Allrisk Engineering

Fire Risk

Long Bolted Flangeless Valves

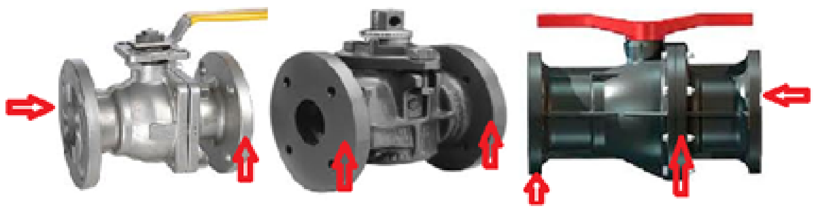
ABSTRACT

The weakest part of any process piping system is its non-welded connections. The partial or complete failure of piping connections to process equipment and valves during intense fires is a well documented occurrence. These piping system failures greatly increase the severity of these fire hazards and inevitably lead to greater damage to equipment and loss of production.

Valves can be constructed into various shapes and styles; therefore, some types of valves are more likely than others to lose containment in a fire. The intention of this paper is to offer information concerning the high fire risk associated with flangeless long bolted valves in the hydrocarbon process industry and offer potential mitigation options for this risk.

WHAT IS A LONG BOLTED FLANGELESS VALVE?

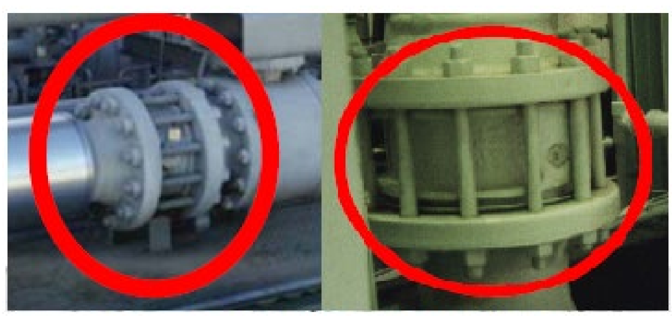
Two major types of valve fittings used in process piping systems are flanged valves and flangeless valves. With flanged valve bodies, there is an exposed lip that allows short bolts to connect it to the extended pipeline system (shown in the following figures). A flangeless valve body has no lip and is commonly attached by two upper or lower long bolts to align in place into a piping system (shown in the following figures). A flangeless valve may also be known as a wafer valve.



Flanged Valves (Red Arrows Show Flanged Lips on Valve Bodies)

Flangeless Valves

A "long bolt", also commonly termed as a 'through bolt', connection is used to squeeze and attach the flangeless valve in between two pipes (shown in the following figures). To be considered a valve with "long bolts", the exposed portion of the bolt is typically considered to be more than 3 inches in length.



Through Bolted, "Long Bolted", Valves

One of the advantages of flangeless valves is its lower material costs. They are also lighter than a flanged valve. Many flangeless valves are used as long bolted wafer (long bolted flangeless) check valves. These valves are frequently used in the discharge lines of pumps and compressors. The lower mass of the flapper in a wafer check valve is often the reason why these types of valves are preferred over conventional flanged checked valves.

INSTALLATION ISSUES

The installation of flangeless valves requires the use of very experienced pipe fitters. A flangeless valve requires the pipe to be hung and aligned before the bolting process begins. The lower bolts are then installed. The valve is dropped between the piping ends and is set on the installed bolts. Then the last bolts are added. The flangeless valve requires a hefty and timely process to align the gaskets and to bolt it together correctly. To install a flanged valve, by contrast, all the pipe fitter has to do is simply raise the pipe up and bolt on the valve to the pipe

The flangeless valve is often physically smaller and lighter than its conventional counterpart and therefore, is easier to fit into a piping system.

FIRE RISK

Fires in the hydrocarbon processing industry tend to burn at a much more rapid pace than conventional fires and can reach up to 2000^0F with a high intensity heat flux within minutes. Flame impingement can be defined as when the flame tips of a fire touch a given object. This is the hottest portion of a fire. If a “long bolted” valve is exposed to direct flame impingement, failure of the valve will occur within minutes.

When the temperature of steel exceeds temperatures of 1000^0F it loses up to half of its strength immediately. Most valve bodies and bolts are composed of carbon steel or carbon steel alloys. When bolts, in the case of “long bolted” valve are exposed to a direct flame impingement; the bolts heat up, expand, and begin to loosen from the fittings holding the pipe together. In a hydrocarbon fire elevated temperatures can occur within minutes of a fire starting. The valve will begin to come apart and leak hydrocarbons- further fueling the fire.

