

ITT ENGINEERED VALVES

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Final Report to the NRC of
10 CFR 21 Event 54118, reported by ITT 06/14/19
Concerning #25 AM diaphragm valves

REPORT BY:

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8/13/19

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1.0 INTRODUCTION

ITT Engineered Valves, LLC (ITT) has identified a defect with an item considered to be a Basic Component for Nuclear industry service. The item in question is certain ITT diaphragm valves powered by the #25 spring to close airmotor. The initial finding was that five airmotor diaphragms had broken down structurally after having been assembled within a valve, tested, and set aside in inventory for a little over one year. The valves containing the damaged parts were constructed at the same time as a second set of five #25 spring to close valves which were delivered to an end user. The observed condition of the damaged diaphragms was such that it was determined that the possibility of a 10 CFR part 21 failure could exist with the other set of valves that was constructed and had been shipped.

This defect is limited to the #25 airmotor diaphragm assemblies that were constructed in May of 2018. This issue is in no way related to any other size of airmotor diaphragm valve, and does not have any effect on the weir diaphragm within the diaphragm valve itself (the diaphragm identified as ITT's M1 diaphragm).

Initial notification of the potential defect was made to the NRC via fax on 6/14/19. The potential defect report was designated Event 54118 shortly thereafter. A 30-day Written Notification was filed with the NRC on 7/12/19 and is available on the NRC web site.

Per 10 CFR part 21 requirements, this report is the 60-day Final Report. The formal evaluation of the potential defect was completed August 9, 2019, and a determination was made that the five #25 airmotors constructed and shipped in May of 2018 are considered to contain a reportable defect. The #25 airmotor diaphragm itself is not the source of the defect; the defect in this case was caused by improper assembly of the airmotor diaphragm joint such that an excessive amount of bolt torque was applied to a set of valves constructed in May of 2018. The resulting forces over time caused the diaphragm to incur damage that may affect the valve's ability to open.

2.0 DETERMINATION OF REPORTABLE DEFECT

On June 14, 2019 ITT's responsible officer convened a meeting of an Evaluation Group in order to review a finding from the production floor in Lancaster, PA.

During May of 2018, ten spring-to-close #25 airmotor valves had been assembled for a customer order. Five valves were shipped together to one customer, while five others were assembled and tested in preparation for shipment, pending customer approval of Code documents. However, customer approval was delayed over issues unrelated to the valve assembly of the second set of five valves; a disagreement in documentation validity occurred over several months such that the order for these five valves was eventually cancelled. The valves were held in production inventory on ITT's shop floor during this time. ITT determined in May of 2019 that the five

valves should be dismantled and the parts dispositioned accordingly. When the valves were being dis-assembled in mid-June 2019, it was discovered that all five of the airmotor diaphragms appeared to have extensive damage, with were cracks around the edges and delamination of the fabric. No root cause of the damage was readily apparent; hence an Evaluation Group meeting was called to determine the potential impact of the damaged component.

The Evaluation Group consisted of the Nuclear Product Engineer, Plant Manager, Manager of Nuclear Quality Assurance and Product Engineering Manager. It was decided by the Evaluation Group that the evidence of damage to the airmotor diaphragms of five retained valves indicated that there was a possibility that a 10 CFR part 21 event could occur in other valve assemblies, the exact scope of which was unknown at the time. The initial notification of a potential failure to comply was faxed to the NRC later that evening, June 14, 2019. This was followed by a 30-day written notification on 7/12/19.

Testing and evaluation activities were carried out at ITT Lancaster in order to determine the root cause of the damage to the diaphragms, and also to provide support to the pending decision as to whether the event should be considered a reportable defect or not. Personnel at the NRC were also consulted during this time. After reviewing the long-term results of an eight-week simulation test, it was concluded on August 9, 2019 that a reportable defect had occurred, and was limited to the five diaphragm valves that had been assembled in May of 2018 and shipped.

3.0 BACKGROUND INFORMATION

The #25 airmotor diaphragm is a 0.19" thick elastomer diaphragm, 9.88" in diameter, used exclusively in ITT's pneumatic actuator identified as the #25 series; reverse acting valves are designated as 3225 airmotors. The airmotor diaphragm is a composite consisting of two layers of Buna-N elastomer with a thin layer of nylon fabric sheet sandwiched in between. The airmotor diaphragm is clamped between the upper and lower airmotor covers and forms upper and lower chambers that are pressurized depending on whether the valve is reverse acting (spring to close, series 3225) or direct acting (spring to open, 3125). The actuator diaphragm is attached to the valve stem such that any movement of the diaphragm transfers to the stem and travels the same amount as the stroke of the valve diaphragm. Reverse acting actuators have a spring or set of springs that force the valve closed when air is removed/vented from the bottom chamber.

The maximum operating pressure of the airmotor diaphragm is 85 psig. During assembly and production testing, ITT will conduct a special airmotor proof test of 110 psig for three minutes to verify that the diaphragm and lower cover will hold pressure. If there is no visible leakage the diaphragm and the valve is considered ready for shipment.

The airmotor diaphragm is assembled between the upper and lower airmotor cover. Both of the flange surfaces that clamp down on the airmotor diaphragm are as cast, not machined.

Past investigations of airmotor diaphragm failures indicate that there are two areas of primary concern:

1. Materials of construction. Are any of the component materials defective?

2. Were the appropriate assembly/test process steps followed during valve assembly?

Delamination is defined as the failure of the bond between a diaphragm's fabric layer and the elastomer which encases it.

