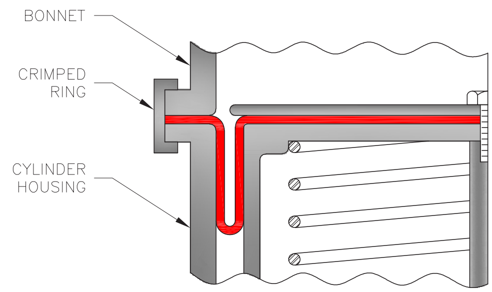


Fig. 21: Crimp-Ring Design

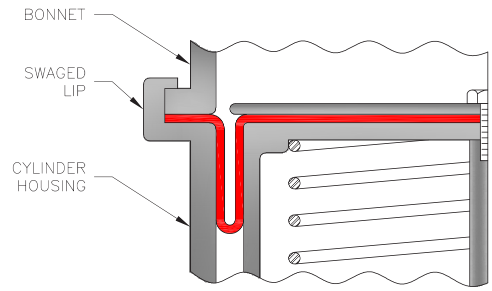


Fig. 22: Swaged Lip

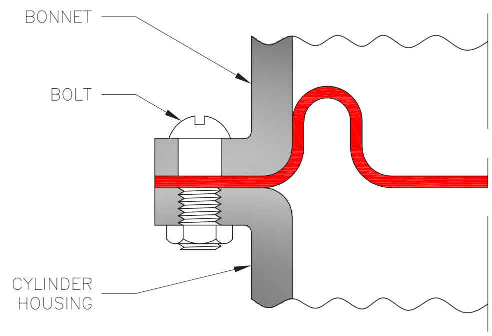


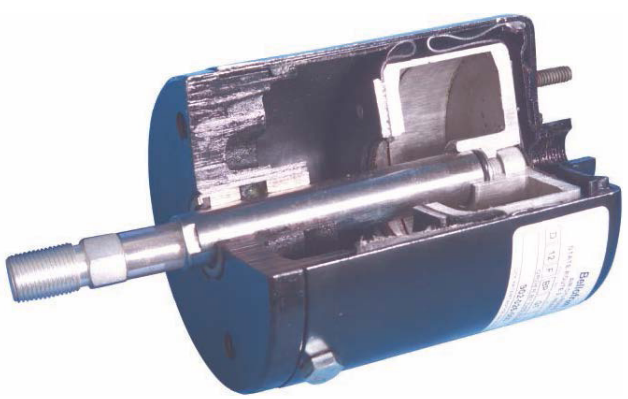
Fig. 23: Bolted Flange

CLASS 3 & 3C DIAPHRAGMS

The dimensions listed below result in a more consistent clamping pressure on the diaphragm bead. The configuration and dimensions of the diaphragm bead and the hardware bead groove provide a convenient means of positioning the diaphragm in the hardware. The bead groove width has been increased, to provide room for the diaphragm bead to deform under compression.
These figures represent a nominal bead compression of 14% (10–20% depending on tolerances), consistent with similar configurations of static "O"ring applications. These relationships may also be applied to non-standard "D" beads.

Cylinder Bore D_C (Ref.) Diameter	Bead Groove Width W_{BG} ± .003	Bead Groove Height H_{BG} ± .002	Flange & Piston Corner Radii R_L & R_P	Flange Lip Width W_L ± .003	Flange Lip Clearance C_L ± .003
0.37-0.99	.109	.081	1/32	.062	.021
1.00-2.50	.141	.116	1/16	.125	.021
2.51-4.00	.228	.172	3/32	.187	.031
4.01-8.00	.281	.232	1/8	.250	.036
8.01and up	.281	.232	1/8	.250	.048

NOTES: The above dimensions will provide adequate sealing and retention for practically all applications. Some unusual or special cases may require minor modification.



