

VALVE LIVE LOADING USING SOLON® BELLEVILLE SPRINGS

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DETERMINING IF YOUR VALVE APPLICATIONS NEED BELLEVILLE SPRINGS

Valves leak. Industry sealing experts have cited that 60% of all fugitive emissions are from valve leaks. In addition, it is estimated that 75% of these valves leak at the stem. Valve manufacturers and industries that use valves must ultimately prevent leaks in order to increase safety measures to avoid costly emission fees and enforcement actions. Improvements in packing materials and design have lead to significant reductions in emissions in all industries. However, any stem seal needs stress to be effective, and packing stress falls over time for a variety of reasons. Valve live loading is effective at reducing the loss of packing stress. In its simplest form, valve live loading is the application of a spring load to the gland follower of a packed valve. Solon® Belleville Springs and Flange Washers are designed to maintain sufficient stud tension to aid in packing performance in high temperature and frequently cycled valves. Determining if your valve application is a candidate for live loading can best be decided by answering yes to any of the following questions:

- Is it a packed valve?
- Does the valve cycle frequently?
- Is it motor-operated?
- Is the valve difficult to access?
- Is the valve subject to high-temperature or high-pressure cycles?
- Is the application critical or a safety concern?
- Is there a history of packing leaks?
- Is the valve subject to environmental safety concerns or EPA regulations?

The more “yes” answers, the greater the risk that the valve may leak or that any potential leak would be costly.

SOLON® BELLEVILLE SPRINGS

Belleville springs, Belleville washers, compression washers, flange washers, Belleville disc springs, disc springs or conical washers are all different names for the conical shaped disc that will deflect (flatten) at a given spring rate. This spring rate is usually low relative to the rate of stretch of the gland studs. However, the design of a Belleville spring will produce elastic deflection at high loads in tight spaces. The working load of a Belleville spring can be much higher than that of other spring designs such as coil compression springs.

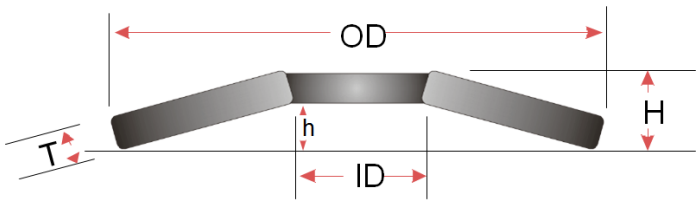


Solon® Belleville Springs

SOLON® BELLEVILLE SPRINGS MAINTAIN LOAD ON A SEAL, GASKET OR PACKING IN VALVE ACTUATORS AND OTHER VALVE COMPONENTS.

A typical Belleville spring is comprised of four main dimensional characteristics:

- Outside Diameter (OD)
- Inside Diameter (ID)
- Material Thickness (t)
- Overall Height (H)



Typical Belleville Diagram
Figure 1

Because of their unique characteristics, Belleville springs offer many benefits:

- Efficient use of space
- High spring forces and elasticity
- Long service life
- No setting or fatigue under normal loading conditions
- Digressive, linear, and progressive deflection curves
- Springs may be stacked in various combinations to produce the required load properties

Belleville springs are available in a variety of materials that can handle temperatures ranging from -400°F - 1100°F (-240°C - 593°C). The most frequently used material for valve live loading is 17-7PH stainless steel. However, Solon Belleville Springs are also available in other materials such as: 301 Stainless Steel, 6150 Alloy and 1074 Carbon Steel, Phosphor Bronze, H-13 Tool Steel, Inconel 718 and Inconel X-750.

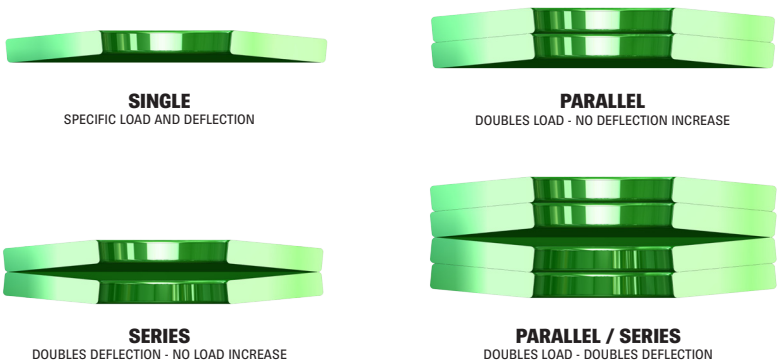
Material selection should be based on application considerations, such as: bolt material, temperature, and environment. Belleville springs can suffer from stress corrosion cracking. Consult technical support at Solon Manufacturing Co. to aid in proper material selection, in addition to coating or plating options.

