**Destructive Testing of Ball Valve Seals
and Effective Sealing Procedures in
High Pressure Natural Gas Pipelines.**

Blowing down or draining long sections of large diameter natural gas pipelines due to valve seat leakage can be an expensive proposition for the pipeline operator. The following tests prove that minor valve seat leakage can be reliably sealed through the use of valve sealing compounds injected through the seat sealant system.

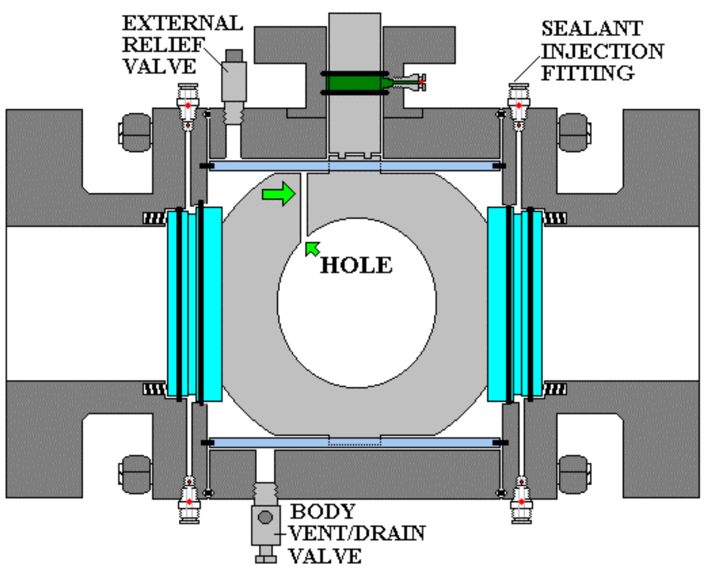
Unique independent seat seals in the Grove B-4C and Grove B-5 trunnion mounted ball valves can be utilized to achieve seat seals even in severe leakage situations. Ultra-heavy emergency sealing compounds, that may be injected directly into the body cavity of these valves, can provide a reliable temporary seal. Once a seal is obtained, in this manner, it will provide a bubble tight seal until the valve is cycled from closed to open.

Pipeline valves in natural gas service are subject to a variety of contaminants that create minor scars on seating surfaces. Most minor damage occurs at start-up as a result of construction debris but can also be caused by such things as the normal erosion of internal pipe surfaces, coupons from hot-tapping operations and damaged pipeline pigging devices.

A series of destructive tests were performed on a pipeline ball valve typically used in high pressure gas service. A variety of lubricant/sealants, sealants and emergency sealing compounds were utilized to seal the valve at various degrees of damage.

The tests performed concluded that most minor seat seal leakage can be sealed through the use of different valve sealing compounds.

The following report will detail the step by step testing procedures and test results.



TYPICAL B-5 BALL VALVE DESIGN

Equipment:

One 12” 600 Class Grove B-5 Ball Valve. The valve was new when first tested. The ball was scarred to .030” for the start of the second tests - otherwise like new. Normally this size and types of valve are supplied with one sealant injection port per seat ring. For testing purposes, a second seat injection port was added 180 degrees opposite the standard location at each seat ring.

Two Sealweld ACTIV-8 sealant injection pumps, 10,000 psig maximum discharge pressure. One modified Sealweld SuperGun manual screw-primed gun, 20,000 psig maximum discharge pressure.

One Turbine Gas Meter with hand held computer providing instant readout of flow fluctuations in a digital format.

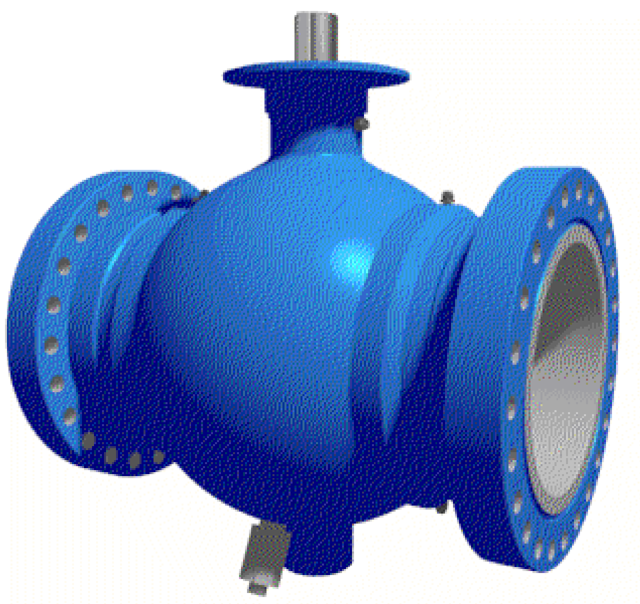
Scarring damage was made during the first series of tests with an electric engraving tool. A hand held electric disk grinder was used in the second series of tests.

A variety of lubricant/sealants, sealants and emergency sealing compounds.

Approximately 12,000 cubic feet of gaseous nitrogen in high pressure bottles.