Common uses for flangeless check valves are on the discharge line of process pumps. Unfortunately, these pumps are the most common sources of leaks and ensuing fires in a hydrocarbon processing facility.

FIRE TESTING

A test report issued in 1977 by the Standard Oil Company of California on “long bolted” flangeless valves in kerosene service exposed to a high intensity temperature (natural gas) fire stated that long bolted flangeless valves failed quicker than flanged valves.

In the study both flanged and flangeless valves were tested in five high intensity hydrocarbon fire tests using natural gas as the fuel source. A high intensity fire demonstrates a ‘rapid’ rise temperature to approximately 2000^0F within 5 minutes. The purpose of using natural gas for the test was to reproduce conditions which might be expected in hydrocarbon processing plant fires. The natural gas fire created a heat flux of 140,000 BTU/HR-FT^2. Natural gas burns clean and allowed observation during testing. Kerosene was used as the process fluid as it readily leaks through the smallest opening. Kerosene also changes the appearance of a natural gas fire making it easy to observe leaks. Kerosene was circulated through a 2 inch piping loop that included a heat exchanger to cool off the heated material. Both 150 # and 300 # ANSI rated 2 inch valves were used in the fire tests to compare leakage rates at the flanges. API 601 spiral wound type gaskets were used in every valve and test. Exposed long bolts, 5/8 inch diameter ASTM Grade B7 bolts, were used in all long bolted flangeless applications. Bonnets were removed and replaced with blind flanges to eliminate any effect from packing leaks.

The 150# valves were used in three tests. These tests directly compared both flanged and exposed long bolted flangeless valves.

The 300 psi rated valves were used in two tests. The first test compared 300 psi flanged valve with a long bolted flangeless valve. The second test evaluated a flanged valve with a long bolted flangeless valve with a steel sheet cover acting as a shield. The 31 gage (0.010") galvanized steel sheet was held in place by a stainless steel band covering exposed bolts and non-welded piping connections. The sheet was cut 3" longer than the end to end dimension of the valve body and trimmed to overlap around the bonnet.

Testing data gathered included the temperature increase of the valve body and the bolts as well as the time at which the piping connections began leaking and finally the point at which a self sustaining fire developed.

Results

Once the exposed long bolt temperatures reached 1000^0F and the bolts reached their yielding temperature, the flangeless valves leaked. Direct flame impingement heated the long bolts which began to expand and grow in length much faster than the valve body, which was being cooled by the kerosene circulation. The leakage was cyclic in nature.

