White Paper

Performance Capabilities of Victaulic Mechanical Grooved Pipe Joints Under Extreme Fire Conditions

By: Len Swantek and Catsy Lam

For the everyday users of mechanical piping systems, the name “Victaulic” is well known for its reliable grooved piping solutions for a wide range of applications. However, what may not be so evident is the ability of Victaulic grooved pipe couplings to withstand direct exposure to fire under some of the industries’ most critical service conditions. Whether it be in a commercial building, chemical plant, offshore platform, fuel refinery, or a ship’s engine room and machinery spaces, exposure to fire in no way disrupts the ability of these products to provide their full rated pressure and designed joint sealing performance. This paper discusses why Victaulic grooved pipe couplings are fire-resistant, what specific fire exposure standards they meet, and actual examples of validation tests conducted by national and international certifying agencies.

The housing: the first line-of-defense against fire

The Victaulic coupling’s housings are cast of durable ductile iron in accordance with ASTM A-536 of material grade 65-45-12. These housings are capable of withstanding direct fire exposure to temperatures in excess of 760°C (1400°F) with no adverse effects to their structural or metallurgical attributes.

This first line of defense shields the internal gasket and protects it from direct exposure to flame and intense heat from the fire source. Depending on the duration of the direct exposure to flames, the ductile iron housings will eventually transfer a portion of the heat to its internal surfaces and thus also to the gasket.

To ensure a consistent level of fire performance, the Victaulic gasket compounds are engineered to provide a unique balance between thermal resistance and pressure responsiveness. The objective here is to maintain the highest degree of sealing performance at the maximum temperature limits. This is where gasket properties come into play.

Gasket properties and how they help to ensure the highest degree of sealing during fire

There are several key factors that determine the gasket’s resistance to extreme heat:

1) The compound formulation and manufacturing process

2) The gasket material properties and the gasket design

The gasket compound formulation utilizes ingredients with high thermal decomposition temperatures to ensure minimum material loss during fire. The compound is also designed to allow certain levels of change in critical material properties such as hardness, tensile strength, elongation, compression set and compressive stress relaxation.

Heat stability of elastomers is based on many factors such as polymer type, filler type, curatives, antioxidants and other additives used in the formulation, and resulting crosslink density in the curing process. Each ingredient is studied using Design of Experiments; the compound formulation is optimized to achieve the highest heat resistance. The curing process is also optimized to achieve the maximum state of cure with desired material properties uniformly across the entire gasket cross section. Both the gasket formulation and manufacturing process are highly controlled to ensure heat resistance performance of the gasket is maintained in its finished shape or geometry.

The fire endurance of the gasket is further enhanced by its design. The design is developed to best fit the specific sealing material properties under different stress conditions. The volume of the gasket cross section is optimized to accommodate thermal expansion of the sealing material as well as the pipe under extreme temperature conditions. The stress concentration and distribution across the entire seal geometry is studied to prevent the gasket from splitting, cracking and from permanent deformation. The gasket geometry is also optimized to ensure there is always sufficient sealing force on the pipe surface to maintain a pressure responsive seal.

Combined, these characteristics help to achieve gasket integrity under extreme heat conditions. The gasket has very limited decomposition; it does not break down inside the housings; its physical property changes are minimal, and it continues to provide leak-tight performance.

Product qualification to codes & standards

In order to qualify the complete mechanical joint for specific markets or applications, the coupling and gasket are assembled onto pipe ends and then placed over a fire source as required by each of the governing standards. The assembled pipe joint is then subjected to intense fire endurance tests as dictated by the individual agencies who have jurisdictional authority in the local market or region.

For example, grooved mechanical pipe joints used in the maritime industry for onboard applications must endure a fire exposure test for 30 minutes at 800˚C (1470˚F) without leaks or malfunction. The test is conducted in accordance with each agency's "Rules", which also follow international fire test standards ISO-19921 and ISO-19922. Thermalcouples are placed at various locations around the test assembly to monitor surface temperatures throughout the test period. Because of the heat transfer rate of ductile iron, these surface temperatures are also consistent through the coupling's cross section, resulting in very similar exposure temperatures at the gasket surface. This dry heat characteristic can be particularly damaging if the material properties cannot be maintained throughout the duration of the test. Following the fire exposure conditions, the mechanical joint is then hydrostatically pressure tested to 1.5 times the rated working pressure with no allowance for leaks. This test represents one of the most demanding fire performance criteria across a wide range of heavy industries.

Another extreme fire exposure qualification test is conducted by VdS Schadenverhütung GmbH in Germany, as part of the certification requirements for mechanical joints used in fire protection systems in buildings and facilities. The laboratory exposes the assembled mechanical joint to a pan fire using methanol as the fuel source. In this scenario, the test joint is completely engulfed in a concentrated fire and must withstand a direct flame temperature at or near 800˚C (1470˚F) for up to 15 minutes with no water inside the assembly. The same heat transfer characteristics experienced in the ISO-19921 fire simulation are again working to deliver these temperature extremes to the gasket surface inside the assembled coupling. In this test, there is no internal pressure to aid the gasket in maintaining an energized seal against the pipe surface. The seal must rely solely on its own physical properties to resist the temperature and maintain its overall shape and geometry and its compressive stress relaxation characteristics throughout the burn period. This fire test is also followed by a hydrostatic pressure test at 1.5 times the product's rated working pressure while the test assembly is monitored for leaks.

