ELECTROFORMED METAL BELLOWS

Servometer®

ISO 9001:2008 Certified

SYSTEM CERTIFICATION ISO 9001:2008 SGS

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Temperature Sensors & Transducers
Valve Seals
Expansion Joints
Short/Full Range Aneroids
Linear Multipliers
Flexible Shaft Couplings
Flexible Bellows Seals
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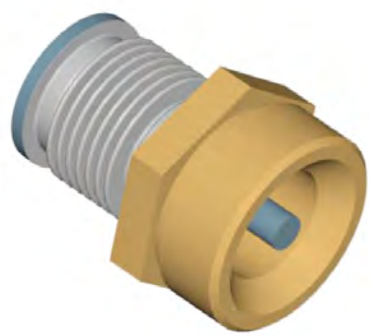
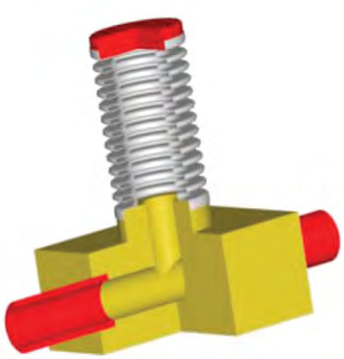




INDEX

PAGE

INTRODUCTION

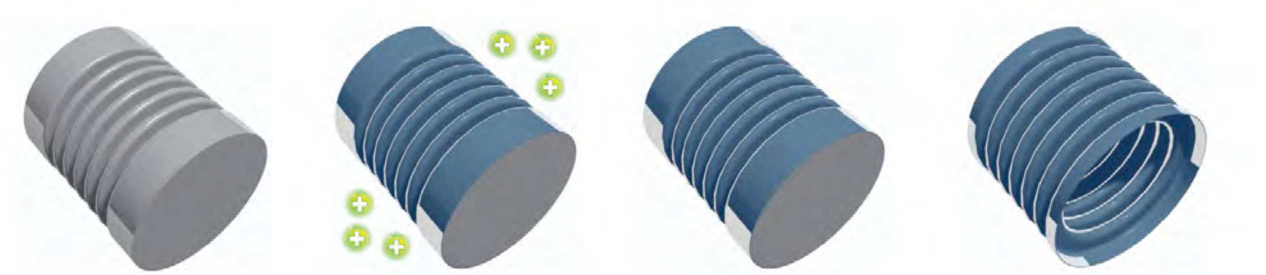
SERVOMETER® ELECTRODEPOSITED METAL BELLOWS

There are five major types of metal bellows: rolled, hydroformed, welded, chemically deposited and electro-deposited. Electro-deposited bellows are manufactured by forming a mandrel to the shape of the inside of the bellows, depositing the proper thickness of spring quality metal onto this, trimming the ends and dissolving out the mandrel.

Servometer is the foremost manufacturer of electro-deposited bellows. These bellows have the following advantages over other types.

1. Because the bellows wall can be thinner than other types (to .0002"), they are extremely sensitive, which makes them excellent for very accurate instrument applications requiring a high degree of sensitivity. They can provide large deflections with only very minute forces. They are up to 25 times as sensitive as hydroformed bellows in the same size range. Servometer manufactures bellows which can be fully compressed by a force as small as 4 grams.
2. They are the most flexible bellows. They offer superb performance in applications such as hermetic sealing of switches and circuit breakers, and other filled instruments.
3. Their stroke can be 60% of their extended length, and combined with a greater I.D./O.D. ratio, this gives them a volume displacement capacity equal to or larger than most other types.
4. They can be designed for infinite life expectancy and have a normal minimum life of 100,000 cycles.
5. They are seamless and non-porous. No dust, dirt or moisture can lodge in seams and cause contamination in critical applications. In addition, Servometer bellows are leak tested to 10^{-9} ccHe/sec. by helium mass spectrometer.
6. They can be made in sizes smaller than any other bellows. Many of today's sophisticated applications require a miniaturized bellows. Servometer bellows can be made as small as .020" O.D. and still retain full sensitivity and flexibility. When other types are smaller than 1/4" O.D., they are usually stiff and useless for sensitive applications.
7. Tooling is not required for most bellows, so that a large quantity need not be ordered to attain a reasonable price.