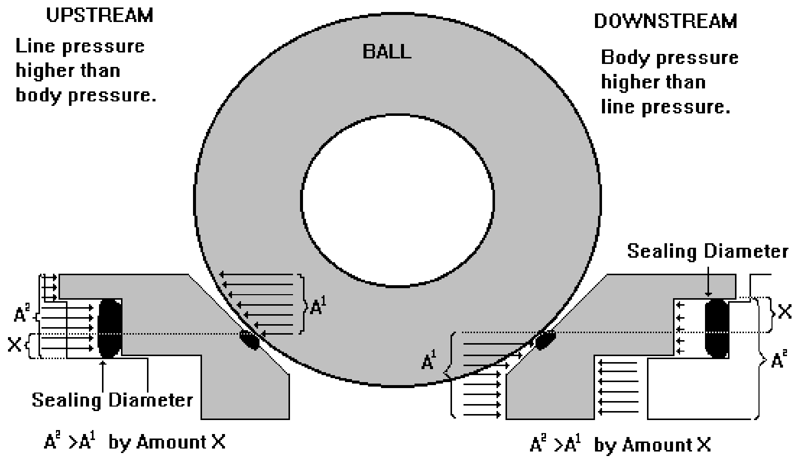
Background:

Many types of trunnion mounted ball valves feature a downstream self relieving seat ring. This prevents the overpressuring the body when the ball is in the closed position and thermal expansion of liquid occurs.



To prevent the valve body from rupturing, a self relieving downstream seat is used. When body pressure exceeds line pressure by more than the spring force applied to the seat ring, the spring's collapse and the pressure escapes out the side of the valve that has the lowest pressure, typically the downstream side.

GROVE B-5 BALL VALVE PISTON EFFECT PRINCIPLE



The "Piston Effect" principle assures dead-tight sealing simultaneously on both sides of the ball.

The Grove models B-4C and B-5 ball valves are designed so that if any leakage occurs past the upstream seat, in the closed position due to damage or wear, the resulting increase in body pressure (A2 > A1 by amount X) will activate the downstream seat. In this situation, the downstream seat produces a positive seal against the ball. Refer to the above illustration. This type of independent floating seat design, with the valve in the closed position and the body cavity pressure higher than line pressure, produces a closed body cavity. Because this design of seat does not self relieve, a standard relief valve is supplied on the body of the Grove B-4C and B-5 ball valves. Any excess pressure (i.e. 1.65 x MOP) that develops in this situation is vented. This relief valve is not required for valves in gas service, due to the compressibility of gas.

For these reasons it was theorized that, due to the unique Grove seat ring design in cases of severe leakage, that an ultra-heavy sealing compound could be injected directly into the body cavity to both close off leak paths and pressure energize the seat rings, thereby producing a reliable temporary seal.

Sealant Detail:

Ball valves are designed NOT to require lubrication for normal operation. Use of lubricants and/or sealants during API hydrostatic testing at the factory is prohibited.

Minor damage may occur after the valve is shipped from the factory due to improper handling or because sand or dirt gets into the valve while sitting at the pipeline right-of-way waiting for installation. The valve is usually cycled during installation of actuators and during hydrostatic testing of the pipeline. The contaminants create tiny scratches on the polished seating surfaces causing minor leak paths. These minor leaks only become obvious after the introduction of high pressure gas into the pipeline.

Factory testing confirmed that minor seal leaks can be sealed through the introduction of light grade lubricants or sealants such as Sealweld Total-Lube #911, into the standard seat injection fittings provided on the Grove B-5 ball valve. More severe leak paths can be reliably sealed through the injection of Sealweld 5050 Ball Valve Sealant. The larger size and variety of PTFE particles used in regular grade

5050 can be safely injected through all types of sealant injection fittings and internal check valves without risk of plugging the check valve mechanism.

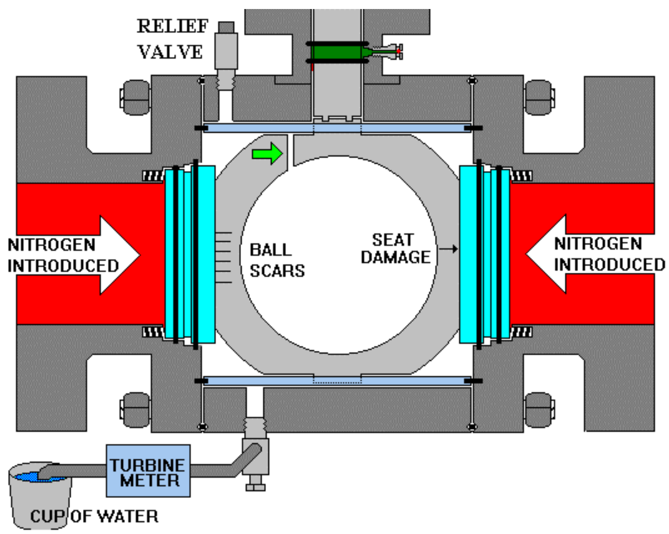
It should be stated that these sealing compounds are designed to provide a reliable temporary seal only. Valves with severe seat or ball damage should be repaired or replaced at the earliest opportunity.

The use of emergency sealants provides a temporary seal for the duration of the pipeline tie-in, pig launching or compressor repair. When the valve is cycled, the seal is lost. In many cases additional sealant will need to be injected in order to bridge-off the leak path the next time a bubble tight seal is required. These types of sealants are commonly utilized in large diameter gas pipelines where valve repair or replacement is impractical and/or prohibitively expensive.