Other similar fire exposure tests including API-607 and UL-852 are used routinely to qualify new seal materials and coupling designs that are intended for high hazard applications where the inherent risk of fire is always present. Such standards can involve direct flame temperatures exceeding 871°C (1600˚F) as part of the qualification requirements for components used in dry fire protection systems.

Comparison with alternative pipe joining methods

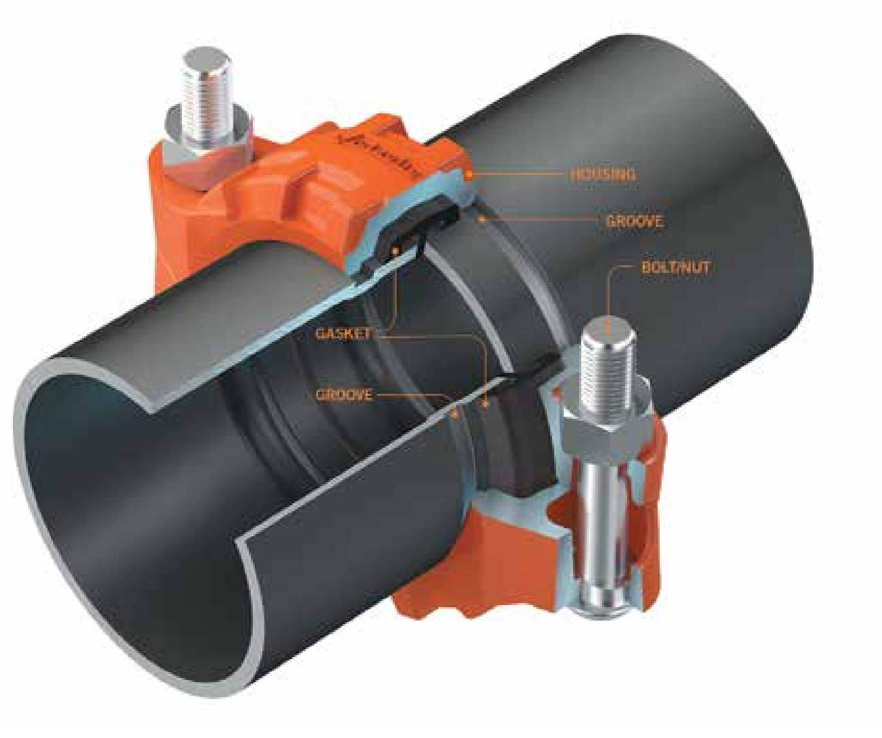
Unlike flanged connections, where the internal seal is exposed between the mating flange surfaces, the seal inside a mechanical coupling is totally encapsulated by the coupling housings and the mating pipe ends. This prevents the seal from being exposed to harmful direct heat or flame conditions. The assembly and seal compression is achieved radially around the pipe ends by the nature of the bolt orientation (perpendicular to the pipe as compared with tangential or bolting in-line with the pipe with flanged connections). In this orientation, any incremental expansion of the bolts in extreme heat is accommodated by the internal compression of the seal along with a certain percentage of seal expansion that is allowed to occur inside the coupling. In all cases, the gasket does not break down under these conditions and maintains its seal with the pipe.

Threaded connections are also susceptible to potential leaks over time as the sealing compounds dry out and crack, causing small leak paths between the mating threads. Direct fire exposure to these same connections accelerates this drying or “aging” effect whereby the joints can develop leaks irrespective of the care and quality of the original thread fabrication and joint installation.