SERVOMETER®'S PROCESS OF ELECTRODEPOSITION



Machine internal geometry to create a mandrel — Electrodeposit metal onto mandrel — Trim plated mandrel to expose unplated surface — Chemically dissolve mandrel leaving plating as final component

SECTION I – BELLOWS DESIGN

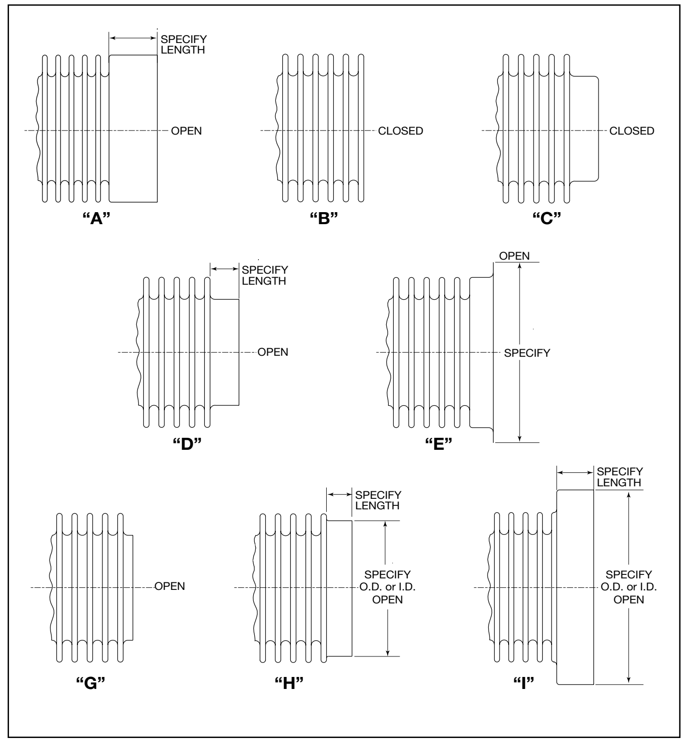
HOW TO ESTABLISH A BELLOWS DESIGN

Determine all of your requirements for the bellows design by answering the following eleven points, or using the Bellows Design Data Form provided on the inside back cover. The complete catalog will assist you with the details.

1. Kind of flexing required of the bellows: Specify extension, or compression, or bending, or swiveling, or parallel-ends off-set, or torque, or speed of rotation. Provide a drawing or sketch showing related fittings and extremes of flexing where possible. This is very important to the manufacturer to enable him to work out a reliable design.
2. Specify the amount of compression or extension or flexing in fractions of an inch or in degrees, or by dimensions on a flexing diagram. (Maximums).
3. Specify pressure difference between inside and outside of the bellows, maximum instantaneous pressure, and whether higher pressure is applied inside or outside the bellows.
4. Specify whether rigid stops will limit the extension or compression of the bellows to its rated stroke, or if the bellows will be required to withstand pressure un-restrained. Note that a restrained bellows can typically withstand higher pressures.
5. The spring rate, in pounds per inch, or conversely the amount of force available to flex the bellows the desired amount, should be specified.
6. Specify the required useful life of the bellows expressed as the number of flexing cycles, and define the flexing cycle.
7. Extremes of temperature, both low and high, should be stated.
8. Corrosive conditions which apply should be described.
9. The method to be used to join the bellows to end fittings, such as soldering, brazing, welding, or adhesive bonding, should be specified.
10. Specify vibration or shock to be experienced by the bellows.
11. Specify types and lengths of ends. Refer to the figure, Types of Bellows Ends.

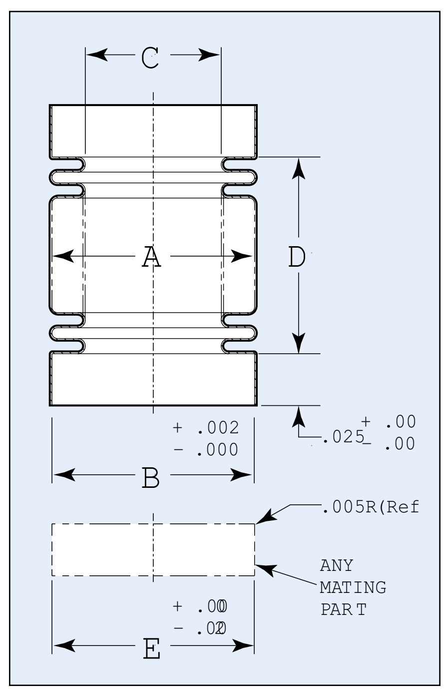
After completing the bellows design data form, or setting down the information according to the eleven points listed above, send the information to Servometer. Our engineers will design a bellows to your requirements.