Review of First Tests - December 1992

Objective

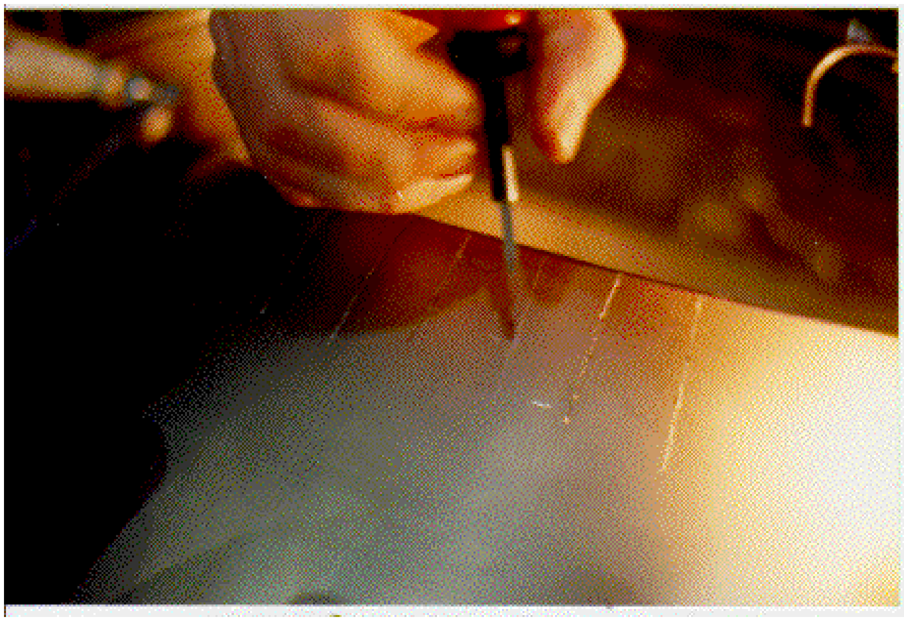
The objective was to intentionally damage the seating surfaces of the ball valve to simulate **minor** seat damage that may occur as a result of construction debris being left in the line at start up and to demonstrate the effectiveness of sealants injected into the seat area.



Initially, at one end of the valve, the ball was deliberately scarred and at the opposite end the seat seal o-ring was deliberately damaged. A hand held electric engraving tool was utilized to scar the ball. A depth gauge was utilized to measure the depth of the scars. A turbine gas meter was utilized to measure gas flow.

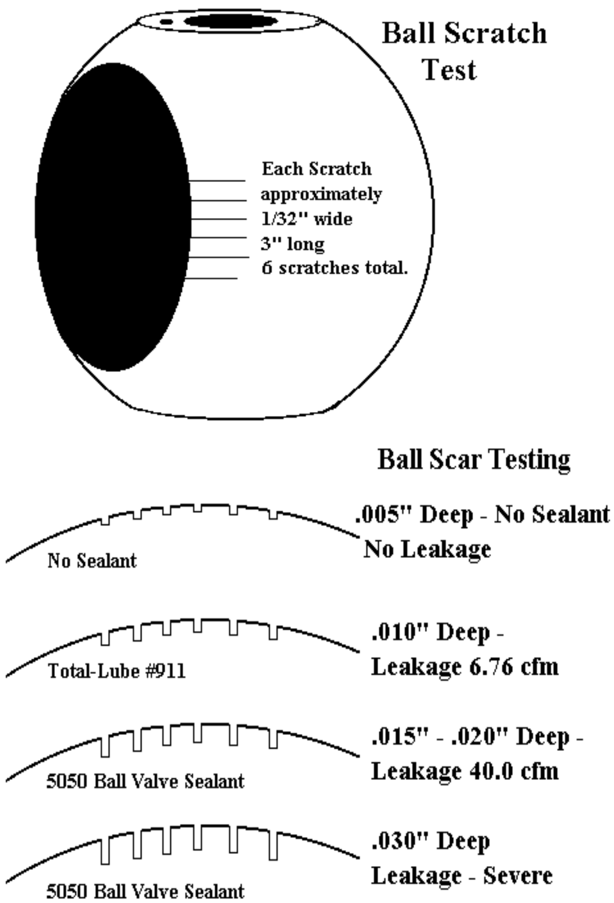
Leakage rates and bubble tight seals were measured by using a small diameter hose connected to the body vent fitting, through a turbine meter and into a container of soapy water. To be considered 100% bubble tight there had to be zero leakage or bubbles passing by the seat seal, for a duration of 25 minutes. 1000 psig gaseous nitrogen was utilized as the test medium. A typical API 6D valve seat test in this size of valve is 5 minutes to each seat independently and 5 minutes to both seats simultaneously. The valve must seal with no visible pressure loss for the duration of the test.

Test procedure:



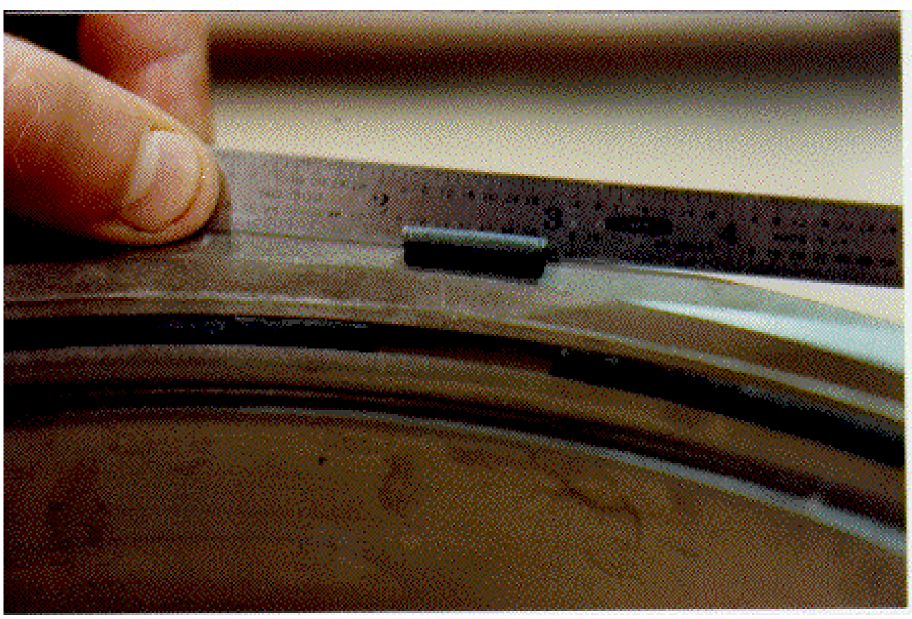
The valve was assembled repeatedly, tested, disassembled, cleaned, seal damage worsened then reassembled until a “worst case” leakage situation was realized.