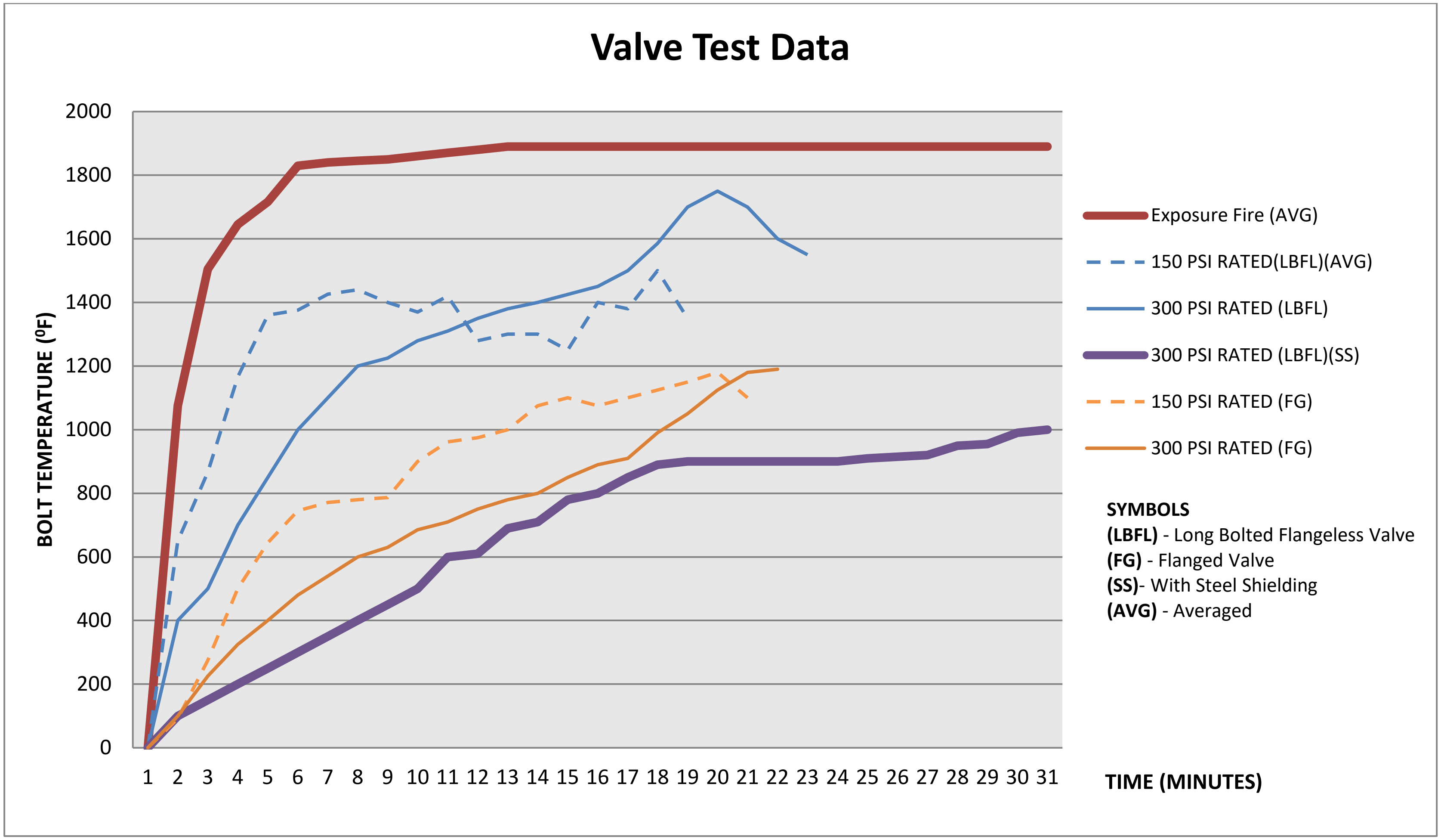
It is hypothesized that the cyclic nature of the leakage was produced when bolt growth reduced gasket loading, which in turn resulted initiated leaks. The leaks started near the hottest side of the valve. The leaking product cooled the hot bolts and thus caused them to shrink and retighten the gasket. As additional fuel in the center of fire is frequently starved for oxygen, localized temperatures may be lowered as burning becomes less efficient. It is thought that this phenomenon permitted the exposed bolts to cool, contract, and retighten. When this sequence reduced or stopped a gasket leak, the fire intensity and temperature immediately surrounding the bolts increased starting the leakage cycle again.

The long bolted 150# flangeless valves began leaking within 5 minutes. The 150# flanged valves had no observable leaks at this point. The cycling gasket leak became self-sustaining after 10 minutes with the long bolted valves. The 150# flanged valves did not leak.

The long bolted 300# flangeless valves began leaking at 8 minutes. It became a self sustaining leak fire in 17 ½ minutes. The 300# flanged valve did not leak.

The final test compared a 300# long bolted flangeless valve covered by a galvanized steel sheathing with a 300# flanged valve without shielding. Minor leakage on the shielded flangeless valve began within 8 minutes; however, the steel sheeting confined and minimized the leaking. This test continued for 28 minutes with flame temperatures exceeding 1850˚F at which point the flanged valve began to leak through a gasket joint. The flangeless valve showed signs of bolt failure at this point but leaking was contained and minimal.

This test indicated that heat shields installed over long bolted flangeless valves helps to prevent direct flame impingement and reduces leakage rates. With shielding installed, the valve body, flange, and bolt temperatures were all fairly close together (within 125˚F). In contrast, during the previous tests, the exposed long bolts ran progressively hotter and approached environment temperature ranges (1500^0F to 1700^0F) in approximately 15 minutes.