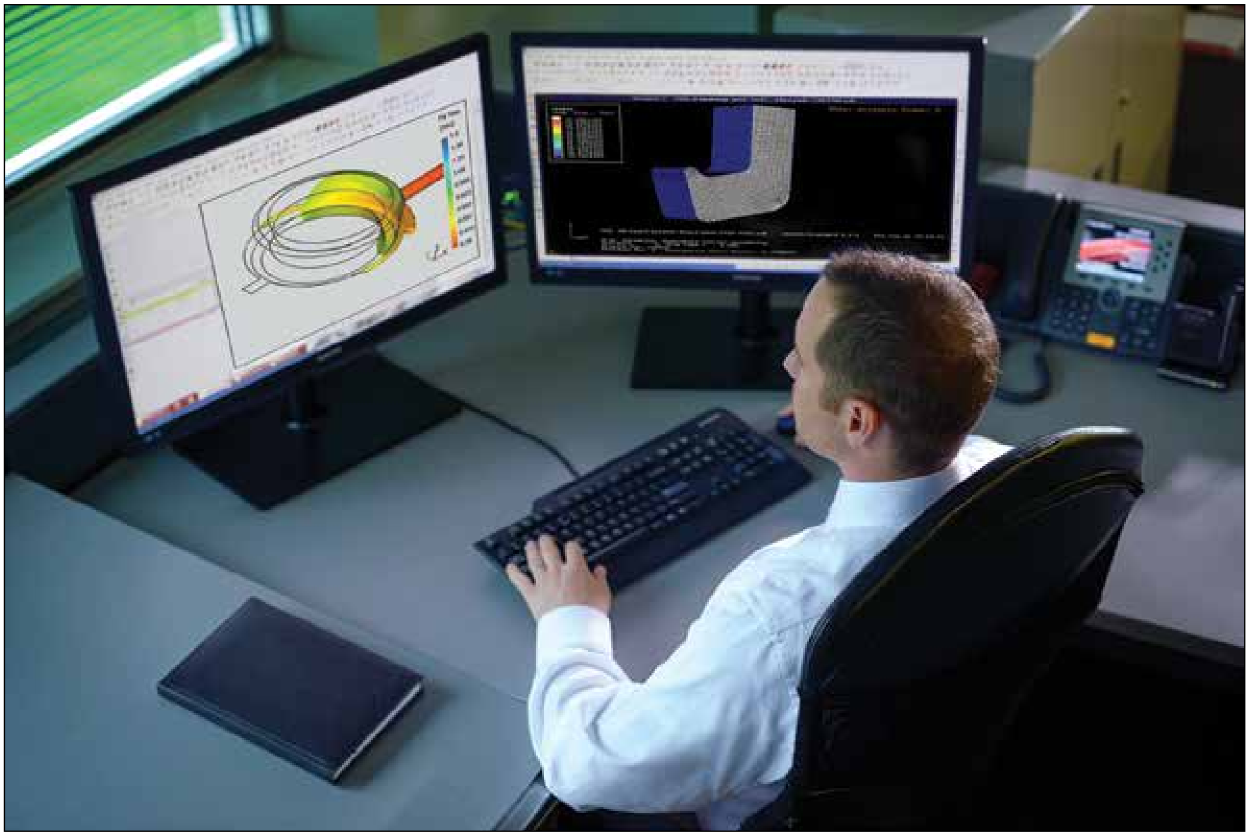
When Victaulic grooved mechanical couplings are properly installed in applications in agreement with the product’s published performance ratings, there is no concern for the joint’s ability to withstand the extreme conditions of a fire event. This is a critically important benefit to the building owner and is often taken for granted as the joints work quietly and reliably for many years behind walls, ceilings and other concealed spaces.

Standing the test of time

For nearly 100 years, Victaulic products have stood the test of time in a vast array of piping systems applications. Whether it be a fire suppression system quietly maintaining its watch over a building and its occupants, or a cyclically operating hydraulic line onboard a sea-going vessel, Victaulic's mechanical pipe couplings, fittings and accessories give customers confidence, knowing those products have been tested and validated in some of the most extreme conditions. By investing in research and development of new products, materials and manufacturing processes, Victaulic maintains its position as global leader in providing reliable, world-class pipe joining solutions.



There are several attributes of the mechanical joint assembly that make it resistant to extreme heat:
the ductile iron housings; the gasket material properties and the resulting sealing force when the bolts and nuts are fully assembled.



Fire endurance of the gasket is further enhanced by its design. The design is developed to best fit the specific gasket material properties, while the geometry is optimized to ensure there is always sufficient force on the gasket to provide a pressure responsive seal.

Victaulic FireLock™ Installation-Ready™ Fittings put to the test by UL, LLC in the United States, as part of the certification requirements for mechanical joints used in dry pipe fire protection systems in buildings and facilities.

Global Manufacturing Consistency

As the originators and innovators of the grooved pipe joining system, Victaulic maintains strict process control all the way through the product life cycle, from initial development to post-production testing and inspection. When temperature, pressure and fluid ratings for these products are established, these ratings must be consistently supported by the materials, sub-assemblies and complete finished products. The organization is dedicated to providing high quality products from all of its global manufacturing locations and works closely with its customers to ensure critical requirements are being met or exceeded. Victaulic products are also closely monitored by a large number of national and international regulatory authorities, who conduct routine assessments to ensure consistency and compliance with local codes and standards.

Author Biographies

Len Swantek is Director of Global Regulatory Compliance at Victaulic. He has over 28 years of experience in various engineering and management roles at Victaulic including applications engineering, codes and standards development, product certifications and agency auditing.

He is also a member of the National Fire Protection Association (NFPA), the National Fire Sprinkler Association (NFSA), the European Fire Sprinkler Network (EFSN) and the Fire Protection Association (FPA).

Len leads the global regulatory team from Pennsylvania, USA, who collectively interface with more than 80 international regulatory authorities worldwide.

Catsy Lam is Material Sciences Technical Leader at Victaulic, and has over 10 years of product development experience with sealing materials, coatings, lubricants, adhesives and non-metallic piping. She is responsible for formulation and compounding, material performance testing and validation, chemical analysis, technical support, product specifications and engineering standards.

Catsy also serves as technical lead in developing sealing materials including elastomers, thermoplastics, engineering polymers and polymer composites for Victaulic piping solutions used worldwide.

She is a member of the Materials Technology Institute (MTI) and the American Chemical Society Rubber Division (ACS).

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