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Instrument Air Application Review – Enertech NozzleCheck Design Eliminates Maintenance Rule and Appendix J Test Failures

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Abstract

The Ginna Station initiated a project to eliminate chronic Local Leak Rate Test (LLRT) and Maintenance Rule failures of a small bore check valve in the Instrument Air System using advanced valve design technology. Starting with the root cause analysis of the problem, this paper outlines all aspects of this project: the evaluation of various replacement candidates, an economic cost justification and the design change process. It concludes with a performance evaluation of the replacement valve after 18 months of operation.

INTRODUCTION

The Instrument Air system at Ginna, a 612 Mwe C-E, Pressurized Water Plant, is used to supply air to various components both inside and outside the containment building. Air is supplied to containment via two containment isolation valves, one AOV and one check valve, **See Figure 1**. To ensure that fission products are contained within the containment boundary during a Loss of Coolant Accident (LOCA) all piping penetrations have containment boundary valves that are required to seat tightly against a postulated accident pressure of 60 psig. Each outage, these boundary check valves undergo a Local Leak Rate Test (LLRT) that is conducted to verify the capability of the valve to contain the release of radioactive fission products.

The performance requirements for containment boundary check valves exceed the ability of many valve designs. Since most check valves were designed to support high-pressure seat leakage tests many will not pass the stringent requirements of site-specific LLRT's even in the as-new condition. When the adverse effects of corrosion, disc oscillation, debris and numerous open-closed cycles are factored in, it is even more unlikely that a check valve will maintain tight shutoff for numerous operating cycles.

To improve performance and resolve obsolescence issues, the Ginna station replaced the original swing check with a poppet style check valve design that utilized a soft seat and spring assisted closure to overcome the obstacles caused by the low differential pressure LLRT. This design also failed to meet the expectations of long-term LLRT success without requiring refurbishment each outage. An alternate design was selected for replacement that utilized a unique pressure-velocity profile along the disk that eliminated wear related degradation by providing the necessary force to fully open the valve. This design has been inspected and tested after one eighteen month cycle with no indication of wear or degradation of seat tightness. Although the implementation of a Design Modification of an ASME Section III component is costly, this proved to be a cost justified endeavor that not only reduced operating expenses but improved plant safety.

APPLICATION DESCRIPTION

Tag #:5393	
Operating Pressure:	150 psig
Operating Temperature:	300° F
Normal Operating Flow:	75 scfm estimated to occur 90% of the time.
Velocity @ 75 scfm:	53.63 ft/sec
Upstream piping configuration:	straight
Valve Orientation:	vertical flow up, **Figure 2**

Testing Requirements: The LLRT is done every 18 months by using a Volumetrics, Thermal Mass Flow Measurement Device connected to the downstream vent connection with the upstream section vented to atmosphere. The test is conducted as follows:

1. Isolate test volume
2. Pressurize downstream side to 60 psig using the integral regulator in the Volumetrics box
3. Measure the makeup flow required to maintain 60psig for a period of 10 minutes with maximum allowable leakage limited to 627 sccm.

In addition to the LLRT, Ginna’s IST program requires a full-open and prompt closure stroke verification during cold shutdown conditions.

SUMMARY OF PROBLEMS

The originally installed swing check valve was replaced in 1993 due to obsolescence and poor performance during LLRT. A soft seated, poppet check valve was selected to replace the swing check based on the advantages of its spring loaded, soft seated design. Although the poppet check valves passed the LLRT during factory acceptance testing, the valves could not pass the site LLRT after one cycle of operation. Once the poppet check valve failed a LLRT, it was removed from the system, disassembled and inspected. Excessive wear along the stem and stem guide was noticed during each inspection. This wear was indicative of disc oscillation over an extended period. It didn’t appear that the valve ever fully opened. This wear increased friction during the closing stroke and imposed angular and transverse misalignment preventing the valve from achieving proper seat-to-disc engagement. This wear also created an increase in closure time during the prompt closure test. Refurbishment of the valve required new O-rings, seat, stem and in some cases, a new body. Parts were kept in stock to support maintenance without impacting outage schedules or equipment availability. A summary of the cost of maintenance activities:

Maintenance to support rebuild of the valve	25 hrs x $65/hr	= $1625
Post Maintenance Testing and data entry	15 hrs x $65/hr	= $975
Analysis by Systems and Performance Engineering	10 hrs x $65/hr	= $650
Replacement Parts		= $4000
Total Refurbishment Cost per Outage		**$7250**

In addition to maintenance costs, the following issues contributed to the cost justification:

- Inability to extend LLRT testing per Appendix J Option B
- Non-compliance with Maintenance Rule
- Appendix J Program Status
- Plant/Public Safety in the event of a LOCA
- Negative impact on Probabilistic Safety Assessment

THE MODIFICATION PROCESS- REVIEW OF SELECTED REPLACEMENT VALVES

The primary cause of the chronic failure of the poppet check valve was attributed to misalignment of seating surfaces due to wear along the shaft. The goal in the replacement valve selection process was to find a valve designed to function without wear of critical surfaces under normal service conditions.

The force acting on the disc at a velocity of 54 ft/sec of air with a density of 0.585 lbm/ft^3 is equivalent to the force exerted by ambient water velocity of approximately 5 ft/sec. To simplify the discussion related to Vmin, we will refer to velocities based on ambient water. Ginna wanted a check valve with a Vmin less than 5 ft/sec(water) to eliminate the wear caused by disc oscillation. Experience with swing check and piston check designs indicated the following Vmin assuming straight upstream piping with no proximity to turbulence:

Vmin of Swing Check:	10-20 ft/sec water
Vmin of lift check:	20 ft/sec water
Vmin of poppet check:	10 ft/sec water

Since swing and lift checks could not meet the design objectives of operating in the full open position, and the poppet check exhibited accelerated wear, an alternate check valve design was evaluated. Ginna had installed 14”Model DRV-B and 8” Model DRV-Z NozzleCheck valves in the Service Water and CCW pump discharge applications, respectively, in 1994 to eliminate problems primarily related to water hammer. These valve designs had shown no indications of wear induced by low velocity operation after many years of operation in contrast to the hinge pin wear observed with the originally installed swing checks.

Ginna requested a preliminary application review from Enertech and they recommended a Model ERV-Z valve design based on its ability to operate in the fully open position at relatively low velocity without sacrificing flow coefficient. The NozzleCheck product line, comprised of four basic models, had been utilized in over 800 critical Nuclear Plant applications around in the world to replace conventional check valves in challenging applications. This experience provided a good experience base but none of the applications were identical to the service and testing conditions of Ginna. A rigorous design review was conducted to ensure that the ERV-Z would provide the desired performance characteristics. This review compared the ERV-Z, **Figure 3**, with the installed poppet check, **Figure 4**, and isolated the similarities and differences that would be the basis for the final selection.

Design Review Summary

Body Design

The Poppet Check and NozzleCheck are both Axial Flow Check valves. Ginna’s Poppet check had a three-piece body consisting of screwed-end, End Pieces with a wafer body sandwiched between them sealed with an O-ring on the downstream and with the seat on the upstream side. The ERV-Z NozzleCheck body is manufactured as a one piece casting, bar or forging. The Poppet Check valve body has no change in internal diameter (ID) along the length of the center section; its shape is symmetric similar to a pipe. The NozzleCheck body is contoured with a gradually decreasing ID, which reaches a minimum on the inlet side of the disc and is gradually increased along the length of the valve. There are no joints that must seal tightly on the NozzleCheck body design eliminating the risk of body leakage.

The Poppet Check integrates the disc guide into the body as one piece. The NozzleCheck design utilizes a separate diffuser that is retained in the body using a Retaining ring that is captured in a slot machined on the body ID near the outlet of the valve. Having a separate diffuser was viewed as an advantage since it could be easily replaced if the sliding surfaces were damaged instead of replacing the center section of the body.

Disc Guiding

The disc and shaft are one-piece in both designs. The weight of the disc/shaft is supported by a bearing surface within the body of the Poppet Check and within a diffuser in the NozzleCheck. This bearing surface is downstream of the seat on both designs offering protection from direct impingement of the fluid minimizing contamination of the sliding surface with media borne debris and corrosion products. The percent of shaft length engaged in the guide was higher for both the fully open and closed disc positions in the ERV-Z design. Maximizing shaft engagement offers an advantage in horizontal applications but was not considered a factor in this vertical application where there is no radial loading.