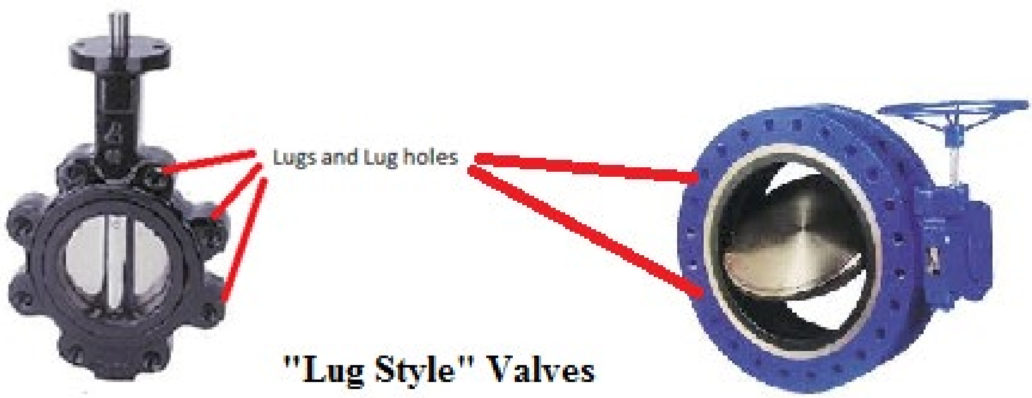

Valve Test Data
BOLT TEMPERATURE (⁰F)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
TIME (MINUTES)
Exposure Fire (AVG)
150 PSI RATED(LBFL)(AVG)
300 PSI RATED (LBFL)
300 PSI RATED (LBFL)(SS)
150 PSI RATED (FG)
300 PSI RATED (FG)
SYMBOLS
(LBFL) - Long Bolted Flangeless Valve
(FG) - Flanged Valve
(SS)- With Steel Shielding
(AVG) - Averaged

RISK MITIGATION ALTERNATIVES

There are three methods of mitigating the leakage problem associated with long bolted flangeless valves and flame impingement: Valve Substitution, High Strength Bolting/Water Spray Protection, and Heat Shields.

VALVE SUBSTITUTION

One potential substitution for a flangeless valve is a “lug style” valve. A lug style valve is designed similar to the flangeless connection. A lug style valve has the same face to face as a wafer, or flangeless valve body. The lug holes provide an opening where pipes can be bolted (shown on the following figure). This opening provides a metal casing for the bolts, which will prevent the bolts from heating up significantly faster than the valve body and protects them from direct flame impingement.



"Lug Style" Valves

HIGH STRENGTH BOLTING / WATER SPRAY PROTECTION

Follow ASTM A193/194, “Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purposes,” whenever installing a flanged or flangeless valve. Using this standard in conjunction with ASME B31.3, ASME guide to Process Piping Design, a suitable bolt can be chosen for high temperature conditions.

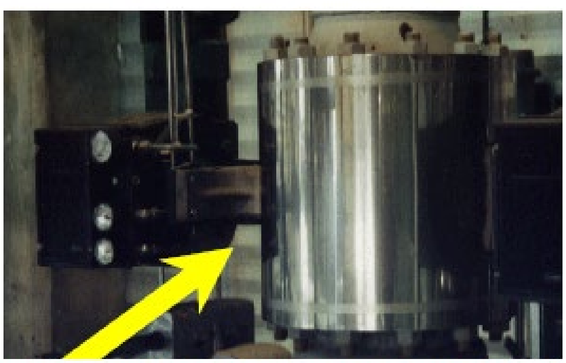
Fire impingement temperatures on process valves can reach 2000°F. Therefore, the high density waterspray protection provided for pump protection should also cover the exposed bolts <u>even if high temperature bolting has been installed.</u>

NOTE: ASME B31.3 (Table A-2 of ASME B31.3) shows that ASTM A193 Grades B7 and B16 bolts are suitable for temperatures below ~1000 ^{0}F. The typical nuts to adjoin these bolts are ASTM A194 nuts.

HEAT SHIELDS

A typical heat shield is a stainless steel sheet wrapped around a valve with long bolts (shown in the following figure). This steel sheet can have up to a minimum thickness of .06 inches and must overlap the entire pipe and give an added 6 to 8 inches of overlap to shed water in cases of condensation. The shield will be held onto the pipe by stainless steel bands.

This shield allows the valve and bolts to heat more evenly and promote even thermal expansion; therefore, slowing the effective leakage point and rate. It should be noted that this shielding will increase the normal operating temperature of the bolts. Therefore, the bolting materials will need to be reviewed prior to installing a shield.



Heat Shield in use with "long bolted" flangeless valve

CONCLUSION

Many companies are starting to limit or even prohibit the use of long bolted flangeless type valves in new projects. API Recommended Practice 2001 & API Recommended Practice 553, both discourage the use of long bolted flangeless valves in general and specifically for use in high fire risk applications. If these piping connections are already installed in high risk areas, such as over process pumps, risk mitigation alternatives should be considered to minimize their fire risk.

REFERENCES

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