

Field test of high hardness O-rings made from Viton extreme with advanced polymer architecture in pipeline valves containing very sour gas

Abstract

High hardness Fluoroelastomers (copolymer of ethylene-tetrafluoroethylene-perfluoro methyl vinyl ether with Advanced Polymer Architecture) compound was used to make thick and large size O-rings and field tested in pipeline valves containing very sour gas. The sour gas contains 23% H₂S, 11% CO₂, CH₄, low molecular weight hydrocarbons, amine corrosion inhibitors, methanol and water at 32°C and 1200 psi. The results show that after the field test these O-rings were in good conditions and were completely resistance to sour gas and no cracks, bubble, blister, swelling, hardening and softening in the O-rings were observed and they were resistant against the H₂S, methanol, amine corrosion inhibitors and steam. High pressure of the system did not produce any defects due to explosive decompression phenomenon or did not cause extrusion in these O-rings. A lower hardness compound also were used to prepare small size and thin O-rings, after O-rings test in very sour gas pipelines valves they were in good conditions. However when thick and large size O-rings were prepared with this compound and tested in the above mentioned field test there were cracks and blisters on the surface of O-rings. Therefore only higher hardness compound can be used to make thick and large size O-rings and its mechanical properties and chemical resistance are proper for this application.

Keywords: viton extreme ETP-600S, thick and large size O-ring, high hardness, very sour gas, high pressure, explosive decompression resistance

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Introduction

Viton is a synthetic rubber and a Fluoroelastomers which is used in manufacturing O-rings and other molded and extruded articles from Dupont Co. USA. Viton Extreme is the latest development in Viton family. This elastomer is a terpolymer of ethylene, tetrafluoroethylene and perfluoro methyl vinyl ether. Viton Extreme is a bridge between Fluoroelastomers (Viton) and perfluoroelastomers. This elastomer has the best chemical resistance among all Fluoroelastomers. This type of Viton designed by Dupont Co. for using in oilfield and contacting with amines and sour oils. Other properties of this Viton are: flexibility at low temperatures, optimum compression set, optimum physical properties for using in seals and also having low volume swell in hydrocarbons. Viton Extreme ETP-600S is a Viton with advanced polymer architecture (APA) technology and it is the new generation of Viton Extremes that have improved processability¹ and has many new applications.^{2,3} Natural gas fields are usually with high pressure and hot and have high percentage of Hydrogen Sulfide (H₂S) and carbon dioxide (CO₂).^{4,5} The conditions in sour gas production contain high pressure and temperature which resulted to a very difficult environment for sealing elastomers. High pressure increases the density of gas and cause the gas to have a nonordinary solubility power. Completely different properties of the three gases (H₂S, CO₂ and CH₄) chemically and molecularly produce a mixed solventary system which the sealing of it is very difficult.⁴ CO₂ and H₂S in the presence of water produce an acidic environment, so, for preventing corrosion, high amount of corrosion inhibitors are needed. Amine corrosion inhibitors which form a film at the surface of the pipe cause permanent swelling of all type of elastomers used for sealing.⁴ Low molecular weight of alcohols also may be injected for preventing clathrates and they can swell the seal. These environments can fail the seal physically or chemically (time dependent).

Explosive decompression phenomenon

Elastomers in contacting with high pressure gases finally will be super saturated.⁴ Penetrated gas in elastomers at high pressure during discharge when sudden pressure drop occurs, expand and want to leave the elastomer. Gas may be entered to the atmosphere without any damage or may produce some blisters on the surface. The controlling variables are: gas pressure, temperature and rubber compound. Slowly pressure dropping and using rubbers with high hardness and density can increase the resistance to this phenomenon. Viton extreme ETP-600S is a rapid gas decompression-resistant fluoroelastomer.⁶ Increasing the hardness of a elastomer article by incorporating high levels of fillers can improve the article's resistance to explosive decompression.^{7,8} Small O-ring cross sections tend to have better resistance to explosive decompression failure than softer, large section O-rings.⁹ Research on the verification of the effects of using high hardness compound of Fluoroelastomers on the performance of thick and large size O-rings in the field test in pipeline valves containing very sour gas is rather rare. Furthermore their comparisons with using a lower hardness compound on the performance of small size and thin O-rings and also thick and large size O-rings tested in the above mentioned conditions is also seldom published. Till now this Viton extreme for using in gas with high percentage of H₂S was not been used as sealing (O-rings) in the real pipeline valves. In this research, properties of Viton Extreme APA (Advanced Polymer Architecture) for using in field test of thick and large size O-rings as well as small size and thin O-rings in very sour gas conditions will be verified. The sour gas had the following compositions: H₂S 23%, CO₂ 11%, CH₄ and low molecular weight hydrocarbons. The pipeline pressure is 1200 psi and the temperature is 29°C. The gas also contains amine corrosion inhibitors, methanol and water. The effects of using high hardness compound of Fluoroelastomers on the performance of thick and large

size O-rings in the field test will be verified which will give an insight to the ability of increasing hardness of the compound to improve the resistance to explosive decompression. This is to ascertain whether using high hardness compound of Fluoroelastomers can improve the performance of thick and large size O-rings in very sour gas with high pressure.

Materials and methods

Two uncured Viton extreme ETP-600S compounds with different hardness were used which were prepared from Dupont Co. of USA. These compounds after curing and post curing had the average hardness of 97 and 87 shore A.