TYPES OF BELLOWS ENDS



SERVOMETER® STANDARD BELLOWS

BELLOWS											
Part	Fin O.D. "A"	Skirt I.D. "B"	I.D. "C"	Conv. Lgth. "D"	Wall Nom.	S.R. Lb./In. Nom.	Comp. Stroke (in.)	No. Of Conv.	Mating Part O.D. "E"	EFF. Area	Maximum Press. for 1/2 Stroke
FC-1	.250	.248	.150	.740	.0015	5.9	.149	24	.246	.0292	290
FC-2	.250	.248	.150	.370	.0015	11.82	.070	12	.246		
FC-3	.250	.248	.150	.245	.0015	17.73	.045	8	.246		
FC-4	.250	.248	.150	.185	.0015	23.63	.032	6	.246		
FC-5	.375	.372	.250	.740	.0018	8.15	.194	24	.370	.0723	265
FC-6	.375	.372	.250	.550	.0018	10.87	.142	18	.370		
FC-7	.375	.372	.250	.370	.0018	16.31	.092	12	.370		
FC-8	.375	.372	.250	.305	.0018	19.57	.075	10	.370		
FC-9	.500	.495	.360	.740	.0025	21.62	.172	24	.493	.1382	410
FC-10	.500	.495	.360	.490	.0025	32.44	.112	16	.493		
FC-11	.500	.495	.360	.370	.0025	43.25	.082	12	.493		
FC-12	.750	.744	.570	.980	.0030	30.73	.208	21	.741	.328	355
FC-13	.750	.744	.570	.730	.0030	40.33	.156	16	.741		
FC-14	.750	.744	.570	.540	.0030	53.78	.114	12	.741		
FC-15	1.000	.994	.740	1.230	.0035	24.66	.320	18	.990	.5678	230
FC-16	1.000	.994	.740	.730	.0035	44.70	.169	10	.990		



SECTION II - PROPERTIES OF SERVOMETER® BELLOWS

TOLERANCES

Dimensions:

I.D.: ± .005" for bellows I.D. .250" or larger.
± .003" for bellows I.D. less than .250".
± .0015" for I.D. of open ends.

O.D.: Tolerance varies with wall thickness and size of bellows.

Length of convolutions: ±.010"

Length of end trims: ±.005"

Spring rate: ±30% standard. Servometer can supply +10% when required.

DESIGN LIMITS

1. Diameters up to 9" are possible.
2. The ratio, I.D./O.D. should be .6 or greater. For an efficient bellows, .65 is the optimum value. Higher values can be supplied where maximum effective area or small space are required, but at the expense of the bellows stroke.
3. Wall thickness, outer groove widths, and inner groove widths, should conform to the values in the chart below.

Bellows O.D.	Minimum Wall Thickness	Outer Groove Width	Depth	Minimum Inner Groove Width
.063"	.0003"	.003"	.011"	.002"
.125"	.0005"	.004"	.024"	.003"
.250"	.0007"	.014"	.049"	.007"
.375"	.0009"	.024"	.074"	.010"
.500"	.0010"	.028"	.085"	.012"
.750"	.0014"	.047"	.122"	.017"
1.000"	.0020"	.075"	.180"	.025"
1.250"	.0022"	.090"	.200"	.030"
1.500"	.0025"	.100"	.250"	.035"
2.000"	.0030"	.100"	.250	.040"
2.500"	.0035"	.125"	.250	.043"
3.000"	.0040"	.125"	.250	.045"

NOTE: For long bellows with internal pressure, a loose-fitting guide rod inside or a sleeve outside must be used to prevent buckling. The rod or sleeve should be about 65% as long as the bellows is in the extended condition. Buckling pressure can be calculated from information in Section III.

METAL COMPOSITION

Electrodeposited nickel alloy is our standard material. Copper, silver and gold are also available either as a surface finish or base metal.

Normally our bellows have a .0001" lamination of copper between equal thicknesses of nickel.

Servometer bellows have about the same chemical properties as commercial "A" nickel with the exclusion of the copper lamina.

Nickel Alloy: 99.8%
Interstitially deposited impurities: .05%
(Oxygen and carbon)

Three grades of nickel alloy are supplied as required:

Regular Nickel: This metal is bright and high in yield strength. However, it cannot be welded or brazed because it may contain as much as 0.040% maximum sulfur which causes it to embrittle when heated above approximately 350°F.

Low Sulfur Nickel: This metal is "satin" finish, equivalent to regular nickel except it contains only .02% maximum sulfur and is much more corrosion resistant. It can be soldered or brazed without embrittlement, but care must be taken to avoid annealing of the convolutions.

Weldable: Equivalent to low sulfur nickel with .02% maximum sulfur, but it can be welded or brazed without embrittlement.

MECHANICAL PROPERTIES OF BOTH TYPES OF NICKEL:

Yield strength	110,000 psi
Tensile strength	125,000 psi
Elongation	1.0%
Hardness	270 Vickers
Young's Modulus	23,350,000
Metal hysteresis	within stress limits is very low.
Specific wgt.	.321 lb./in^3.

SURFACE FINISHES

Servometer bellows normally have a bright corrosion resistant surface, but the following finishes are available:

1. Gold plate, 24 carats, to ASTM B 488-01 is supplied either for enhanced corrosion resistance or to provide a surface for microwave fields.
2. Silver plate is sometimes applied where a bellows is used for a microwave guide.
3. Parylene® coating can be supplied for certain corrosive conditions.