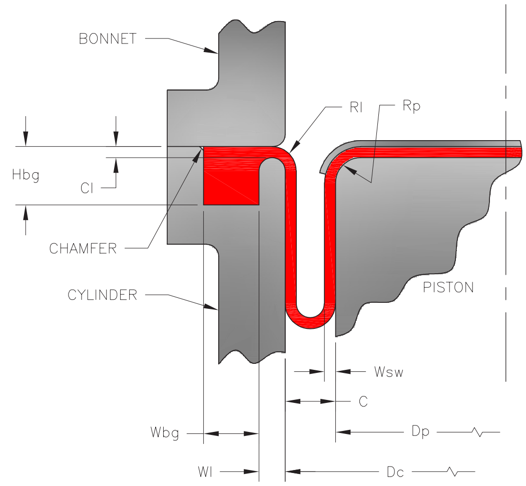


Fig. 24: Classes 3 and 3C Hardware Dimensions

Diaphragm Flange Retention Methods

Ring Clamp (Fig. 25) – In order to provide for fast disassembly, a "V" style clamp ring is frequently used. This type of ring can be opened quickly for disassembly by removing one toggle clamp lever. The retainer plate is provided with a "keyhole slot" and the retaining screw is provided with two wings which bear against the top surface of the retainer plate. This retainer plate is quickly removed by turning it 90º at which point the wings and the bolt drop into the keyhole slots. In general, this design is for low pressures.

Pivoted Rocking Bracket (Fig. 26) – This is another low cost design which also has the advantage of quick assembly and disassembly. A pivoted rocking bracket is attached to the housing flange. The central jam screw holds the bonnet firmly against the mating flange area. The unit can be disassembled quickly by loosening the screw and pivoting the bracket to release the bonnet assembly and rolling diaphragm. In general, this design is also limited to low pressure.

Beveled Edge Retainer Plate (Fig. 27) – By the use of a beveled edge retainer ring, flange bolts can be eliminated. A groove is provided in the extension of the cylinder housing flange and during assembly the beveled edge ring is snapped into the groove which, in turn, loads the bonnet assembly onto the mating bead. Generally, the clamping forces produced by a design of this type are fairly low, and therefore, these applications should be restricted for use with low pressure.

CLASS 1A DIAPHRAGMS

Hardware Design (Fig. 28) –The Class 1A bead is placed into a closely machined bead groove. It seals by axially compressing the bead into a bead groove of lesser height (usually about 12% compression) with allowance in the bead groove width for radial displacement.

Cylinder Bore Diameter D_C (Ref.)	Bead Groove Width W_{BG} ± .002	Bead Groove Height H_{BG} ± .002	Flange & Piston Corner Radii R_L & R_p	Lip Radius R_R ± .005	Lip Height H_L ± .005
1.00-2.50	.125	.96	1/16	.025	.100
2.51-4.00	.156	.122	3/32	.032	.130
4.01-8.00	.250	.196	1/8	.045	.204
8.01and up	.250	.196	1/8	.045	.190

NOTES: The above dimensions will provide adequate sealing and retention for practically all applications. Some unusual or special cases may require minor modification.