Hardness test

Hardness of the cured and post cured compounds was measured (shore A) according to ASTM 224D.

O-ring preparation and field test in the very sour gas pipeline valves

Several O-rings with different dimensions from 26.3×3.3mm to 711.2×8mm were molded and cured at 165°C in a hot press under high pressure. The post curing of O-rings was done in air oven at 220°C for 16h. The pipeline contains very sour gas with the following compositions: H₂S 23%, CO₂ 11%, CH₄, low molecular weight hydrocarbons, amine corrosion inhibitors, methanol and water. The pipeline pressure is 1200 psi and the temperature is 29°C. The pipelines located between Masjed Suleiman gas wells and Razi Petrochemical Co. in Mahshahr at the South of Iran. Manufactured O-rings with proper dimensions directly installed on the valves in the pipeline for 2weeks. Then the pressure discharged during several minutes and O-ring removed from the valve and inspected. In order to assure that the O-rings can be reused several times again after one hr O-ring reinstalled on the valve and for another 2weeks exposed to sour gas. Later after 2weeks O-rings removed from the valve and inspected.

Results and discussion

Curing time

Rheometry test results at 165°C, show that the cure time of the compound was 12min however for large diameter and thick O-rings this curing time was not sufficient and curing times for some of them were last up to 40min.

Hardness test

Two series of O-rings were prepared with different hardness. The average hardness of the first series of O-rings was 97shore A and the average hardness of the other series was 87shore A. 97shore A hardness is suitable for preventing producing defects due to explosive decompression phenomenon or extrusion in large diameter and thick O-rings. Having this hardness bubble/crack and blister in the surface of O-ring after exposure to sour gas with high pressure will not exist. Normally hardness higher than 80shore A is suitable for omitting defects due to explosive decompression phenomenon in O-rings applications. Furthermore high hardness will reduce compression set which is very useful for improving O-ring performance.

Tensile, compression set and heat aging test

In our previous research work we verified the tensile, compression set properties and heat aging resistance of 87shore A compound. Those

results showed that mechanical properties of this compound were proper for manufacturing small size O-rings for using in high pressure and were proper to control defects due to explosive decompression phenomenon and extrusion. High modulus can help the O-rings to tolerate more pressure. Also average compression set was 25.5% and this amount was acceptable for O-ring application. Furthermore due to Heat aging test, hardness did not change considerably and there was no extra softening or hardening and the changes in tensile strength and elongation percent were low enough and the seal will not be failed due to heat aging.

O-ring test in very sour gas pipeline valves

As we show in our previous research work¹⁰ for 87Shore A small size and thin O-rings, after O-rings test in very sour gas pipelines valves they were in good conditions and were completely resistance to sour gas. However in current research when thick and large size O-rings were made with this compound and tested in very sour gas pipelines valves there were cracks and blisters on the surface of O-rings therefore this compound hardness is not enough high for application of O-rings with these sizes. Therefore 97Shore A compound was used to make thick and large size O-rings and after the test of these O-rings in very sour gas pipelines valves (field test) they were in good conditions and were completely resistance to sour gas and no cracks, bubble, blister, swelling, hardening and softening in the O-rings were observed. For reapplication testing of the O-rings, they reinstalled in the pipeline valve and after several times of reuse still they were in good conditions even after one year. This test shows that this fluoroelastomer with high hardness is resistant against the sour gas, methanol, amine corrosion inhibitors and steam. High pressure of the system did not produce any defect due to the explosive decompression phenomenon in this compound. Its compression set resistance is good because after one month test the O-ring can do the sealing again very well. Furthermore it can be concluded that mechanical properties such as modulus of this high hardness fluoroelastomer is proper for this application because it has enough resistant to extrusion rupture, crack and blister. This high hardness fluoroelastomer is appropriate for this application temperature and in this temperature is not degraded by heat or oxidation. In terms of resistance to H₂S, this high hardness fluoroelastomer is completely resistant and is not attacked chemically. Also in some literatures¹¹⁻¹⁶ the behavior of some fluoroelastomers in sour gas were verified and can be compared with this fluoroelastomer. It can be concluded that the solubility parameter, chemical resistance and mechanical properties of this fluoroelastomer is suitable for this application.

Conclusion

High hardness compound of fluoroelastomer (Viton Extreme ETP-600S) was used to make thick and large size O-rings which were suitable for application in pipeline valves containing very sour gas (23% H₂S, 11% CO₂ and the rest CH₄ and low molecular weight hydrocarbons, amine corrosion inhibitors, methanol and water) at 32°C and 1200 psi. However the same compound with lower hardness can be used for small size and thin O-rings, but when thick and large size O-rings were made with this compound and tested in the above mentioned conditions, there were cracks and blisters on the surface of O-rings. Therefore only higher hardness compound can be used to make thick and large size O-rings and after the test of these O-rings in very sour gas pipelines valves (field test) they were in good conditions and were completely resistance to sour gas and no cracks, bubble, blister, swelling, hardening and softening in these O-rings were

observed. This test shows that this fluoroelastomer with high hardness is resistant against the H₂S, methanol, amine corrosion inhibitors and steam even in thick and large size O-rings and its mechanical properties and chemical resistance are proper for this application and prevents producing defects due to phenomenon like explosive decompression and extrusion of these O-rings in the field test.

Acknowledgments

None.

Conflicts of interest

The author declares that there are no conflicts of interest.

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