SEAT SEAL DAMAGE TESTING

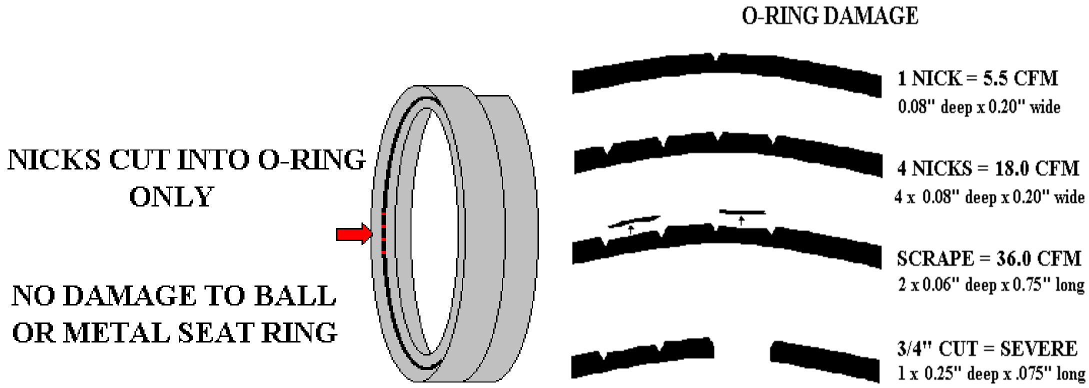


Ball Scar Test

	DAMAGE TYPE	RESULTS
Test 1	**No damage:**	- The valve sealed 100% bubble tight. - No sealant required.
Test 2	**Ball Scars: .005"**	- The valve sealed 100% bubble tight. - No sealant required. - The resilient seat seal o-ring conformed to the shape of the .005" scars.
Test 3	**Ball Scars: .010"**	- A leak rate of 6.76 CFM before injecting sealant. - Injected Total-Lube #911 - sealed 100% bubble tight.
	Ball Scars: .015"to .020"	- A leak rate of 40.0 CFM before injecting sealant. - Injected Total-Lube #911 - appeared to hold for 10 minutes then started to leak, gradually increasing back to 40 cfm. - Injected 5050 Sealant - sealed 100% bubble tight.
Test 4	**Ball Scars: .030"**	- Insufficient Nitrogen supply to conduct flow test, leak rate estimated as severe. - Injected 5050 Sealant, then applied 1000 psig N2 pressure, sealed 100% bubble tight.



O-Ring Damage Test



O-Ring Damage Test

	DAMAGE TYPE	RESULTS
Test 5	Seat o-ring - 1 nick	- Leak rate 5.5 CFM. - The intention was to simulate damage caused by pinching off a welding rod
Test 6	Seat o-ring - 4 nicks	- Leak rate 18.0 CFM.
Test 7	- 2 scrapes	- Leak rate 36.0 CFM - Simulating the damage caused by pinching a pig off or pinching a coupon from hot tapping operations.
Test 8	- Cut-out a 3/4" section of O-ring completely	- Insufficient Nitrogen to conduct flow test. - This is considered a worst case situation for o-ring damage

In all 4 cases of seat seal o-ring damage, a bubble tight seal was achieved with Total-Lube #911 through the injection fittings. The heavier 5050 sealant was not required.

We believe the turbine meter may be useful as an analytical tool, it will not be known if the leak path is one large scar or several smaller scars. By starting with a light grade sealant the smallest leak path may be sealed off first and a heavy sealant may not be required.

One may conclude as a result of the o-ring damage test, that just because the valve is leaking severely, application of heavy sealant may not be necessary.

Without the introduction of Sealweld sealants, in a typical pipeline application, the valve would have continued to leak, possibly eroding and enlarging the leak path size over time.

Second Tests - January 1995

A second series of tests were conducted 2 years after the first test.

The second tests verified the results of the first series of tests. The ball scar damage was again gradually worsened. Progressively heavier sealants were injected until the seat sealant system became inoperable. The body cavity was then filled with an ultra-heavy sealing compound.

As previously described the Grove B-5 ball valve has a unique seat ring design. Contrary to other trunnion mounted ball valve designs that feature a downstream self-relieving seat ring, the Grove B-5 is designed so that any leakage past the upstream seat ring pushes the downstream seat ring harder against the ball.

