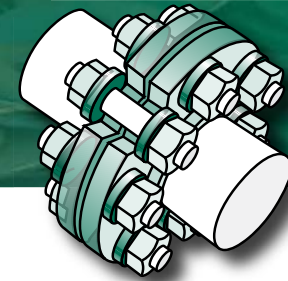


Why Do Gasketed Joints Leak?

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Why Bolts Loosen

Bolted flange joint leaks have always been a problem. In the past, little was done to try to eliminate the problem. New gasket materials and some new bolting techniques have made some improvements. But in high temperature / high pressure applications, the problem still exists.

Prior to 1990, a flange was considered leaking if the leak rate was 10,000 PPM or greater. Under today's new rules, a leak must be repaired if the leak rate is 500 PPM or above. This rate can even be lower depending on the process in the system and varying state and local regulations.

Not only must the flange be leak free at installation, it must maintain a leak rate of 500 PPM or below for a longer period of time. This is due to the EPA's monitoring regulations on Fugitive Emissions.

Flange joints encompass conventional ANSI pipe flanges, heat exchangers headers, tube sheet, sight gages, manways, handholes, valve bonnets and almost any bolted gasketed joint.

A bolted flange joint leaks when the material contained in the system escapes through the gasket pores or around the gasket and the flange face. This usually occurs because the load on the gasket has fallen below its minimum seal pressure. Preventing flange leaks can be a difficult task. It is necessary to maintain the contact pressure above the minimum seal pressure between the flange and the gasket surfaces. This must be done initially, as the gasket and bolts relax, and also as the temperature and pressure of the contained process changes.

The initial preload can be attained by using several tried and true methods. The problem is maintaining this preload through the life of the joint. This paper discusses the main factors that cause bolted flange joints to leak and how and why the use of Solon Flange Washers® (specially engineered Belleville springs for high temperature flange applications) can prevent flange leaks and reduce Fugitive Emissions.

Embedment Relaxation

When new studs and nuts are first tightened, both the stud and nut threads and the joint contact surfaces, contact each other only on microscopic high spots. These high spots will be grossly overloaded, well beyond their yield point. Therefore, plastic flow will continue until the contact area increases sufficiently to stabilize or stop the yielding process, relaxing the load on the bolt. This can account for as much as 5 - 10% loss in initial preload. Retightening the parts can partially compensate for this type of relaxation. Embedment relaxation is virtually unavoidable and cannot be prevented, but you can compensate for it.

Gasket Creep

Most gaskets are made of plastic or semi plastic materials. They must deform to do the job intended. Like any plastic material, they will creep and flow when first subjected to high surface loads. Most of the gaskets used today in high temperature and high pressure applications have reasonable loading curves and fairly steep unloading curves. (Figure 1) Because of this, even the slightest loss in load can cause a joint to fall below the minimum seal pressure. Like embedment relaxation, gasket creep is unavoidable.

**Load Deformation Curve
304 SS Asbestos Filled Gasket**

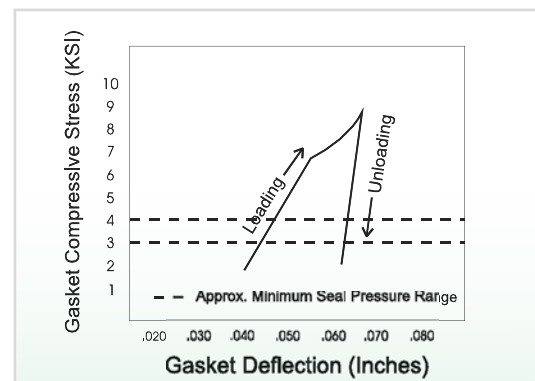


Figure 1

304 SS Asbestos Filled Gasket

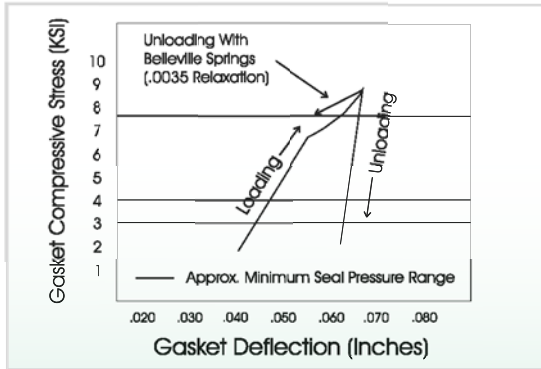


Figure 2

Figure 2 illustrates the effect on the unloading of a gasketed flange joint using Belleville springs. Solon Flange Washers compensate for the gasket relaxation sufficiently to maintain the joint compression well above the minimum seal pressure.

Bolt Creep

Bolted flange joints in high temperature service will have a reduction in tension due to a reduction of the Young's Modulus and will relax with time. This is in addition to the initial embedment and gasket relaxation. Figure 3 illustrates this reduction in bolt tension at 1000 hours versus the bolt operating temperatures.