LEAK TIGHTNESS

Servometer bellows and bellows assemblies, if required, will be leak tested to $1x10^{-9}$ cc He/sec on a Helium Mass Spectrometer. This rate amounts to one cubic centimeter of helium in 32 years.

ENVIRONMENTAL TOLERANCES

Temperature Tolerances:

Servometer nickel bellows are ideal at temperatures as low as -423°F as in liquid oxygen or liquid hydrogen applications, where they retain toughness and gain some 30% in operating strength.

At high temperatures, the operating limit is about 350°F, above which the regular nickel embrittles and the low sulfur nickel anneals. Under certain conditions, higher temperatures are attainable. Our engineers are ready to discuss your requirements.

Magnetic Properties:

Servometer's electrodeposited nickel alloy is ferromagnetic. Electrodeposited copper is non-magnetic and can be utilized for special applications.

Corrosion Resistance:

Nickel is more resistant to corrosion than brass or bronze but not as much so as stainless steel. Nickel bellows will not oxidize in air nor be affected by liquids that are alkaline, but will not withstand acids. In sea water, nickel bellows are attacked after a few weeks because of electrolysis where dissimilar metal fittings are used.

As in all corrosion problems, each situation must be evaluated alone. Many corrosive conditions are successfully handled by nickel bellows, and the customer should request data and operate prototypes under their environmental conditions before adopting a design.

JOINING OF BELLOWS TO END FITTINGS

Success or failure of a bellows application depends on proper procedures for joining bellows ends to fittings. We urge our customers to consult with us on methods and specifications for making soft soldered, brazed, welded or adhesive joints.

Soldered Joints:

To get consistently leak tight joints, pre-tin the bellows end and the engaging fitting rim first, then sweat the two pieces together, rotating the bellows 1/4 turn on the fitting while the solder is molten, to work out pockets of air or flux residue. Wash off all flux by soaking the assembly in boiling or hot tap water.

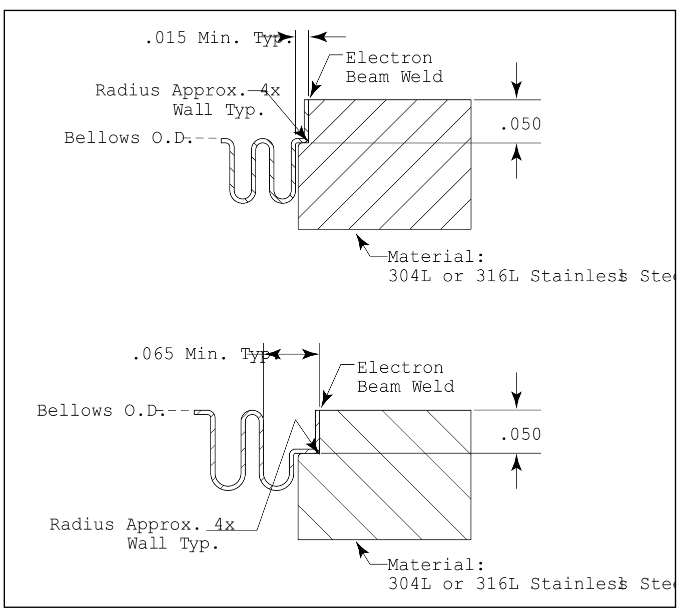
Flames or high temperatures will anneal or embrittle most bellows. Therefore, do not apply flames or induction heat to the bellows. Apply it to the fittings instead, and let the heat flow into the joint from the fitting. The bellows will then retain its spring qualities. Take care to apply only enough heat to flow the solder.

Silver Brazed Joints:

Typically, Servometer recommends using methods other than brazing for connecting directly to the bellows because the high temperatures required to create the joints can permanently cause damage. However, Servometer assemblers frequently build brazed sub-assemblies, which can later be soldered to bellows, as discussed above. Consult Servometer on each application to review capabilities.

Welded Joints:

Electron beam welding has the advantage of localized heat right at the weld. Hence, the bellows spring properties are not affected. Weld joint geometry and welded end piece design are specified custom for welded assemblies. Use the examples below as a guide only. Consult Servometer Engineering for additional specifications.

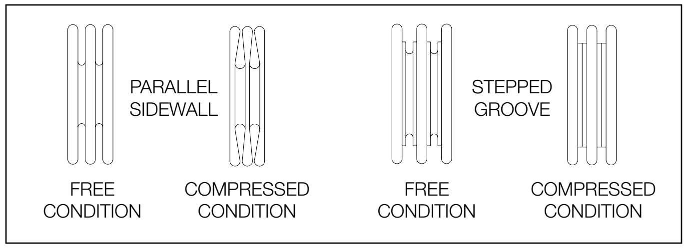


SPECIAL TYPES OF BELLOWS

HIGH COMPRESSION BELLOWS

Bellows with parallel side-walled grooves cannot be compressed more than about 40% of their active convolutions length.