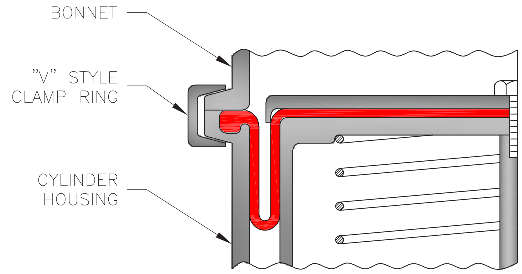


Fig. 25: Ring Clamp

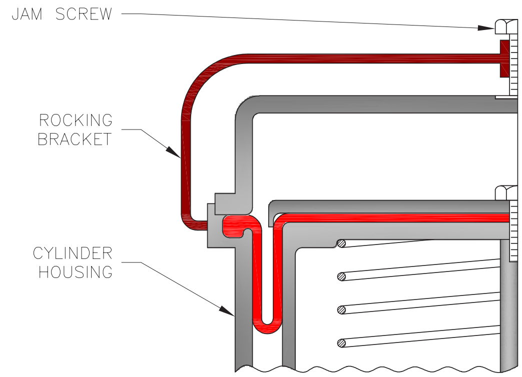


Fig. 26: Pivot Rocking Bracket

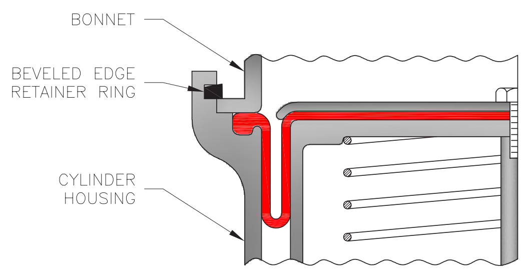


Fig. 27: Beveled Edge Retainer Plate

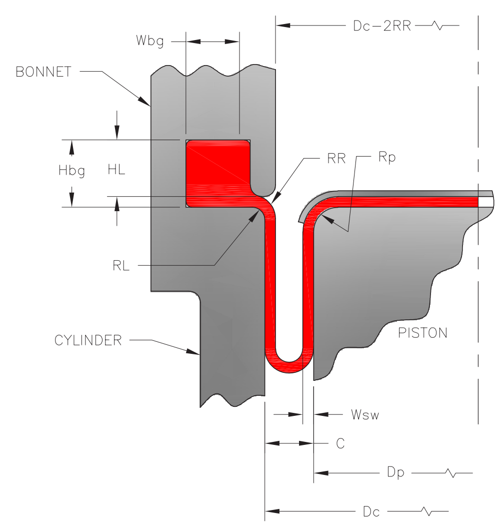


Fig. 28: Class 1A Hardware Dimensions

Diaphragm Bead Retention Methods

Crimped Ring (Fig. 29) – The use of a crimped ring to retain the diaphragm, coupled with die cast bonnet and cylinder lends itself to low cost hardware design and high volume production. This unique design eliminates conventional flange construction as well as the need for bolted type construction.

Grooved Bonnet (Fig. 30) – In some installations it is desirable to use a drawn metal cylinder housing with a molded or die cast bonnet. In installations of this nature it is recommended to make a provision for the bead groove in this molded or cast bonnet. The housing should be retained by a sufficient number of circumferential clamp bolts to prevent distortion between flange bolts.

Bezel Ring or Grooved Bonnet (Fig. 31) – Many applications require absolute minimum outside diameter of the housing in the plane of the bead retention. A fairly common method of fastening the bonnet to the cylinder housing, and at the same time providing adequate retention, is by using a threaded bezel ring as shown. The male threads are machined on the cast bonnet in order to make use of low cost drawn sheet metal cylinder housings.

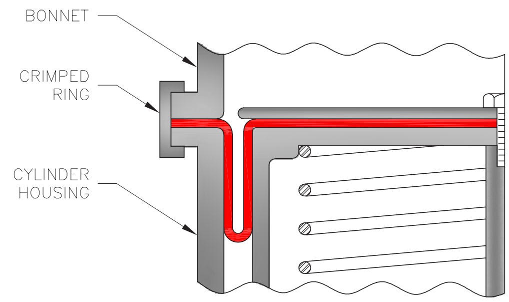


Fig. 29: Crimped Ring

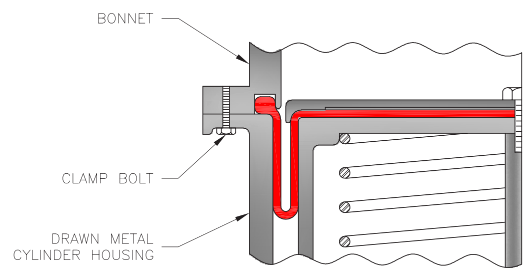


Fig. 30: Grooved Bonnet

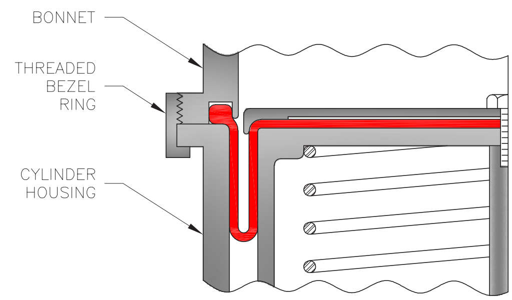


Fig. 31: Bezel Ring or Grooved Bonnet

CLASS 1B DIAPHRAGMS

HARDWARE DESIGN –The Class 1B relies on a complete volumetric fill of the retaining hardware. In order to provide proper sealing, radial compression of the bead is not essential. Under a differential pressure the bead pulls down and tightly seals against the retainer.