Stress Relaxation - 1000 Hours as a Function of Bolt Temperature ASTM A193 B7 Stud

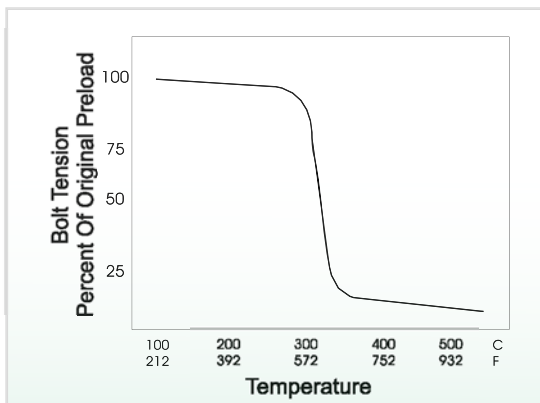


Figure 3

Vibration

Vibration can also be a factor causing flange joints to leak. Loosening due to vibration starts at a very low rate and a very gradual relaxation from the original preload.

(Figure 4) When the preload tension falls below a critical value, the relaxation rate increases, and the nut may even rotate and further loosen the joint.

Vibration Joint Loosening

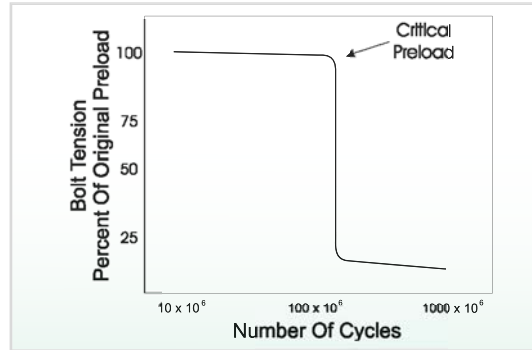


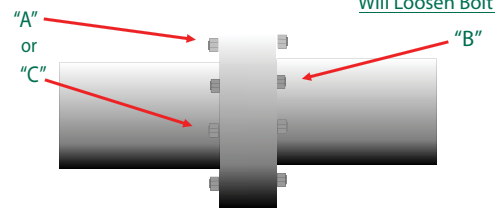
Figure 4

Elastic Interactions

Gasketed bolted joints should be pattern tightened in stages. Irregular tightening or loading can distort and damage the flange and gasket. In theory, one should tighten all bolts simultaneously. This is very difficult to do in practice. Therefore, a more

practical procedure is to tighten all the stud bolts in stages. This is usually

Tightening Bolt



done by using a cross pattern sequence around the bolt pattern. The first pass is tightened to approximately 30% of the final desired preload. The second pass is done using 60% of the final preload, and the same bolting sequence. The third pass is done using 100% of the final preload, again using the same sequence.

Elastic Interaction is a phenomenon which occurs between bolts and joint members as a group of bolts are tightened. When the first bolt in a joint is tightened, the bolt is stretched and the joint is partially compressed. When an adjacent bolt is tightened, the joint in the vicinity of the first bolt is further compressed. This allows the first bolt to relax. Even if a perfect initial preload had been achieved on these bolts, only the second bolt would have that preload. These load losses, depending on the stiffness of the joint, may be 50 to 60% of the original bolt tension. Just the tightening of the second bolt eliminates some of the preload of the first bolt. The amount of the elastic interaction depends on the size of the joint, the type of gasket used, the distance between bolts, and the stiffness

of the members. Figure 5 shows the relaxation of a single bolt using this procedure.

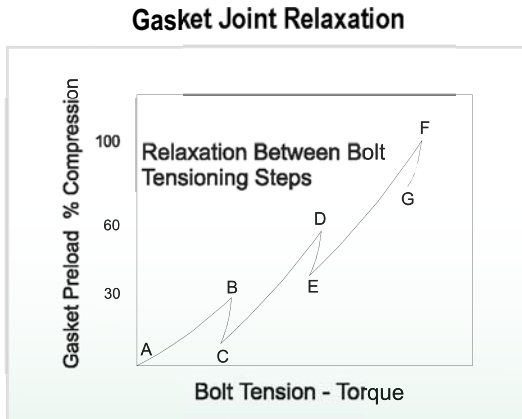


Figure 5

In the event all studs are tightened simultaneously, relaxation can and will occur after the final tightening. This is shown in Figure 6.

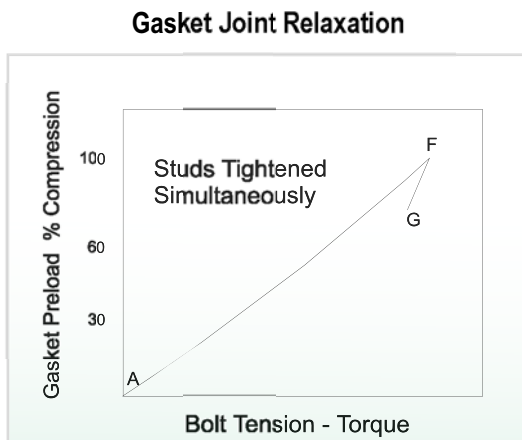
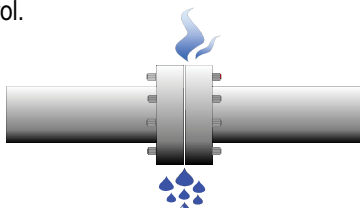


Figure 6

Another problem that occurs when tightening bolted gasketed joints, is the inconsistent preload between all the bolts. This is thought to occur because of bolt relaxation and elastic interaction. This inconsistency or scatter seems to be a common problem with joints that are tightened using torque control.