It is important to note that in certain environments, 17-7PH Stainless Steel is the most frequently used material for valve live loading, stress level and heat treat conditions should also be taken into consideration when used in coastal applications. For more information, please refer to *Coastal Applications* **(link when live)**.

STACKING ARRANGEMENTS OF SOLON® BELLEVILLE SPRINGS

Combining Belleville springs and washers in a variety of stack/series configurations achieves a variety of different levels of load and deflection to sustain heavy loads in small or tight spaces. There are four types of stacking arrangements:

- **Single:** One Belleville spring / washer
- **Parallel:** All Belleville's stacked with the orientation in the same direction
- **Series:** Belleville springs stacked in alternating directions
- **Parallel/Series:** A combination of parallel sets in alternating orientation as shown



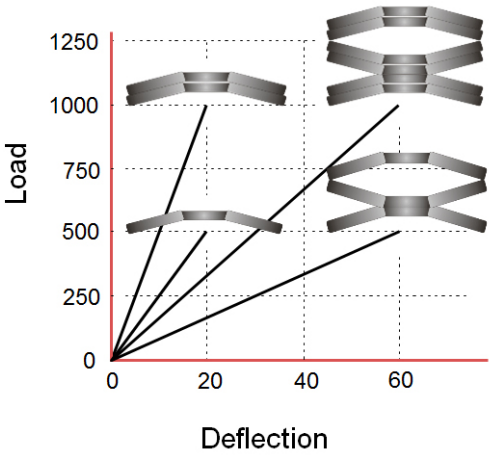
Typical Stacking Arrangements
Figure 2

SOLON® BELLEVILLE SPRINGS SHOULD BE USED ON VALVES TO KEEP BOLTED JOINTS TIGHT WHEN THE BOLTED JOINT INTEGRITY IS A CONCERN.

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For valve applications, it is typically recommended to use stacks for six to ten (6-10) springs in series when space allows. This provides in greater elasticity and results in optimal performance relative to cost.

Figure 3 shows a chart of the load versus deflection of various stacking combinations. For example, six springs in series provides 6X the deflection of a single spring at the same load. Two springs in parallel requires 2X the load to deflect this stack as much as a single spring. A stack of two in parallel with six sets in series would result in 6X the deflection at 2X the load of a single spring.



Deflection Chart Diagram
Figure 3

VALVE APPLICATIONS WITH SOLON® BELLEVILLE SPRINGS

Belleville springs maintain the load on a seal, gasket or packing in valve actuators and other valve components. They can easily be retrofitted into existing valve designs with minimal revisions.

LIVE LOADING OF PACKING

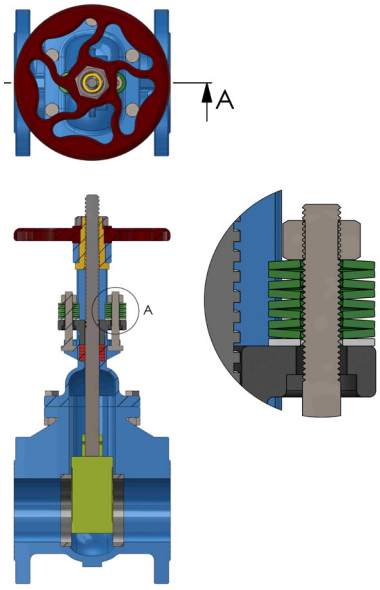
Many valves utilize studs or bolts to exert load onto the gland follower, which applies stress to the packing. As the valve is operated, the seal material consolidates during each operation. High temperature and thermal cycling can accelerate this loss. As this occurs, preload is lost on the seal. Once the preload falls below a certain threshold, a leak will occur. Since the stretch in the stud is small, loss of preload and packing stress can occur quickly.

FLANGE/BONNET GASKET LIVE LOADING

Flanges and bonnets are often sealed with a gasket. The gasket's ability to seal partly depends on the stress maintained on its sealing surface. Flange bolts are tightened to a given preload to generate this sealing stress. Similar to valve packing, this original preload is lost over time due to effects such as differential thermal expansion and thermal cycling. Once a certain amount of preload is lost, a leak can occur. Therefore, Belleville washers are used to increase the elasticity of the fastening system to reduce this preload loss. Solon Flange Washers are often used for bonnet applications.