Seat Design

The poppet check design used Viton seat captured in the body that acts as both a seat and also a body seal. There is a wide area contact between the disc and seat. As the nuts are tightened on the studs, compressing both the upstream seat/seal and the downstream O-ring seal, the seat moves in response to the compression. This may have been a factor in the inability of the poppet valve to pass the LLRT since there is a potential for misalignment between seat and disc.

The NozzleCheck soft seal is retained within the disc, **Figure 5**. The Viton O-ring is the primary seal with a metal-to-metal backup seal if the O-ring were to be removed. The O-ring provides a relatively narrow contact band compared to the poppet check valve and is not affected by any compression of the body. This was viewed as a contributing factor affecting seat leakage performance.

Geometry of Flow Path

The difference between the two check valve types is most apparent in the comparison of flow patterns. The flow through the NozzleCheck is similar to that through a convergent-divergent nozzle, a gradually decreasing and then gradually increasing area creating a low-pressure zone immediately downstream of the disc. This low-pressure area generates a force on the disc in the open direction. The low pressure is gradually recovered as the area expands towards the outlet of the valve. The shape of the diffuser, coupled with the body contour, provides a smooth, symmetric flow path with no projected disturbances to cause vortices or turbulence. The poppet check disc protrudes into the flow path with no diffuser on the downstream side. This allows pressure to equalize on both sides of the disc once the poppet partially opens. This equalization of pressure prevents the disc from achieving a fully open position and causes the disc to oscillate degrading the surfaces of the shaft and bearing surfaces.

To model the effect of different valve geometries, Enertech built a test loop similar to the configuration of the Ginna application with the check valves in a vertical, flow up orientation. This loop was used to circulate water through specially designed NozzleChecks with see-through bodies. The test was conducted with two different diffuser designs. Valve 1 had a 2” diffuser with the outside diameter decreased eliminating the nozzle shape resulting in a larger flow area. Valve 2 had a standard ERV-Z NozzleCheck geometry with a 1.5” diffuser. **Figure 6** compares the Cv and **Figure 7** compares the difference in percent open. This test illustrates the dramatic effect of the geometry of check valve internals. Without a specific convergent-divergent nozzle geometry, there is no low-pressure area created which is necessary to provide the force required to hold the disc fully open without oscillation.

When velocity was increased to greater than 13 ft/sec (135 gpm) , the modified NozzleCheck didn’t open past 30%. When the standard diffuser was used, with the same spring, the valve fully opened at the calculated velocity of approximately 4 ft/sec (40 gpm). Even with smaller internals, the valve achieved the full open position and attained a much higher Cv compared to the larger diffuser with the standard contour machined away. This allows a stronger spring to be used, providing seat load and alignment, and still achieve full open operation compared to valves without this specific nozzle geometry.

Final Selection of a Replacement Valve

The decision was made to purchase two, 2” ANSI 300, ASME Section III, Class 2, ERV-Z NozzleCheck. Part of the factory acceptance testing was a Prompt Closure Test in addition to a 60 psid low-pressure seat leakage test. The final NozzleCheck configuration was designed to minimize the extent of the modification by maintaining the following characteristics similar or identical to the poppet check valve:

- Body material
- Disc material
- Seat material
- End connections
- Weight
- Face-to-face dimension

The factory test results were 0.1 sccm and 0.3 sccm for seat leakage. The valve had an instantaneous closure during the Prompt Closure Test and maintained the 60 psig downstream pressure after the upstream volume was rapidly vented.

The standard ERV-Z design has been upgraded over the last few years by providing sliding surfaces of a differential hardness and of extremely wear resistant materials to allow operation in high cycle applications without wear or galling. In this application, since full-open operation was expected during normal operation, the 316SS-on-316SS sliding surface configuration was maintained with little expected risk of galling.

IMPACT ON SYSTEM HEALTH

The installation of the ERV-Z, Figure 7, was a relatively easy evolution since the size, end-connections and weight of the valve were maintained. The estimated payback was estimated to be two cycles when all factors were evaluated.