Pattern of Residual Preload

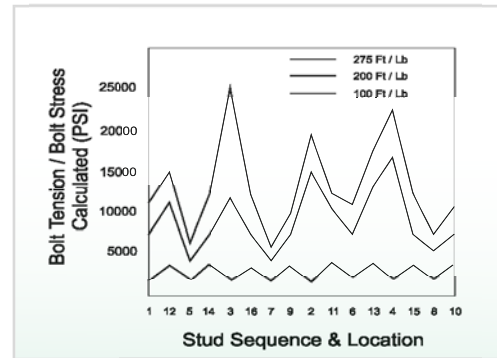


Figure 7

Figure 7 is a plot of the residual preload of a flange with 16 1¼ inch bolts. The bolts were torqued using the method previously mentioned. Measurements were taken after each pass. The sawtooth pattern is the result of relaxation and elastic interaction between the bolts. This sawtooth pattern remained even after four additional clockwise passes at a torque of 275 ft. lbs.

Pattern of Residual Preload

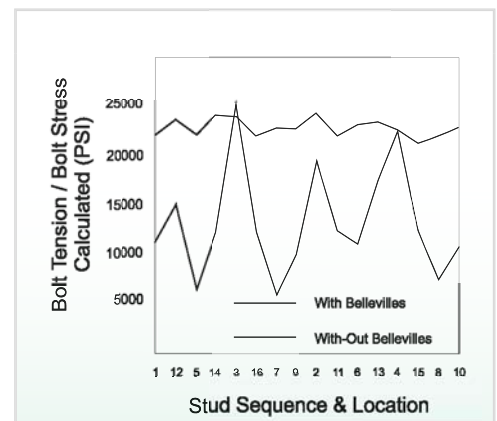


Figure 8

Figure 8 shows an additional plot of this same flange with Solon Flange Washers (Belleville springs) added to each bolt. The addition of these reduces the preload scatter and nearly eliminates the sawtooth bolt tension pattern.

Differential Thermal Expansion

As temperatures rise most materials expand. In a flange joint the heat is usually coming from the process in the system. Since the gasket and the flange are in closer contact with the process stream, they heat up faster than the bolts. This means that the joint members are expanding more than the bolts.

This increases the tension in the bolts and increases the load on the gasket. The extra load on the gasket compresses it more than it was during assembly, which occurred at ambient temperatures. If the system cycles and the joint cools down, the joint members will return to their original thickness. Since the gasket was further compressed and it is not fully elastic, it cannot return to its initial compressed thickness. This allows the bolt to relax, and some of the initial bolt load is lost. If this heating and cooling repeats enough times, it can reduce the initial bolt load and gasket load to a point that the flange will leak. Solon Flange Washers can be used to eliminate the effects of differential thermal expansion. The movement in the joint is taken up by the movement of the flange washer, and the load on the bolt and gasket will still be above its minimum seal pressure. An additional benefit of using Solon Flange Washers is that they may not need to be retorqued after the system has come up to operating temperature. Also, some flanges can now be insulated that could not previously be insulated.

Summary

Gasketed joints may leak due to a variety of reasons. One of the most prevalent causes is due to a loss of bolt preload.

There are many methods used to compensate for the

Solon Flange Washers... maintain a tight, leak free joint.

various factors working to reduce the initial bolt load and gasket load on a bolted joint. Some are better than others, but none of them do much to maintain the loads needed to prevent the joint from leaking once the system is in operation and cycling for any amount of time. Solon Flange Washers are constantly working to maintain a tight, leak free joint. They do this by increasing the elasticity of the bolting system often by a factor of 7 to 15. When considering the alternatives, the use of Solon Flange Washers is the most economical method to reduce bolted flange joint leaks, thus reducing fugitive emissions.

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Founded in 1949, Solon Manufacturing Company engineers and manufactures Solon Belleville Springs® and Industrial Pressure Controls for a variety of industries worldwide. Sound engineering resulting in practical answers is the basis upon which Solon designs and manufactures all of its products.

Solon's Belleville Spring Division carries a wide range of Belleville springs and flange washers in a variety of materials and coatings for use in applications where high spring loads are required in a very small space. Solon's Industrial Controls Division carries a complete line of standard and custom engineered pressure controls such as vacuum, differential, hydraulic, bellows-actuated, diaphragm-actuated, piston-actuated, explosion-proof, gauge indicating and temperature-compensated.

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