Solon Manufacturing Company
Chardon, Ohio
"Valve Live Loading Using Belleville Springs"

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The "Live Loading" of valve packing has been the topic of many articles and papers over the past few years. It has been highly recommended by some, and claimed to have no value by others. The truth is both statements can be correct. It all depends on the individual application. The problem is determining if a valve is a candidate for "Live Loading". In most cases this can be decided by answering a few questions

- Is it a packed valve?
- Does the valve cycle frequently?
- Is it motor operated?
- Is the valve difficult to get at?
- Is the valve subject to high temperatures & pressures?
- Is the valve in a critical application?
- Does the valve have a history of packing leaks?
- Does the valve have to be monitored under the new EPA regulations?

If the answer to the first question and any of the others is yes, there is a good possibility that the valve in question is a candidate for live loading.

Many different packing materials can and have been live loaded, but since the graphite based materials are the most commonly used in live load applications, the data referred to has been based on these materials.

To understand how live loading works, let's first look at how belleville springs work, what live loading is, and when live loading can be used.

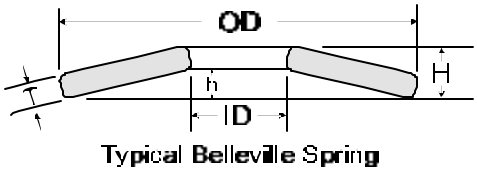

Figure 1

Belleville Springs

Belleville Spring, Disc Spring, Belleville Disc Spring, and Conical Compression Washer are all different names for the same type of spring, one that is conical in shape, designed to a specific relationship between OD, ID, material thickness and height, and made from a variety of spring materials. Because of their unique characteristics, Belleville Springs offer a number of benefits:

- Efficient use of space
- High spring forces with a small deflection
- Largely self-damping
- No setting or fatigue under normal loads
- Long service life
- Straight line load / deflection curves
- Simple adjustment by the addition or removal of individual springs, altering the spring stack characteristics
- Large range of possible applications for individual spring sizes simplifies stock-keeping

Belleville springs are available in materials that can handle temperatures from 400^0 F to $+1200^0$ F. The most frequently used material for live loading is 17-7PH Stainless Steel, but belleville springs are also made from other materials such as 301 Stainless Steel, 6150 Alloy Steel, Spring Temper Phosphor Bronze, H-13 Tool Steel, Inconel 718, and Inconel X-750.

The material selected should be based on the application, environment and temperature to which the spring will be subjected. Because belleville springs can suffer from stress corrosion cracking, the selection of the proper spring material and / or additional protection, such as plating, is very important.

It should be noted that even though 17-7PH Stainless Steel is the most frequently used material, it is <u>not</u> a good material in chloride or fluoride applications. This includes coastal applications where the springs are exposed to salt air. In these applications it is recommended that the 17-7PH springs be plated.

It should also be noted that because different materials have different tensile strengths and different modulus of elasticity, a belleville spring made with the same dimensions but made from a different material may not have the same load characteristics.

The ability to stack belleville springs to increase either spring load or deflection or both is another unique characteristic of this type of spring. There are four different ways a belleville spring can be used: (Figure 2)

1. Single, one spring
2. Parallel, all springs stacked the same way
3. Series, springs stacked opposing each other
4. Parallel / Series, a combination of the two

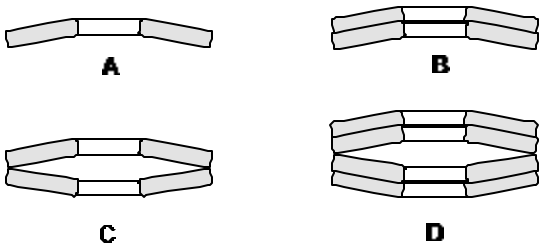

Figure 2

A single belleville spring has a specific load and deflection or movement. Utilizing belleville springs in stacked arrangements provides the user the ability to increase load and / or movement. (Example) Two springs stacked in parallel (Figure 2B) doubles the load of a single spring with no increase in deflection. Three springs stacked in parallel triples the load of a single spring with no increase in

deflection. Two springs stacked in series (Figure 2C) doubles the deflection of a single spring with no increase in load. Three springs stacked in series triples the deflection of a single spring with no increase in load. Two springs stacked in parallel opposed by two springs stacked in parallel (Figure 2D) is a parallel series combination. This combination results in the load of two springs and the deflection of two springs. Adding a spring to each side results in tripling the load of a single spring with the deflection being double the deflection of a single spring. (Figure 3)