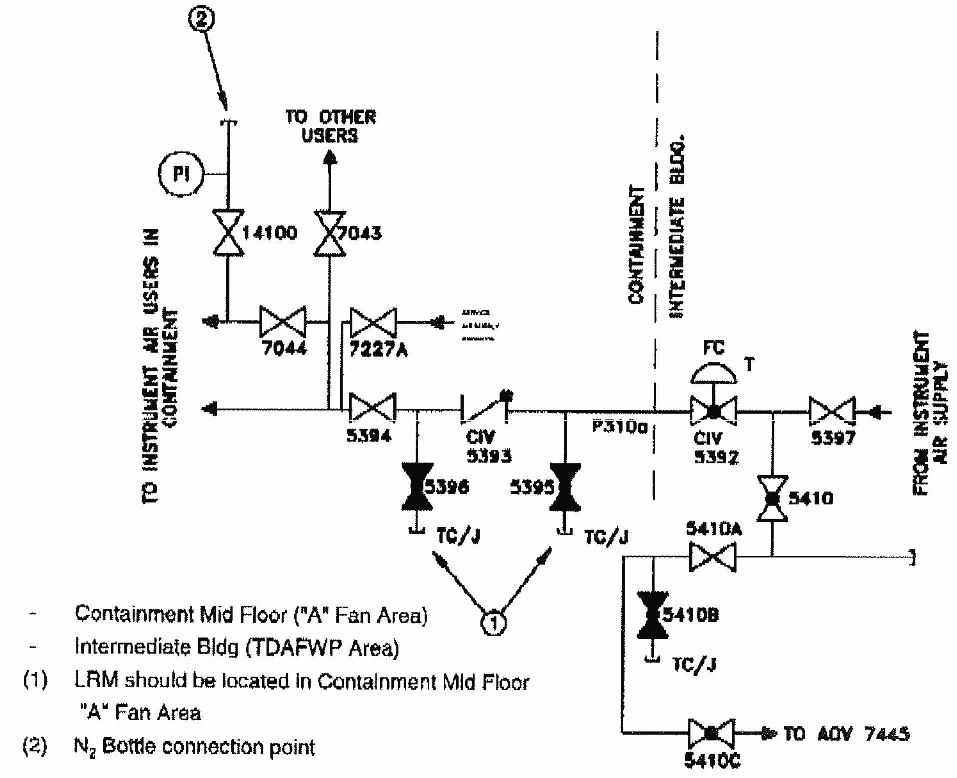
After 18 months of operation, the NozzleCheck was tested at 60 psid per the LLRT procedure with zero leakage. It also assessed the CSD exercise/prompt closure IST test with essentially an instant closure with no measurable delay or lag when traveling to the open or closed position.

Upon consecutive rounds of ASME Code and Appendix J LLRT testing during RFO's 2003 and 2005,the test interval for the LLRT can be extended out to 60 months in accordance with OPTION B. In addition, all associated repetitive maintenance tasks could likewise be extended. The Maintenance Rule compliance issue will be resolved which has a valuable regulatory, albeit intangible, price benefit. The Appendix J program would be rid of a consistent poor performer, which would positively impact the status of the overall program. The availability is not really impacted since the poppet check valve always remained operable and in service even at its peak as a poor leakage performer. There is no significant ALARA benefit since the valve is in a non-contaminated system and is located in a low-dose rate area (typically 1 MREM or less).

CONCLUSION

Many of the testing, inspection and performance requirements imposed on check valves in safety related, nuclear plant applications exceed the capabilities of many traditional check valve designs. Normal flow rates are many times much less than worst-case accident/design flow rates causing check valve discs to oscillate causing wear to sliding and rotating surfaces. Even the highest quality check valve designs may moderate wear that is sufficient to create misalignment of the seat/disc interface preventing the valve from passing under low pressure seat leakage tests. In these applications, valves that fully open at very low velocity, are necessary to provide a long term, maintenance free operation without leakage.

The proprietary design of the NozzleCheck valve was developed in 1935, primarily to eliminate water hammer damage, and has been installed in nuclear plants since 1972. The low-pressure area created by the conversion of pressure to velocity provides a valuable opening force on the disc allowing the valve to function in the fully open position when other check valve designs operate partially open. The full open, non-oscillating operation, in combination with a strong spring force, provides a tight shutoff at both low and high-pressure after many cycles of continued operation. In many applications, the NozzleCheck is an economical alternative to repetitive corrective and preventative maintenance that also increases safety and reliability.