It was theorized that due to the unique Grove seat seal design, filling the body cavity with an ultra-heavy sealant would accomplish two things:

1) the filled body cavity would apply hydrostatic pressure to both the upstream and downstream seat seal rings, thereby forcing both seats against the ball.
2) the increased size and quantity of the PTFE particles in the ultra-heavy sealing compound would seal even <u>severe</u> leak paths.

The ball was deliberately scarred on both the upstream and downstream sides. This worst case scarring damage was quantified.

All testing was conducted indoors at room temperature of +20 degrees C.

To be considered 100% bubble tight, zero leakage must be held for 25 minutes. Nitrogen served as the test medium.

An electric disk grinder was utilized to deepen the scars on the ball, the grinding disk was approximately 1/8" wide.

Test Procedures:

The valve was assembled utilizing the same ball that was used in the first tests. All elastomers in the valve were new. The valve was set-up in a vertical position for ease of assembly and disassembly. Piping attached to the end closures allowed for high pressure nitrogen gas to be applied at either end. Only one seat ring was tested at a time until damage could no longer be sealed by injecting into the seat rings.

The valve was assembled with the existing .030" scars at the top and the undamaged side of the ball at the bottom. The bottom side seat ring displayed slight damage that had resulted from the first test and reassembly.

The bottom side was pressurized to 1440 psig and no sealant was applied. A very slight leak of .029 to .030 CFM was measured. The seat ring was injected with 12 ounces of Total-Lube #911 and a 100% bubble tight seal was achieved.

The top seat ring was injected with 12 ounces 5050 sealant and 1440 psig nitrogen pressure applied. A minor leak of 5.0 CFM developed after 2 to 3 minutes. The seat ring was "topped up" with 1 to 2 ounces of additional 5050 sealant and a 100% bubble tight seal was achieved. Later, when the valve was disassembled and inspected, the PTFE particles in the 5050 could be seen compacted in the scars.

The bottom side of the ball was scarred to a depth of .010" in 5 places. A leak rate of 9.50 CFM was measured. Total-Lube #911 was injected into the bottom seat ring and a 100% bubble tight seal was achieved.

The successful results of these tests verified the results of the testing conducted two years earlier.

The top side scars were then deepened to .037" to .047", and five additional scars .010" deep were added 180 degrees opposite the scars. The top seal ring was injected with 12 ounces of 5050 sealant and 1000 psig nitrogen pressure was applied. A momentary seal was achieved. Then leakage occurred and gradually increased to 10.00 to 15.00 CFM. Finally, 12 ounces of XXXH (triple extra heavy) 5050 sealant was injected and a 100% bubble tight seal was achieved.

The valve was disassembled, cleaned and scars to both ends were deepened.

The bottom side scars were deepened to between .020" to .027" and 12 ounces of 5050 Sealant was injected into the bottom seal. A seal could not be obtained with a 1000 psig differential. The leak was reduced to approximately 1 to 2 CFM but would not hold, and eventually increased to 20 to 30 CFM. 12 ounces of XXXH 5050 Sealant was injected but a seal could not be achieved. The leak could be reduced to 1 to 2 CFM but would not hold. Eventually the leak increased to 20 to 30 CFM. By injecting small quantities of additional XXXH 5050, the leak would diminish to 1 to 2 CFM and then build back to 20 to 30 CFM as the sealant became displaced. This step was repeated 6 times with identical results. A seal could not be achieved.

The top side scars had been deepened to between .050" and .060". Injecting XXXH 5050 sealant into the top seal ring, reduced the leakage from 15 to 20 CFM to 1 to 2

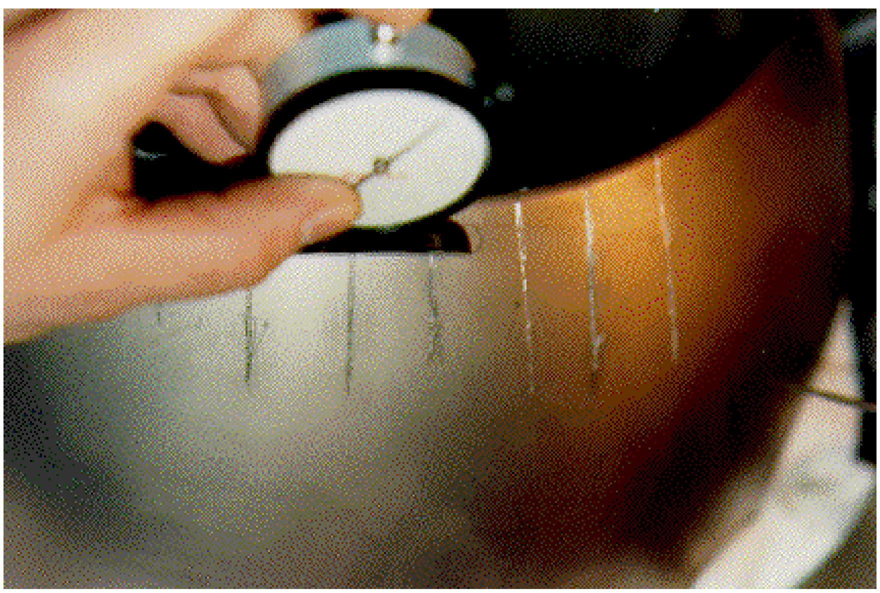
CFM. When sealant injection was stopped the leak would build back to 15 to 20 CFM. This step was repeated 3 times with identical results, a seal could not be achieved.

We injected 12 ounces of Sealweld Valve Cleaner into both seat rings and cycled the valve 12 times. We could feel a short increase in turning effort during each cycle. We suspect this was caused by the ball scars catching the seat ring as it passed by.