Under certain conditions, stepped convolution bellows can be designed to compress up to 60% of active length. Stepped grooves are suitable only in compression; not extension.



MULTI-PLY BELLOWS

The pressure handling capabilities of a bellows can be doubled or tripled by using 2 plies or 3 plies of electrodeposited material. For example, one wall thickness will give a certain compression and withstand a given pressure. Two laminations of the same wall thickness will give the same compression and twice the pressure rating. Three laminations triple the pressure at the same stroke. The spring rate increases only as the first power of the laminations.

Thickening a bellows wall reduces stroke and increases spring rate as the cube of the thickness, and therefore, is no substitute for lamination.

PRE-COMPRESSED BELLOWS

The extension stroke of a typical bellows is shorter than its compression stroke. By artificially adjusting its free length, we can take advantage of the bellows' natural compressive stroke in extension. Please consult with our engineers when this type of bellows appears desirable.

SECTION III - MATHEMATICAL DESIGN OF A BELLOWS

Symbol	Definition	Units
O	Bellows outside diameter	inches
I	Inside diameter	inches
t	Nominal wall thickness	inches
N	Number of convolutions active in the bellows	integer
E	Young's modulus of elasticity for the bellows material Use 23,350,000 for Servometer nickel	psi
S	Maximum permissible storke for the bellows	inches
s	Maximum permissible stroke per convolution	inches
n	Length of one convolution	inches
L	Bellows active convolution length	inches
P	Bellows pressure rating or pressure applied to the bellows	psi (differential)
A	Angle substended by a bellows bent in a circular arc. Angle is measured from bellows' free (straight) condition	degrees
r	Spring rate of one convolution	lbs/inch
R	Bellows spring rate (axial stiffness)	ibls/inch

PRESSURE RATING

$$P = \frac{1.25 \times 10^6\, t^2}{(O - I - t)^2} \text{ psi}$$

The above formula gives "nominal pressure rating".

Proof pressure is 1.75 times the above.

Burst pressure is 2.50 times the above.

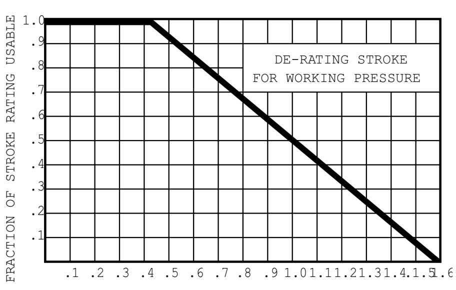
STROKE RATING

$$S = \frac{.0010\,(O - I - t)^2 N}{t}$$ inches compression, for 100,000 cycles life expectancy

The rating in extension is 75% of the above, and applies only to convolution V and stepped convolution bellows can be used only in compression.

RATING BELLOWS FOR COMBINED STROKE & PRESSURE

Where the working pressure exceeds 40% of the nominal pressure rating of the bellows, select the permissible stroke (axial) from the chart below.



For example, assume a bellows rated at 100 psi (from pressure formula) is to work at 80 psi in service. Enter the chart above with 0.8 (for 80%) on the pressure scale and read out 0.67 on the usable stroke scale. Multiply this by the rated stroke (from the stroke formula) and get the usable stroke for the bellows at 80% working pressure.

LIFE EXPECTANCY

The life expectancy of a metal bellows is expressed in stroke cycles and not in time or speed of repetition of the cycles.

The following data, based on emperical life testing of Servometer bellows, is conservative.

LIFE EXPECTANCY TABLE

Minimum Life Expectancy In Cycles	LIFE FACTOR, as a fraction of the bellows stroke at 100,000 cycles life expectancy	
	In Compression	In Off-Set Rotation
1,000	1.50	1.70
10,000	1.25	1.40
100,000	1.00	1.00
1,000,000	.84	.82
10,000,000	.78	.74
100,000,000	.75	.73
Infinity	.72	.72

EXAMPLE: Suppose a given bellows design requires a minimum life expectancy of 1,000,000 cycles at a compression stroke of 0.313". The table shows a LIFE FACTOR of 0.84 for this case. This means that the permissible stroke is 0.84 times the formula value. Therefore the formula value 0.313 divided by 0.84 = 0.372". Enter this in the stroke formula and the result shows a bellows 19% longer would be required.