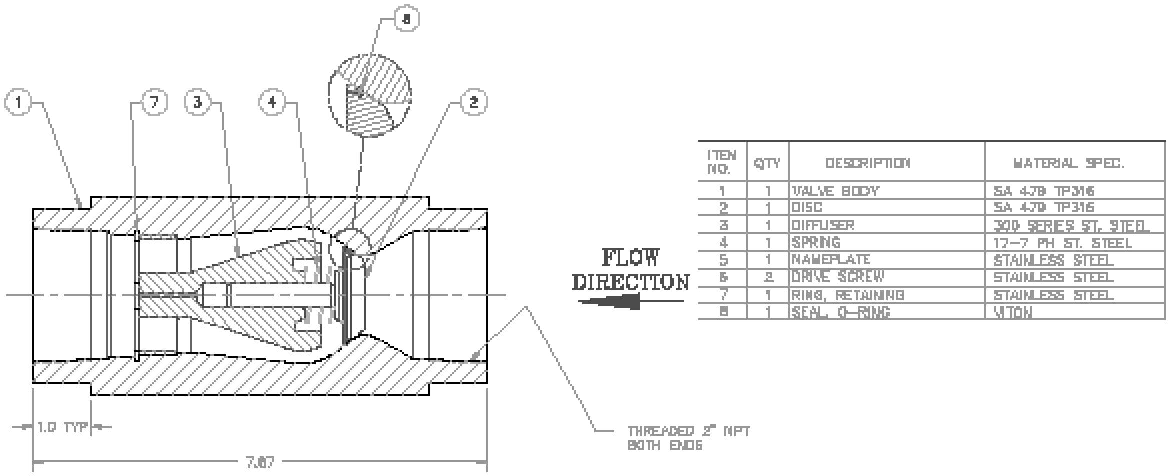
- Containment Mid Floor ("A" Fan Area)
- Intermediate Bldg (TDAFWP Area)

(1) LRM should be located in Containment Mid Floor "A" Fan Area

(2) N_2 Bottle connection point

Figure 1 – System Schematic

Figure 2 – Picture of Poppet Check Valve Installation



ITEM NO.	QTY	DESCRIPTION	MATERIAL SPEC.
1	1	VALVE BODY	SA 479 TP316
2	1	DISC	SA 479 TP316
3	1	DIFFUSER	300 SERIES ST. STEEL
4	1	SPRING	17-7 PH ST. STEEL
5	1	NAMEPLATE	STAINLESS STEEL
6	2	DRIVE SCREW	STAINLESS STEEL
7	1	RING, RETAINING	STAINLESS STEEL
8	1	SEAL, O-RING	VITON