The bottom side was pressurized to 1000 psig and a leak rate of 1.0 to 2.0 CFM was observed. The valve was injected with 12 ounces 5050 sealant and a 100% bubble tight seal was achieved.

The top side was pressurized to 1000 psig, 5050 sealant was injected and a leak rate of 10 to 20 CFM measured. The leak rate fluctuated wildly as a partial seal was achieved then lost. We injected 12 ounces of XXXH 5050 and reduced the leak rate to 1 to 2 CFM. After injecting was stopped, the leak would gradually increase back to 10 to 20 CFM. This was repeated 5 times, with identical results each time. A seal could not be achieved.

We then injected 12 ounces of XXXXH (quadruple extra heavy) 5050 and achieved a seal that held for 2 minutes before slight leakage started again. This was repeated three times, a temporary seal was obtained each time, only to have leakage begin again. However, by topping up a forth time, a 100% bubble tight seal was obtained.



Upon disassembly the scars were re-measured for depth. Measurements were taken 1/2” from the balls’ through bore, where the seat seal contacts the ball.

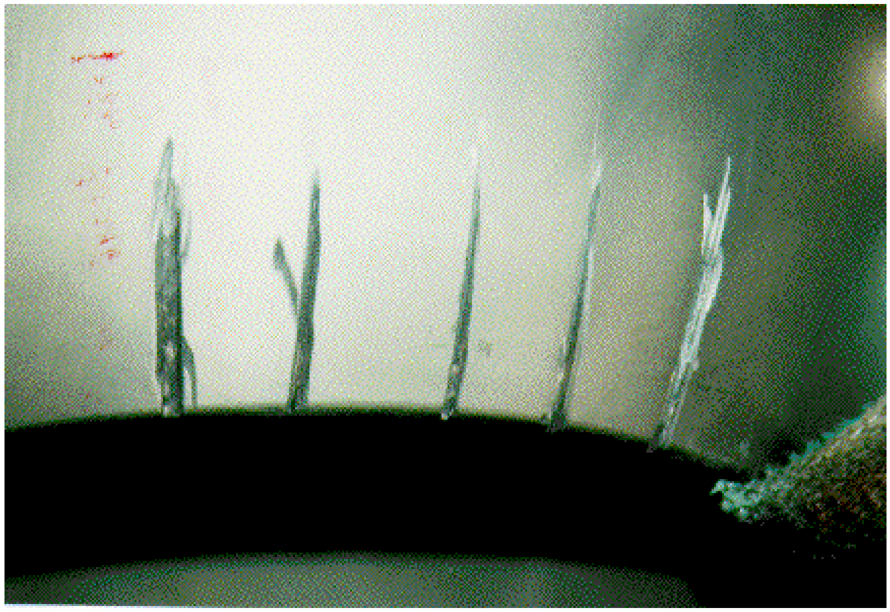
Scar Depth - Top Side

.060”	**.055”**	**.061”**	**.055”**	**.050”**	**.050”**
.023”	**.023”**	**.027”**	**.023”**	**.025”**	

Scar Depth - Bottom Side

.015”	**.024”**	**.018”**	**.023”**	**.025”**

We inspected the upper seat ring and discovered several small nicks and shallow scratches (.002”-.004”) to the seat ring as a result of cycling the valve.



The valve was further damaged as follows:

Scar Depth - Top Side

.073”	**.080”**	**.070”**	**.090”**	**.075”**	**.080”**
.045”	**.067”**	**.066”**	**.085”**	**.075”**	

Scar Depth - Bottom Side

.071”	**.070”**	**.065”**	**.068”**	**.068”**

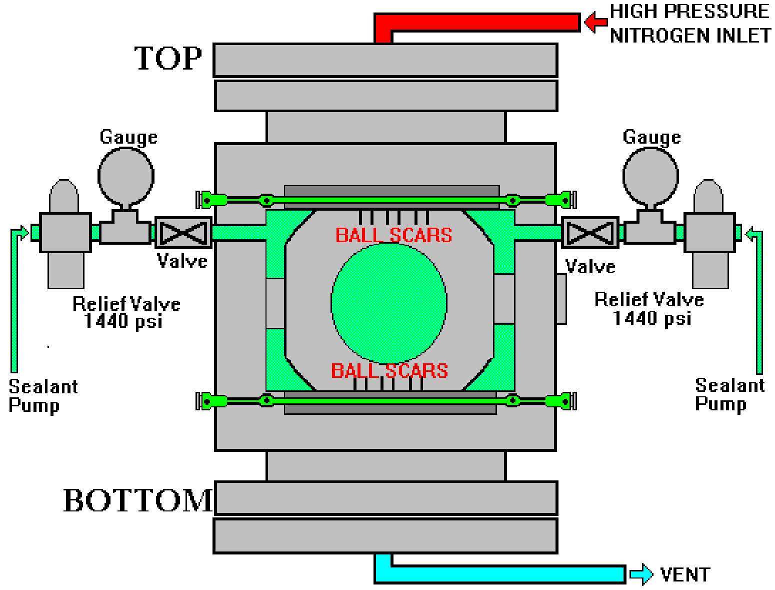
A small amount of XXXXH 5050 was injected into both the top and bottom seats, but the injection fittings apparently became completely obstructed. The valve was de-pressurized, and the sealant and inner check valve fittings were removed. As expected, the inner check valves were found to be blocked by large PTFE particles. The valve was reassembled, without inner check valves, and again only a small amount of XXXXH 5050 was injected before the valves’ internal sealant channels became obstructed for the same reason.