EXAMPLE: Suppose a shaft coupling bellows must operate at .020" shaft parallel off-set for 5,000,000 revolutions. Multiply 5,000,000 by 2, since 1 revolution is 2 bend cycles. Enter the 10,000,000 in the Off-set Rotation column and come out with the LIFE FACTOR (.74). Since the Off-set formula on Page 10 gives the allowable off-set for 100,000 cycles, the formula value for this case is 0.20 divided by .74 or .0272". Enter this in the formula and come out with the relationship between bellows length and bend angle. The bellows will be about 15% longer than would have been required for 100,000 cycles life.

DE-RATING BELLOWS STROKE FOR PRESSURE & LIFE

Obtain the FRACTION OF STROKE RATING USABLE from the chart, DE-RATING STROKE FOR WORKING PRESSURE on this page. For example, assume this fraction is 0.65. Next, extract the LIFE FACTOR from the Life Expectancy Table for the required life. Assume this is 1.25. The bellows stroke rating would be (0.65 x 1.25) times the formula value of the stroke.

SPRING RATE

$$R = \frac{4.3\, E\, (O + I)\, t^3}{(O - I - t)^3 N} \text{ pounds per inch}$$

This formula gives values for bellows with convolutions having parallel side walls. For bellows with stepped and V grooves the rate is 1/3 greater.

This formula gives a straight line compression vs. force characteristic and represents the spring resistance due to the bending of the convolution walls.

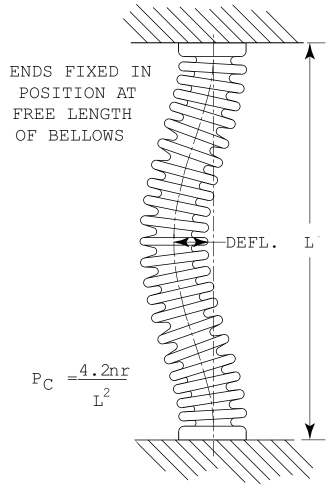
EFFECTIVE AREA

$$\text{Effective area} = 0.785\, \frac{(O + I)^2}{4} \text{ sq. inches.}$$

This formula is not theoretically accurate but gives results close to actual bellows values.

CRITICAL BUCKLING PRESSURE

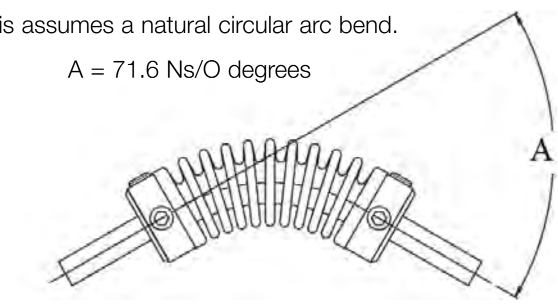
With increasing pressure applied inside a bellows whose ends are fixed, a critical pressure, P_C, will be reached at which the bellows will suddenly bow sideways. Below this P_C the bellows will not buckle; above it the bellows will buckle outward without control and damage itself at a few percent more pressure than P_C. The critical pressure is given by the following formula.



ALLOWABLE CIRCULAR ARC BENDING

This assumes a natural circular arc bend.

A = 71.6 Ns/O degrees



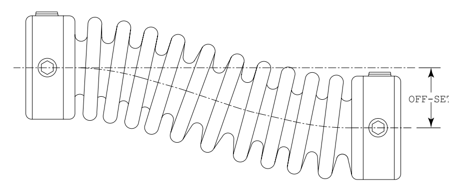
The value given by the formula may exceed the angle attainable by the bellows, unless the stroke per convolution, S, is limited to the value at which bellows convolutions touch.

The formula gives the value for 100,000 cycles life expectancy. For any other value use the LIFE FACTOR from the Life Expectancy Table and multiply this by the formula value of the angle.

OFF-SET BENDING WITH ENDS PARALLEL

Off-set = 0.25 N^2n s/O inches

The above formula is for bellows with bend angles smaller than 30°.



Note that in this arrangement the middle third of the bellows convolutions are nearly straight and unstressed while the end thirds get sharp bends.

Since the number of convolutions, N, varies as the length of the bellows, the allowable off-set varies as the square of the active length.

This type of usage is encountered in flexible shaft couplings.

The formula value is for 100,000 cycles. For any other value multiply the formula value by the LIFE FACTOR from the off-set rotation column of the Life Expectancy Table (page 7).

BELLOWS ASSEMBLY SERVICES

OVERVIEW

For over fifty years, Servometer has developed tens-of-thousands of proprietary solutions to sub-assembly challenges. For medical, military, aerospace, and other high-technology applications, Servometer offers a range of efficient precision assembly services that reduce component costs and lead times, and sustain quality. Quantities can range from one piece to full production runs.