Cylinder Bore Diameter D_C (Ref.)	Bead Groove Width $W_{BG} \pm .002$	Bead Groove Height $H_{BG} \pm .002$	Lip Radius $R_R \pm .005$	Piston Corner Radius Rp	Lip Clearance $C_L \pm .003$
1.00-2.50	.080	.150	1/16	.030	.023
2.51-4.00	.100	.200	3/32	.040	.032
4.01-8.00	.120	.260	1/8	.050	.043
8.01and up	.160	.300	3/16	.060	.059

NOTES:
1. Alternate construction use where adequate clearance is available, or where reduced half-stroke is usable. (see Fig. 33)
2. Reduce hardware by .005 for radial compression configuration.
3. The above dimensions will provide adequate sealing and retention for practically all applications. Some unusual cases may require minor modification.

Diaphragm Flange Retention Methods

Stamped Retainer Plate (Fig. 32) – A stamped retainer plate can be utilized, as is shown, which pulls up on the bead and seals against the cylinder bore. This is a very economical design which utilizes low cost hardware and ease of assembly. The piston diaphragm retainer assembly slides up inside the cylinder shell and the retainer is fastened to the top of the shell with seal nuts.

Cast or Machined Retainer Plate (Fig. 33) – An alternate design shown is a machined, cast, or tip retainer which allows for retention of the bead at the open end of the cylinder shell. The diaphragm bead and retainer bead groove are dimensionally the same as the previous method discussed.

Both of these methods of Class 1B bead retention are employed in the variety of single and double acting diaphragm air cylinders manufactured by Bellofram.

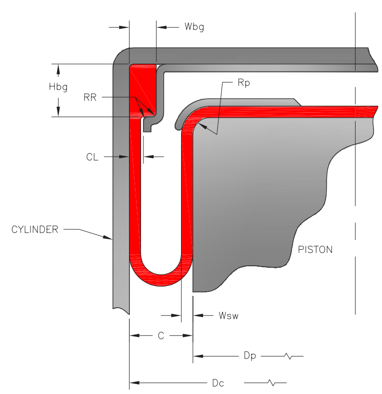


Fig. 32: Axial Compression with Stamped Retainer Plate

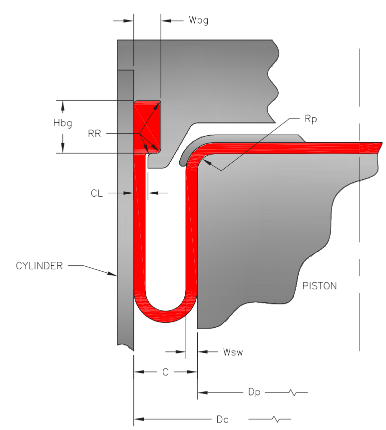


Fig. 33: Radial Compression (note 1) with Cast Machined Retainer Plate

APPLICATION DATA

Designing For Diaphragm Trim & Perforation

Some rolling diaphragms require perforations through the flange or head to accommodate a fastening means either to the flange or head. This necessitates a punching operation for head holes, flange holes, or trimming the outside flange periphery, so that the rolling diaphragm will mate with the configuration of the piston, bonnet or cylinder housing.

We recommend that all perforations or flange trim be performed by us prior to shipment. Please submit sketches of required perforations or trim with quotation request, or with your order. Good design procedures for trim and perforation are as follows:

Relationship of Hole Pattern – Whenever there are holes in the head and flange, always indicate whether the hole pattern in the head and the hole pattern in the flange must be trimmed with a definite angular relationship. The manufacture of trim tools which will maintain this fixed angular orientation involves additional expense.