A leak rate of 8.0 CFM was measured. The leak rate did not fluctuate and was steady.

At this stage of testing, the seat sealant injection system was considered disabled due to blockages formed by large PTFE particles.

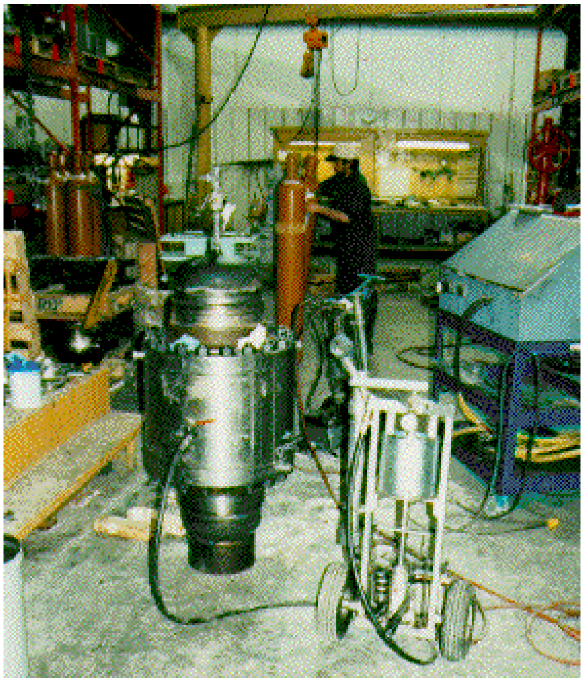
The only alternative to get the valve to seal was to fill the body cavity with Ultra-Heavy Sealweld “Chameleon” sealant. It was calculated that filling the body of the valve including the hole through the ball would require 9.4 gallons of sealant.

Chameleon sealant was injected via 2 Sealweld Activ-8 pumps into the body cavity. Total pumping time was 2.5 hours. The ACTIV-8 pumps transfer sealant one pound at a time by means of filling a hydraulic cylinder from a 10 pound pail. The sealant is dispensed with a floating piston assembly by means of hydraulic pressure. A conventional reciprocating plunger pump could not be utilized for this operation as the PTFE particles would pack-off in the plunger assembly.



When the valve was approximately 1/2 full of sealant, 400 psig of Nitrogen pressure was applied to the top side. A leak of 6.0 CFM passed both upstream and downstream seats, and vented out the bottom side of the valve.

When the valve was 3/4 full, 400 psig of Nitrogen pressure was again applied and a seal was achieved. However, when pressure was increased to 1000 psig the seal was lost, and roughly 1/2 pound of Chameleon sealant was blown out of the bottom vent. The valve continued to leak until pressure dropped to 400 psig at which time the seal returned. A leak of 1.0 to 2.0 CFM developed after 5 minutes.



With approximately 400 psig pressure head maintained, the small leak continued as we injected additional sealant. As we approached the estimated full capacity of the valve body (approximately 95 pounds), leakage across the valve stopped completely. After 2 minutes we noticed a small release of approximately 20 bubbles and then the valve sealed off 100% bubble tight.

The gas pressure was increased to 820 psig and a 100% bubble tight seal was maintained.

The gas pressure was increased to 1000 psig and a 100% bubble tight seal was maintained.

The nitrogen bottles were disconnected leaving 1000 psig nitrogen pressure in the top end of the valve. The 100% bubble tight seal across the valve was then maintained for 17 hours.

The next morning the valve was still holding bubble tight but had lost 20 psig pressure. All flanges and threaded connections were inspected with soapy water and a sealant fitting was found to be leaking very slightly by its threads. The fitting was tightened and no further leakage was observed.

Gas pressure was increased to 1440 psig and a 100% bubble tight seal was maintained for 40 minutes. The testing was stopped.

Conclusion:

We concluded that a 100% bubble tight seal could be achieved in a worst case leakage situation by utilizing an ultra-heavy sealing compound in combination with the unique seat sealing characteristics of Grove B-4C and B-5 ball valves.

Sealant Recovery:

In order to recover as much sealant as possible before cycling the valve, the valves body vent fittings were opened. Approximately 20% of the sealant was blown out before a channel for gas opened. We estimate that under full line pressure conditions, approximately 50% of the sealant should be recoverable by venting through the body cavity connections.

There is concern that when the valve is cycled to the full open position most of the sealant in the hole of the ball would be launched downstream. In order to prevent this from occurring we recommend flushing the body cavity repeatedly with a cleaning fluid such as gas condensate, glycol, methanol or compressor oil prior to cycling the valve.

Safety Considerations:

There is a considerable risk that rapid injection of sealant with high pressure injection pumps into the body cavity could cause the valve body to rupture when the body becomes completely full.

To prevent this from occurring we recommend this procedure be performed by experienced valve technicians only.

Excess pressure can be avoided by attaching a pressure relief valve to the sealant injection hose leading from the pump or into the valve body. The pressure relief valve should be set to the rated maximum working pressure of the valve. The pressure relief valve should have sufficiently large internal orifices for large PTFE particles to pass safely through.

While injecting sealant the injection pumps were slowed as we neared the calculated capacity of the body cavity. We watched the pressure gauges on the sealant pumps very closely looking for a rapid increase in pressure once the body became full.