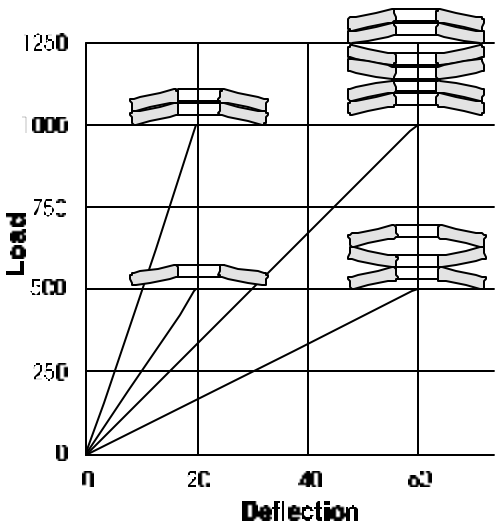

Figure 3

Belleville springs can be and are used in simple applications like replacing lock washers to complex applications as on the Space Shuttle. In the middle are applications where vibration differential thermal expansion, relaxation, and bolt creep are problems, and where high spring loads are required in restricted space. These are exactly the reasons belleville springs are used in valve live loading applications.

Live Loading

In its simplest form, live loading is the application of a spring load to the gland follower

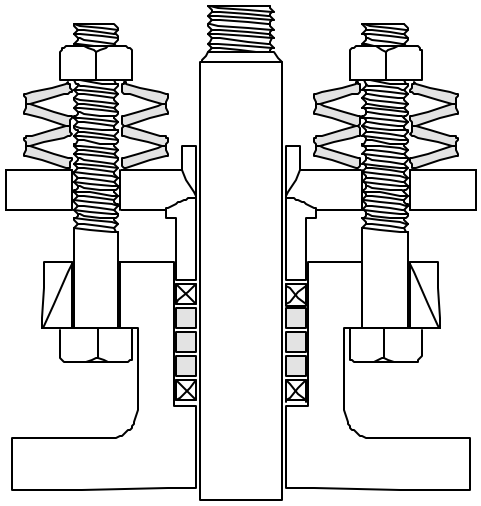

Figure 4

of a packed valve. A belleville spring between the gland follower and its fastening studs and nuts provides an effective way to establish and maintain a controlled amount of stress in the packing set. The amount of the packing stress in a live loaded system can be controlled by the size of the belleville spring used and how far it is compressed or deflected.

In a live loaded packing system, the follower will continue to push against the packing even when packing volume is lost. (by friction, extrusion, consolidation, etc.) The spring load will be slightly reduced as the springs expand, but this reduction in load will be much less than the load that is lost if the packing set was not live loaded. This remaining load allows the packing stress to remain at a level above the minimum sealing stress and enables the packing to remain leak free.

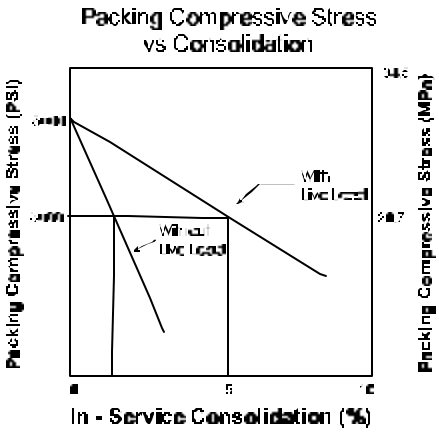

Figure 5

There are many reasons why packed valves leak. The following are some of the most common problems. Some of these cannot be overcome by live loading alone.

Wrong packing material for the application (Self explanatory)

Bent, scored, or pitted valve stems

No amount of spring load can overcome the damage these can cause to a packing set.

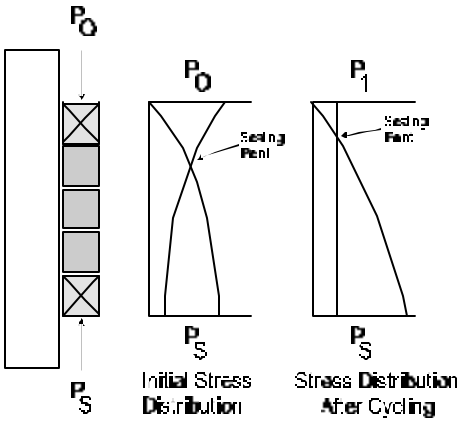

Figure 6

Improper packing installation

This may be the single biggest reason repacked valves leak. The new graphite based materials are not as forgiving as asbestos. These new materials must be installed properly. This includes initially consolidating the packing by cycling the valve and retorqing. This may take from as few as three to five times, to as many as fifteen to twenty. Installation procedures can vary from one packing manufacturer to another. It is best to follow their procedures, whether doing the repacking in house or by an outside contractor. The benefits of live loading are the greatest when the packing has been installed properly.