Hole Spacing – Perforations through the head or the flange should be located so that there is at least .100 inches minimum between the edges of holes. Also, holes must be located so that there is at least .125 inches between the edge of a hole and the trim periphery. If the bolt holes are less than this distance, the holes should be "notched" similar to shown in photo in Fig. 34. It is also important to arrange the hole pattern so that the radial distance from the edge of the hole is at least "E" inches from the start of the blend radius at either the piston head or cylinder clamp flange. This condition is illustrated in Fig. 35 and the "E" dimension is given for various working pressures.

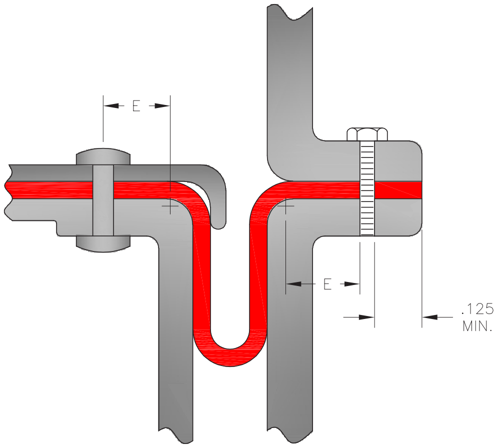
Hole Diameters – Perforations should generally be designed to have a diameter of .093 inches or greater, in increments of .015 inch. The diameter of all perforations should provide a radial clearance between the maximum diameter of bolts and the perforated hole of at least 15% of the bolt diameter. This design practice is most important in order to eliminate the possibility of fraying the edge of the perforations during assembly by insertion of screws, etc.

Head Perforations – The size and number of perforations in the head should be kept to an absolute minimum since the load bearing threads supporting the side wall and convolution pressure loads are actually severed by these perforations. Whenever bolt holes in the bead are required, they should be placed as close to the center of the head as possible, and the hole diameters should be kept to a minimum.

Drawings Specifying Trim and Perforations – It is requested that a sketch or drawing be submitted indicating required perforations and trim. Make sure sketches are in accordance with these recommendations. Hole punching, perforations, and flange trimming are provided at no extra cost by the Bellofram Corp. There is, however, a fee for the design and manufacture of special trim and perforation tools.

FORMING THE CONVOLUTION DURING ASSEMBLY – To form the diaphragm convolution during assembly operations. Classes 4, 3, 1A & 1B ("Top-Hat") designs require that the head corner of the be inverted from the "as -molded" configuration to the "as-installed" configuration. The pre-convoluted designs, Classes 3C and 4C, do not require any inversion since they are molded in a convoluted configuration.

Fig. 34: Notched Diaphragm



Max. Working Pressure (PSI)	0-50	51-150	151-300	301-500
"E" Minimum (In.)	.100	.150	.200	.250

Fig. 35: Hole Spacing Dimensions

ALTERNATE METHODS OF ATTACHING DIAPHRAGM TO PISTON – Whenever it is undesirable to attach the diaphragm to the piston head by means of rivets, screws, etc., which require a hole through the head of the diaphragm, attachment may be made by either of the following means:

1. Double Sided Pressure Sensitive Tape: Apply to one of the areas to be bonded and then press on the mating surface. Clean all surfaces to be bonded with perchloroethylene and acetone to remove all surface films. It may be necessary to abrade the surfaces prior to cleaning to obtain improved bonds. The tape should be die cut in the shape of a disc with the diameter equal to the piston head diameter allowing sufficient margin for the disc to form down over the head corner radius. To prevent pleating in the area of the head corner radius, the head disc should be die cut with frequent notches. The above procedure works well with most elastomers, however, for bonding silicone to metal piston heads, see below.