Figure 3 – ERV-Z drawing

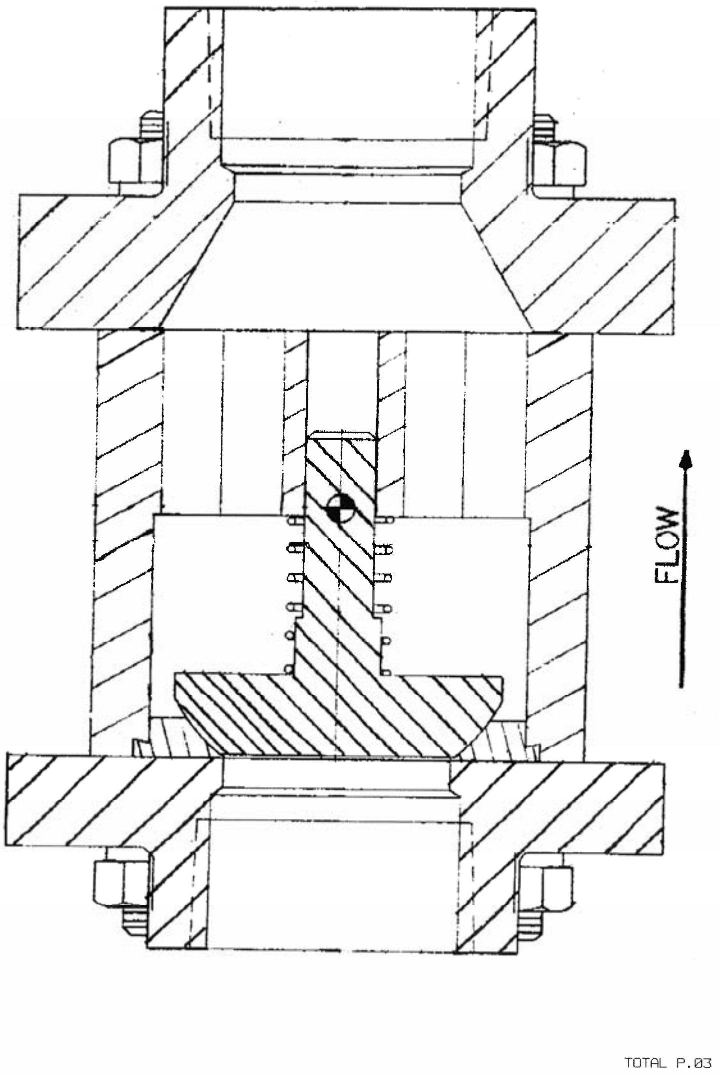


Figure 4 – Poppet Check Valve Drawing

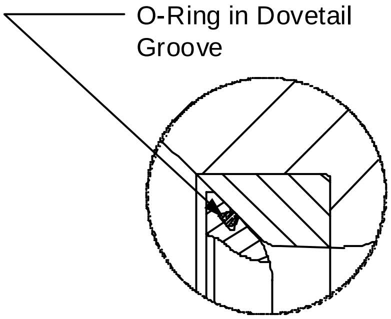


Figure 5 – ERV-Z Soft Seat detail