LIVE LOADING BALL SEATS

Ball seats provide a seal between the ball and the valve's body. There are many materials and styles of seat designs to consider. For more information, see our paper, *Using Belleville Springs on Ball Valves.* The load on the seat must be within a certain range for the seat to be effective. If the load is too low, there will be leakage. If the load is too high, excessive wear will occur and/or the valve will not operate. Often, the seat will have little elasticity (especially metal seats). Since the valve components are generally machined to a set of tolerances, it is difficult to guarantee the seat is properly loaded. The ball seat can be live loaded with a Belleville spring to ensure that the load is within the proper range. Since these loads are usually much lower than those used to seal packing stems or gaskets, the spring stresses can be lower.



Live-Loaded Valve
with Belleville springs
Figure 4

ACTUATORS OR MECHANISMS

Some low stress Belleville's can be designed to "snap over". This is similar to an "oil-can" effect. Some relief valves are designed with snap-acting Belleville's to open the valve quickly at the desired load. These springs are usually custom designs for each application.

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COMPREHENSIVE RISK ANALYSIS

Solon Manufacturing Co. can assist with designing a live loading system. In order to make a recommendation for a valve live loading stack, it is helpful to know the following:

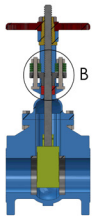
- What is the stud diameter (B)?
- What is the torque or aim preload? Typically calculated by the supplier of the packing.
- What is the radial clearance (R.C.) of the stud? Or, what is the maximum OD of the Belleville?
- What is the axial clearance (A.C.)? Or, what is the maximum height of the stack of Belleville's (including flat washers)?
- What is the maximum estimated temperature at the studs?
- Is the valve in a corrosive atmosphere? If so, what are the corrosive elements?
- What is the expected consolidation of the packing over a given unit of time? (This is optional and would be used to calculate the stack height needed to maintain packing stress over that same time period).
- What is the required residual stud load over that same time period as above? (This is optional and would be used to calculate the stack height needed to maintain packing stress over that same time period).

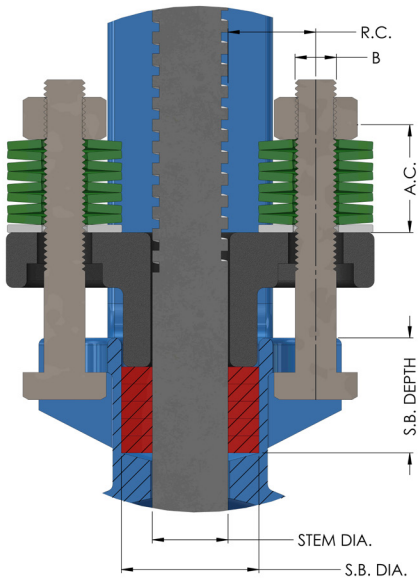
If the packing supplier does not provide the stud load or torque, the following information will help make that determination (see Figure 5):

- What is the valve stem diameter or packing ID?
- What is the stuffing box diameter or packing OD (S.B. DIA.)?
- What is the stuffing box depth (S.B. Depth)?
- What is the number of studs? (Typically 2).
- What is the packing style/type? Who is the manufacturer?

Based upon the application requirements, a comprehensive risk analysis will provide an optimized solution to increase the value of the design by identifying and communicating recommendations with evidence and justification, such as:

- Springs and spring arrangements
- Assembly techniques
- Best practices for live-loading design
- Cost-saving opportunities





Valve Section with Dimensions
Figure 5

Contact Solon Manufacturing Co. and one of our applications engineers will be able to assist you with additional options or suggestions for your pipe and valve live loading applications - *techsupport@solonmfg.com* or call **800.323.9717**.

ABOUT SOLON MANUFACTURING CO.

Since 1949, Solon Manufacturing Co., manufactures Belleville springs and washers and pressure switch instrumentation in Chardon, Ohio. George Davet, BSME, MBA is Vice President and Chief Engineer at Solon and has written and published numerous articles on the application of Belleville springs. To contact George, email *techsupport@solonmfg.com* or call 800.323.9717. To learn more about Solon Mfg. visit *www.solonmfg.com*, where you will find additional technical resources; data worksheets, case studies, material and specification guides, addtional literature, or to chat with a live support representative.

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