2. Liquid Cements: In using liquid cements or semi-liquid cements for bonding a diaphragm to a piston head, the cement must be restricted to the area to be bonded. The adhesive should be applied to the entire top surface of the piston including the head corner and to the mating "Fabric side" of the diaphragm. Any cement which inadvertently comes in contact with the sidewall area of the piston of the diaphragm (excluding the Head Corner Radius) must be completely removed prior to application, of the diaphragm. All surfaces must be pre-cleaned as noted previously.

EFFECTS OF PRESSURE REVERSAL – Any condition which introduces even a temporary pressure reversal may cause sidewalls distortion, overstressing, and a scuffing action, similar to that indicated in Fig. 36. Generally, any pressure reversal causing multiple pleats will not be corrected by application of pressure on the high pressure side. Operation with pleats will result in early failure of the diaphragm.

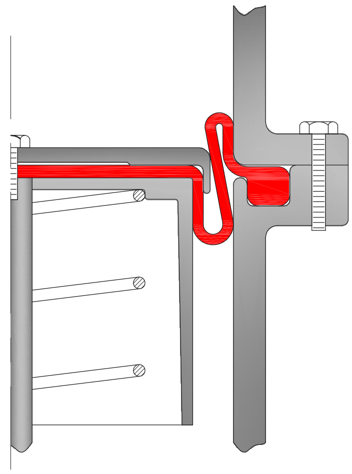


Fig. 36: Pressure Reversal of Diaphragm

SURFACE COATINGS – In order to prevent possible adhesion of elastomeric material of a diaphragm to mating material surfaces, especially under heavy clamping loads, a surface release agent should be applied to surfaces in intimate contact with metal surfaces. This release agent is of a particular importance whenever frequent disassembly of the unit is required for inspection purposes. Two of the commonly used release agents are silicone oil, wiped on appropriate rolling diaphragm surfaces, and Molykote. These release agents should be thoroughly worked into the surface of the fabric side and the elastomer side prior to installation.

PISTON ECCENTRICITY – Any piston-cylinder eccentricity experienced during a normal operating stroke should be minimized in order to provide a uniform convolution width around the entire periphery. In general, the eccentricity should not exceed 10% of the working convolution width. If piston shaft bearings are provided, the bearing installation should be designed so that the overall eccentricity of the piston with respect to the cylinder is within these limits over the entire operating stroke of the mechanism. In many applications, shaft bearings are not required since the shaft itself is guided by some other related mechanism. Whenever the applied thrust is not parallel to the piston shaft axis, it is well to provide an alignment bearing. If a spring is employed to return the piston to its top stroke position, some means for ensuring concentric motion of the piston during its stroke should be provided. In general, compression springs do not have a motion parallel to the spring axis, thus introducing a bending moment at the head of the piston.

SHAFT TORQUE – If there is a possibility that the piston shaft may be subjected to wrenching or other torques during assembly or operation, a rotating slip joint is recommended in order to prevent the torque from being transmitted to the rolling diaphragm. A typical shaft assembly having a slip joint to prevent this transmission of torque is shown in Fig. 37. Torque may also be applied to the piston in certain designs using compression springs, when compressed, will twist through an angular displacement. If this twisting effect is more than one half degree, one end of the spring should be supported on a ball bearing thrust plate.

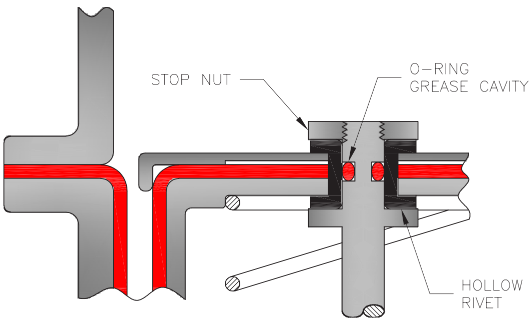


Fig. 37: Slip Joint Shaft Assembly

UP-STOPS AND DOWN-STOPS – In order to prevent over-stroking, a positive up-stop and down-stop should be provided in every mechanism. These stops, or buffers, prevent the rolling diaphragm from being damaged by excess travel beyond values.