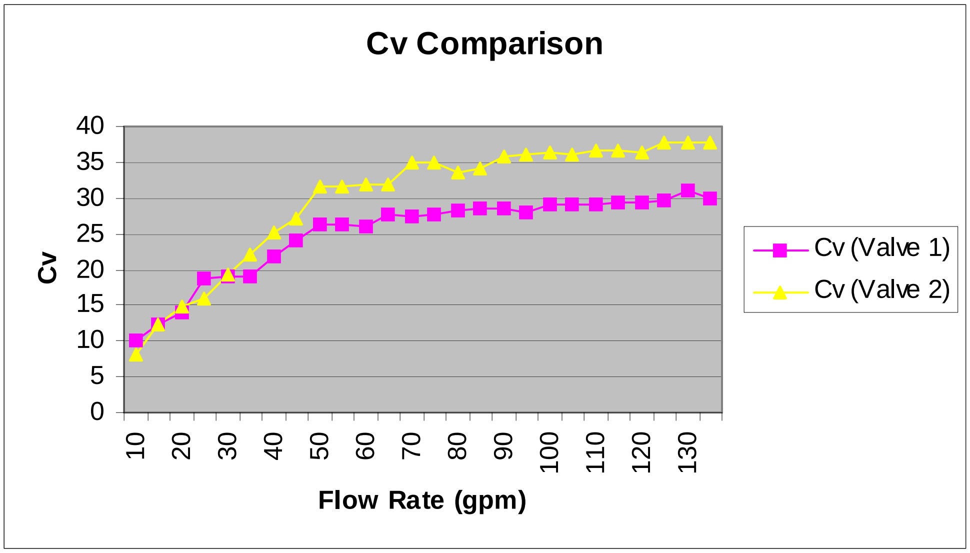


Figure 6 – Cv Comparison

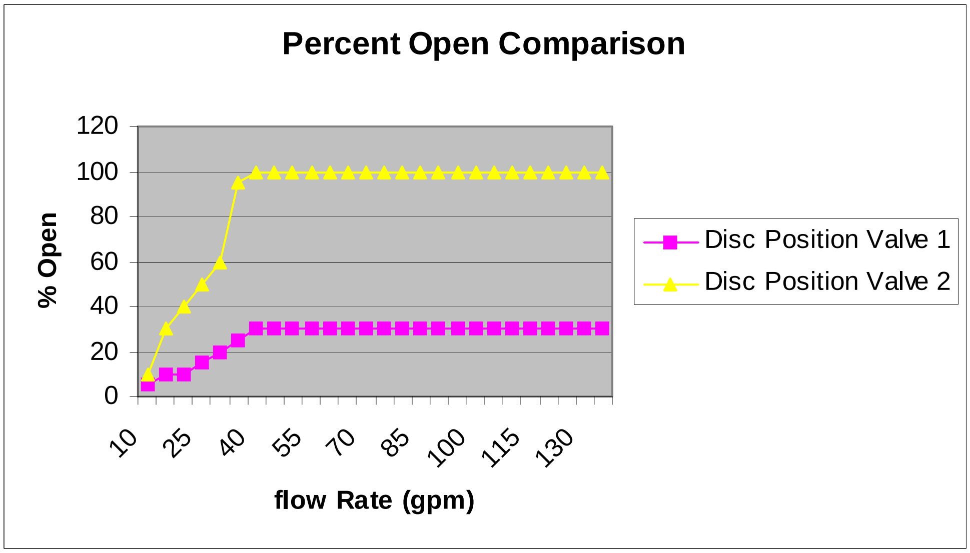


Figure 7 - % Open Comparison

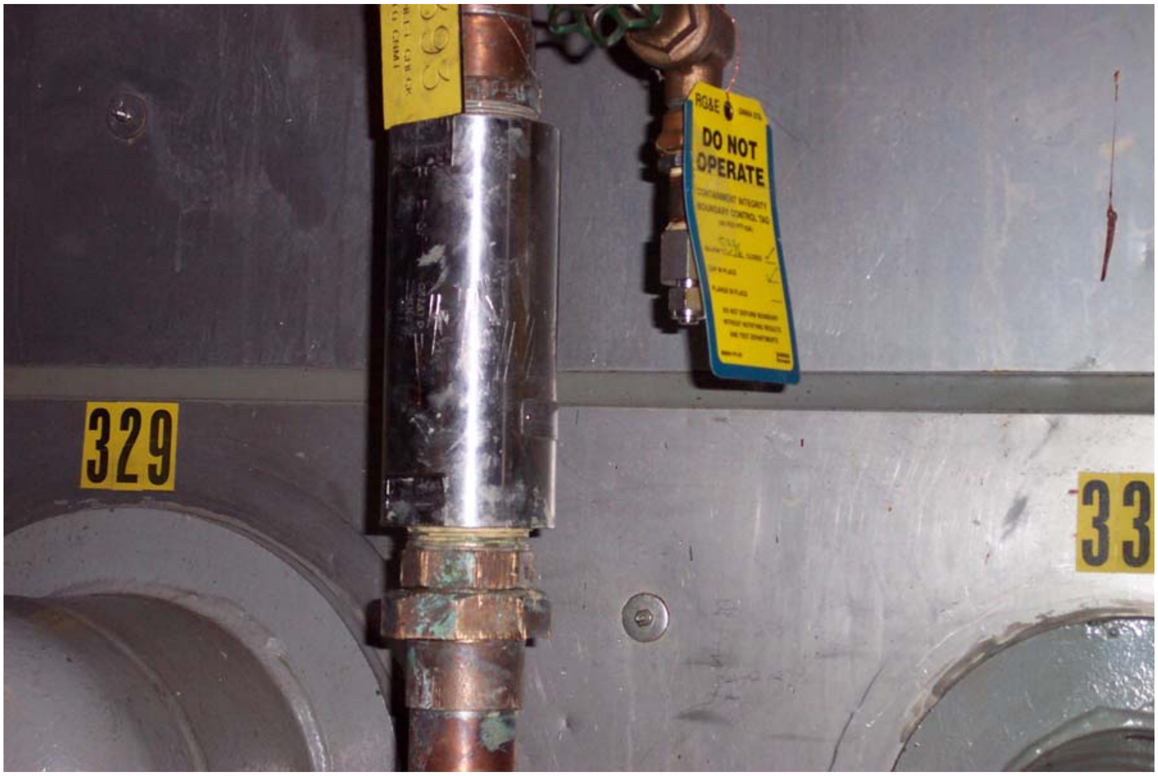


Figure 9 – ERV-Z picture installed