Servometer assembly services satisfy the most stringent application requirements. For example, Servometer assembles key parts for a precision adhesive dispenser, brazing a tungsten carbide sealing ball to a steel solenoid pin without dents, pits or flats on the shaft surface. Our services are also employed due to our manufacturing capability and assembly with miniature components. From liquid filled sensors, to miniature soldered assemblies, Servometer has the in-house capability to provide the complete solutions.

Available Assembly Services

SOLDERING

Servometer's assembly personnel are experts in soldering Servometer miniature metal bellows and electroforms to custom end pieces. To avoid overheating the bellows, Servometer's assembly experts do all the soldering by hot irons or custom hot plates, never with flame, employing time-tested proprietary processes. Servometer's solder joints are leak tight and can be tested to 1 x 10^{-9} cc He/sec. By practice, Servometer employs only ROHS compliant solders, unless otherwise specified by your requirements.

ELECTRON BEAM WELDING

Servometer's assembly personnel are experts in electron beam (e-beam) welding of Servometer miniature metal bellows and electroforms to custom end pieces. Electron beam welding enables Servometer to weld electroformed nickel components in leak-tight assemblies with state-of-the-art computer process control. Electron beam welding imparts only localized energy to the work piece, minimizing distortion of thin parts. It also produces exceptionally clean welds in applications that cannot tolerate contamination or volatile outgassing. Servometer produces a precision sensor assembly for a military aerospace application by e-beam welding a bellows less than .001 thick to a stainless steel end piece. With a properly designed weld joint, Servometer can e-beam weld parts from 0.03" to 8" in diameter.

TORCHLESS BRAZING

Servometer does not usually suggest brazing electrodeposited nickel bellows to custom end pieces due to the heat involved and the difficulties protecting the bellows material from overheating. Servometer employs brazing to join sub-assembly end pieces together with a proprietary induction brazing process, so the pieces can be subsequently soft soldered to a bellows or an electroform.

ADHESIVE BONDING

Servometer specializes in close-tolerance adhesive bonding with epoxy, anaerobic or cyranoacrylate adhesives. The adhesive application area and thickness are closely controlled for cleaner, sounder assemblies.

MACHINING

Three- and five-axis computer numerically controlled (CNC) screw machines and multi-task turning centers produce the most challenging shapes to tight tolerances. Our machinists produce bellows from 0.020" to 8.5" in diameter with diametral tolerances as close as +/-0.0005" (+/-0.013 mm). In addition to the multi-spindle machine tools, our wire electrical discharge machine (EDM) creates complex geometry using wire as small as 0.003" in diameter. All of Servometer's precision machining capabilities are supported by state-of-the-art computer workstations hosting Pro/ENGINEER 3D design software.

SUB-COMPONENT SUPPLY

Servometer can manufacture or procure all of the necessary sub-components for your assembly requirements, to save you the expense of handling the supply logistics yourself. Servometer will assume single-source responsibility for quality, delivery and price of the finished subassembly.

ENGRAVING

Our computerized engraving services handle part identification and serialization for production lot control. Due to the thin walls of electrodeposited bellows and electroforms, we do not suggest that these components be serialized, but that the engraving be applied to the custom end pieces assembled to these electroformed components.

HELUIM LEAK TEST

Our Helium Mass Spectrometer detects any leakage beyond 1 x 10^{-9} cc He/sec – less than 1 cc in 32 years. Our equipment is calibrated to NIST standards. 100% inspection ensures that a leak tight assembly is delivered every time.

Explanation of Design Data Form Terms

Application Description: This gives a description on how the bellows will be used.

Application: This relates whether the application is for a commercial, defense, or other application, and assists in determining what, if any Export Controls would apply to the bellows or bellows assembly.

Dimensional Requirements

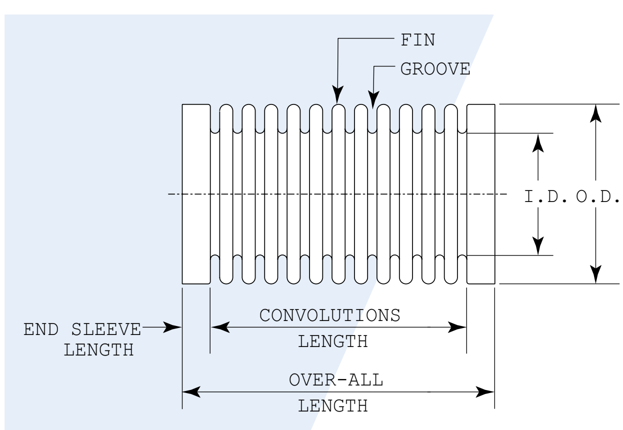
- **Bellows OD, max. /min:** The bellows acceptable outside diameter range for the application. This helps to define the acceptable size envelope for the bellows. It is critical for tool selection and to optimize performance.
- **Bellows ID, max. /min:** The bellows acceptable inside diameter range for the application. This helps to define the acceptable size envelope for the bellows.
- **Effective Area:** The mean diameter between O.D. and I.D., squared and multiplied by .785. It is the equivalent piston area that will produce the same fluid displacement as the bellows for the same axial compression or extension.
- **Bellows Free Length:** The as manufactured length of the bellows convolutions, with the bellows at a neutral at rest position with no applied forces acting on it.
- **Assembly Required:** This lets the design engineer know if assembly of the bellows to end pieces is required.