DESIGNING FOR INCREASED DIAPHRAGM LIFE – There are many factors which contribute to the durability of Bellofram Rolling diaphragms. Under normal operating conditions the diaphragm will last millions of cycles, but in special situations additional considerations are employed.

PISTON CONFIGURATION – The Rolling Diaphragm must elongate and compress circumferentially as it rolls back and forth from piston to cylinder wall. Tapering the piston, as shown in Fig. 38, will contribute to improved cycle life by reducing the amount of circumferential change required of the diaphragm as it rolls back and forth. This tapered configuration relieves the condition which can cause axial wrinkling of the diaphragm. This taper of the bottom of the piston skirt should be such that the convolution at the bottom of the skirt is half the standard width (diameter at bottom of piston skirt is DP plus one convolution width). It is important that the piston skirt length be to specification. *This modification is not recommended where cylinder bores are less than 1.00 in. diameter.*

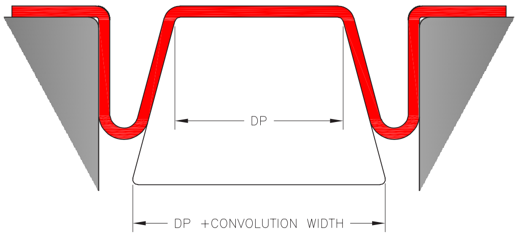


Fig. 38: Tapering the Piston

REDUCE STROKE – Reducing the stroke minimizes the amount of diaphragm stretch and circumferential reduction required for the diaphragm.

CYCLE DOWN (S_B) ONLY – When the diaphragm moves in the S_A direction it must compress circumferentially to conform to the piston. These circumferential compressive stresses are the principal cause of axial wrinkling in long stroke diaphragms. By cycling in the S_B direction the diaphragm elongates circumferentially avoiding the compressive stresses.

PRESSURE CONTROL – Pressure should be maintained at all times when the diaphragm is moving. In order to minimize fabric stresses, recommended operating pressures should not be exceeded. Of equal importance there should be sufficient differential pressure maintained to ensure that the diaphragm conforms to the hardware. This will preclude any interference and side wall scuffing.

DECREASE CYCLE RATE – Rapid cycle rates can cause cavitation or negative pressures that could force the diaphragm into double-convolution. Double-convolution will cause early diaphragm failure. As a general rule a maximum cycle rate of one cycle per second is recommended.

INCREASE HARDWARE SMOOTHNESS – In high cycle applications there is some relative movement between the diaphragm sidewall and the mating hardware surfaces. Abrasion results over a prolonged period of operation. Smoothing the hardware surfaces to 32 micro inches will help improve this condition. In cases of spot failures, check for burns as well as piston/cylinder eccentricities. Wherever possible, Teflon coating the hardware or use of molded plastic in the hardware construction can provide smooth surfaces for long life.

LUBRICATION – Periodic lubrication is not required for a rolling diaphragm, as there is no sliding friction. However, a light coating of molybdenum disulfide (Molykote) on the fabric and/or elastomer side of the diaphragm, prior to assembly, and possibly on the mating hardware, will reduce potential for scuffing. In some severe applications the fabric side of the diaphragm can be coated with an abrasion-resistant urethane spray.

FABRIC SELECTION – Fabrics should be selected to provide optimum working pressure capabilities. They should be strong enough to meet the pressure requirements and open enough to allow strong fabric/ elastomer impregnation resulting in strong adhesion.

DOUBLE-TAPERED DIAPHRAGMS – Tapering the hardware piston, to relieve the effects of circumferential compression, also means that there will be a change in the effective area from one end of the stroke to the other.

An alternate means of relieving circumferential compressive stresses is the double-tapered diaphragm. This diaphragm is used with a straight piston skirt so there is no change in effective area. The sidewall angle is designed to conform closely to the piston diameter reducing the amount it must compress to conform to the piston skirt.

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A HIGHER SEALING

8019 Ohio River Blvd.
Newell, WV 26050 USA
800-727-5646

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