We did not see the rapid increase in gauge pressure at the time the leakage stopped. At the conclusion of the pressure tests we injected additional sealant and watched very closely for the gauges to "spike" or increase very rapidly. After injecting only 2.5 pounds of additional sealant we observed the "spike" we expected and pumping was stopped immediately. Extreme caution must be taken when utilizing high speed sealant pumps. The rapid increase in body pressure occurs instantly and there may not be time to stop the pump before the valve body ruptures. Always use a pressure relief valve.

When the body cavity was drained we discovered a substantial quantity of trapped high pressure gas.

Additional Tests

A final test was performed to determine if high pressure injection of sealant could be utilized to clear the blocked sealant passages. The ACTIV-8 pumps used initially have a maximum discharge pressure of 10,000 psig. A manual screw-primed pumps with a maximum discharge pressure of 20,000 psig was connected in an attempt to blow the passages clear.

Each seat ring had two sealant injection ports. Total-Lube #911 was used as purge compound.

The first port for the first seat required 18,000 psig before a passage was blown clear. Upon disassembly the ball from the lower inner check valve was found to be blown out. The other port accessing the same seat ring blew clear at approximately 11,000 psig with no damage to the check valves.

For the second seat ring, both fittings blew clear at approximately 11,000 psig with no damage to the check valves. Upon disassembly all other elastomers on the back of the seat ring and in body seal areas were inspected for damage. All such elastomers appeared to be in perfect, like new condition..

Other Considerations:

The valve body cavity should always be flushed with cleaning fluid before and after filling the body cavity to flush out all foreign contaminants and material that may have collected in the body cavity. The cleaning fluid should be approved by operations/engineers and should also be compatible with all elastomers in the valve. The recovered cleaning fluid should be disposed of using environmentally safe methods.

Summary:

Minor seat damage can be reliably sealed by means of injecting Sealweld Total-Lube #911 and Sealweld 5050 Ball Valve Sealant with PTFE bridging agents without risk of plugging off the sealant fittings, insert check valves or sealant injection system.

Major seat damage can be sealed by injecting heavier sealing compounds such as XXXH and XXXXH 5050 sealant. There is a potential of plugging standard seat sealant systems with such heavy sealants.

The Ultra-heavy "Chameleon" Sealing compounds can be utilized in Grove B-4C and B-5 ball valves, to seal severely damaged seating surfaces. These types of sealants have percent concentrations of solids that are too high to be injected through conventional sealant injection fittings, but may be injected through Sealweld Flow Wolf Fittings or through full port ball valves.

Sealant Summary

Damage	**Sealant**
O-Ring Damage Only	Sealweld Total-Lube #911
Scar Damage -Minor to .010"	Sealweld Total-Lube #911
Scar Damage -.010" to .030"	Sealweld 5050 Sealant
Scar Damage -.030" to .047"	Sealweld XXXH 5050 Sealant
Scar Damage -.047" to .060"	Sealweld XXXXH 5050 Sealant
Scar Damage -.070" to .090"	Sealweld CHAMELEON Sealant

The testing demonstrated that valves that utilize double acting seats, like Grove B-4C and B-5 ball valves, can be sealed 100% bubble tight by utilizing body filling techniques. The ultra-heavy sealant filling the body cavity activates both the upstream and downstream seats. With seats activated, the filled body volume is pumped up to higher than line pressure, creating a positive seal.

Many types of gate valve designs should also be capable of sealing by utilizing body filling techniques.

Gate valve design can vary greatly depending on the manufacturer and model. Some pipeline gate valves feature a self relieving UPSTREAM seat ring while other types feature NO RELIEVING seat ring. Gate valves that rely on a mechanical seal do not have any provision for internal pressure relief and extreme caution must be taken to prevent rupturing the valve body.

Fatalities have been reported when the technician failed to relieve trapped body pressure in gate valves with mechanical seals. Valves in liquid service may over pressure very rapidly therefore we recommend this procedure be performed by technicians with considerable experience.

Field trials have been performed on numerous Grove G-4 and G12 gate valves. Both these designs utilize a self-relieving upstream seat ring. In every case, a 100% bubble tight downstream seal was obtained by filling the body cavity Sealweld Chameleon sealant.

Destructive testing in the valve plant and field testing has proven that it may not be necessary to blow down long sections of pipeline, depending on the type of valve and the nature of the leakage problem.

The technician should **always** verify that the valve is fully closed prior to injecting sealants into the seat sealant system and/or body cavity.

For best results always inject Sealweld Valve Cleaner to soften any old dried sealants that may have collected in the seat sealant system. Old sealant may have built-up on the seating surfaces or in the machined areas behind the seat ring preventing proper seat ring travel.

When the critical seal is no longer required, heavy sealants should be purge from the seat sealant system with Total-Lube #911. Top-up with small quantities of Total-Lube #911 as part of the routine annual valve maintenance program.

Acknowledgments:

We would like to thank Valgro Ltd. of Edmonton and Calgary, Canada, Grove Valve and Regulator Company of Oakland, California for donating the valve, their shop time, engineering and manpower assistance.

PTFE - Polytetraflurouethelene. The size, assortment and specific type of specially processed PTFE particles used in the various sealant formulations is the proprietary information of Sealweld Corporation Ltd.

Testing and metering conducted by: Dean Chisholm, Sealweld Services - Pipeline Valve Maintenance Company.

Illustrations by Dean Chisholm, illustrations are not to scale and are for descriptive purposes only.

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