Environmental Background

- **Bellows Material:** The bellows material required for the application, if known.
- **Temperature, Max/Min:** The potential range of temperatures that the bellows or bellows assemblies might be exposed to in the application.
- **Operating Temperature:** The temperature that the bellows or bellows assembly will experience during normal operation.
- **Media / Environment:** The type of environment or substances (gas, liquids, and materials) that the bellows would be exposed to in the application.

Performance Requirements

- **Pressure Responsive:** Will the bellows or bellows assembly need to respond to changes in pressure in the application?
- **Leak Test Required:** Determines whether the application requires that the bellows or bellows assembly be leak tight.
- **Leak Rate:** If the bellows or bellows assembly is required to be leak tested, if known, give the required leak rate. The achievable leak rate will vary as a function of the bellows material.
- **Operating Pressure:** If the bellows needs to be leak tight, this is the differential pressure the bellows will be subjected to in the application. It is important to specify if the pressure will be applied internally or externally to the bellows.
- **Maximum Internal Pressure:** If the bellows needs to be leak tight, this is the maximum differential applied internally to the bellows, in the application.
- **Maximum External Pressure:** If the bellows needs to be leak tight, this is the maximum differential applied externally to the bellows, in the application.
- **Compression:** In the application, this is the axial deflection, from its nominal free length, that the bellows will see in compression.
- **Extension:** The axial deflection from its nominal free length that the bellows will see in extension.
- **Lateral Offset:** The distance between the centerlines of the ends of the bellows that are parallel but not on the same line.
- **Angular Offset:** The angle between the centerlines of the ends of the bellows.
- **Spring Rate:** The force in pounds applied axially to a bellows, divided by the compression (or extension) in inches resulting from this force, and is a measure of stiffness. The value in the table is for small compression or extension, not exceeding 10% of bellows convolutions length.
- **Cycle Life:** The expected life expectancy of the bellows, as required by the application, considering the loads and deflections that the bellows will be subjected to in the application.
- **Cycle Rate:** The rate or speed (cycles per unit time) that the bellows will experience in the application.



Refer to the "Types of Bellows Ends" figure on page 4

Servomometer®
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501 Little Falls Road • Cedar Grove, NJ 07009-1291
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www.servometer.com

Bellows Design Data Form

Contact Name: ______________________

Company Name: ______________________

Address: ______________________

City, State, Zip: ______________________

Country: ______________________

Telephone: ______________________

Email: ______________________

Please use this Guide to detail your bellows requirement. If you have any questions, please contact us.

Application Description: [ ]

Application (Check One): ☐ Defense ☐ Commercial ☐ Other (Explain): ______________________

Quantities Required: ______________________ Date Required: ______________________

Target Price at Quantity: ______________________

Dimensional Requirements

Please enter bellows characteristics below. If a characteristic is unknown (UK), not applicable (N/A), or to be determined (TBD), please enter to clarify design requirements.

Bellows OD: Max: __________ Min: __________ Effective Area: ______________________

Bellows ID: Max: __________ Min: __________

Bellows Free Length: ______________________

Assembly required: ☐ No ☐ Yes (Please Provide Drawing or Sketch to detail concept and/or end pieces if applicable)

Environmental Background

Bellows Material: ______________________

Temperature: Max: __________ Min: __________ Operating: ______________________

Media / Environment: [ ]

Performance Requirements

Pressure Responsive:
☐ No ☐ Yes

If Yes, please explain:

Leak Test Required: ☐ No ☐ Yes Leak Rate ______________________

Operating Pressure: ______________________

Max. Internal Pressure: __________ Max. External Pressure: __________

Total Stroke: __________ Compression: __________ Extension: __________

Lateral Offset: ______________________ Angular Offset: ______________________

Spring Rate: ______________________ Cycle Life: ______________________

Cycle Rate: ______________________

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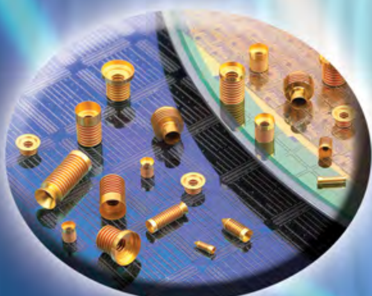
Flexible Shaft Couplings

Electroforms



Electrical Contacts

Edge Welded Bellows

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