Infrequent Use

A valve that is not used often, like an isolation valve, tends to leak when it has opened or closed after remaining unused for an extended period of time. What has happened is that the packing has consolidated over time, and the initial compressive load is reduced. Also, when the valve is actuated, additional compressive load is lost. If this reduction in packing stress falls below the minimum seal pressure, the valve will leak. Valves that fall into this category are not typically live loaded, but it has been found that the addition of a single set of springs has been beneficial.

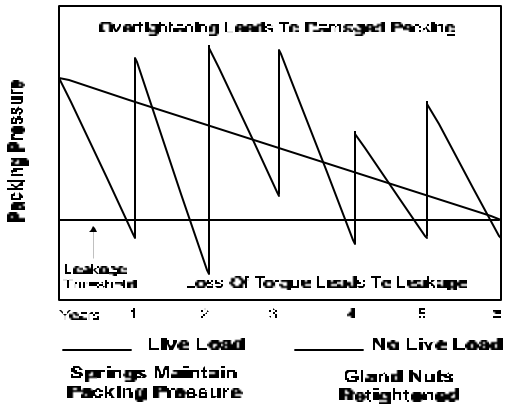

Figure 7

Frequent or high cycles

When a valve is cycled the packing around the stem wears. As the packing is lost, the stress on the packing is reduced. If left unchecked, the valve will eventually leak. This becomes very apparent on highly cycled valves, typically control and motor operated valves. The normal method of overcoming this is frequent retightening of the gland follower bolts. Live loading can alleviate this stress reduction and eliminate the need for constant retightening. (Figure 7)

High temperatures, pressures and critical applications

When valves work at high temperatures and pressures, they are usually in a critical application. Keeping these valves from leaking can be a difficult job. They are subjected to additional factors that make it harder to keep the proper stress on the packing set.

Higher temperatures can cause the gland follower bolts to creep or relax. This will reduce the stress on the packing set. High pressures usually mean higher packing loads, which can be difficult to maintain. Critical application usually means a need for a higher standard of safety. Live loading can be used to help eliminate all of these problems.

Maintenance Headaches

Valves that have been chronic leakers and valves that are inaccessible are also good candidates for live loading. Live loaded valves require less packing maintenance, and the controlled load on the packing set may just help those chronic leakers.

EPA Monitoring

The "Clean Air Act of 1990" has made everyone take a new and closer look at packing leaks. If a valve has to be monitored, it must not only meet the EPA standard leak rate, but it must be able to maintain that leak rate. Also it must be able to do this without being adjusted. Controlled load on the packing set is essential in attaining this. Live loading may be the most cost effective way to meet the EPA's standards.

Almost all of the major valve manufacturers, valve rebuilders, packing manufacturers, and packing distributors now have live loading programs. Some are more complex then others, but all of them work in basically the same way, belleville springs are used to maintain the load on the packing set. The end user must decide which one is best for them.

References

"Manual on Design and Manufacture of Coned Disk Springs (Belleville Springs) and Spring Washers" SAE HS 1582 First Edition, June 1988

AValve Stem Packing Improvements" RP 2233-3 EPRI I Foster-Miller, Inc. December 3,1986

"Engineering Design Manual" Union Carbide, Cleveland, Ohio

AValve Packing and Live Loading Improvements" Aikin,John Valve Magazine I Summer 1992

ACompression Packings and Gaskets in Changing Times" Ferland,R.H. Valve Magazine / Summer 1990

"Packing and Gaskets" McKillop, George R. John Crane Inc. Valve Magazine / Summer 1991

"Maintenance Guide for Air Operated Valves, Pneumatic Actuators and Accessories" Nuclear Maintenance Application Center

"Composite/Graphite Packing Friction & Performance Testing" VanTassell, Doug Argo Packing Co. June, 1992

"A Practical Approach to Implementing a Live Load Valve Packing Program" Caputo, Ted Seals Unlimited Inc.

"Minimize Fugitive Emissions With a New Approach To Valve Packing" Brestel, R. Fisher Controls, Chemical Engineering Progress, 1991

For catalogs and additional information on valve and flange live loading, contact:

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