4.0 INVESTIGATION OF DEFECT

Description of damage

The damage to the airmotor diaphragms was evident once the valves were retrieved from storage and brought out for disassembly. Splitting of the elastomer was visible on the edge of the diaphragm, even before the valves were taken apart, see Figure 1. After disassembly, the splitting could no longer be easily seen, but the delamination of each diaphragm was now plainly visible, see Figure 2. All five diaphragms showed the same type of splitting and delamination, with the delamination ranging from 30% to 75% of the circumference. The delamination in all cases began at the outer diameter of the diaphragm and extended radially to the inner edge of the flange clamping area.

Investigation of damaged diaphragms

All five diaphragms had come from the same material lot, signified by the date code of December 2017 (the other five diaphragms from the shipped set of valves was from the same material lot as well). The material of the airmotor diaphragm construction and its manufacturing process were obtained from the diaphragm supplier and reviewed. There were no indications of any discrepancies or deviations from the technical requirements, as all technical data and manufacturing steps were properly documented and found to be in order. From this information it was concluded that the diaphragm material or diaphragm manufacturing process were not the cause for the failure of these airmotor diaphragms.

It had been noted at the time of disassembly of the valves by the shop floor technician who had worked on the original assembly that these particular assemblies that were assembled in May of 2018 required excessive bolt torque in order to pass the production test for this component, which is pressurization of the lower chamber at 110 psig.

The reason that excessive torque was applied in this case was that the joint formed by the upper and lower cover and the diaphragm was not able to pass the 110 psig production test using the specified assembly torque of 72-79 in-lb. The finish of the covers is as cast, and was not sufficiently flat enough to accommodate the seal without compensating by applying torque well in excess of the specified value.

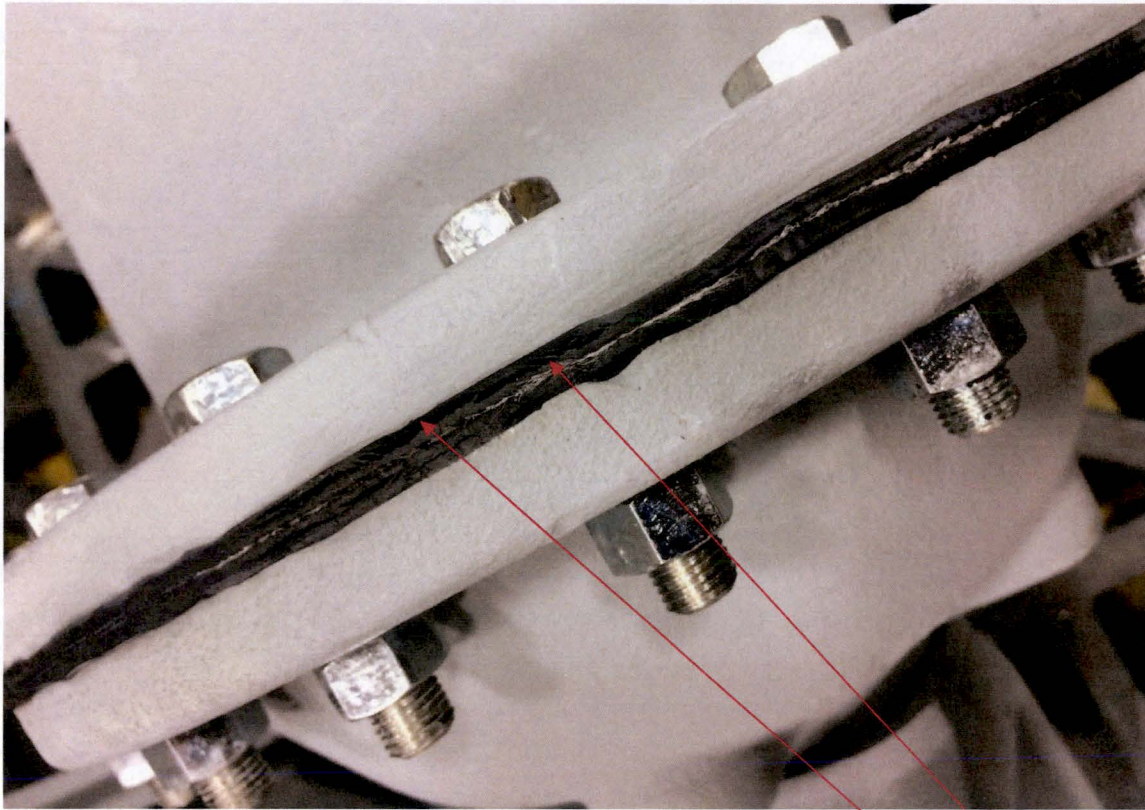


Figure 1: Diaphragm damage noted before disassembly. Note splitting of elastomer on edge of diaphragm.

Despite the damage, these diaphragms were re-assembled into the same valve hardware in which the damaged diaphragms were found, and each one was cycle tested in turn. While the diaphragms were found to leak air from the perimeter (the leakage was actually audible), it was noted that all five diaphragms were demonstrated to be able to successfully operate. Each one was cycled 5,000 times open-to-close-to-open, and all five diaphragms were able to function well enough to be able to open the valve at high or minimal actuator pressure, despite leakage at the perimeter of the diaphragm.

While it may seem that there is evidence to suggest that the damaged diaphragms can still perform their safety function despite the damage, thus avoiding the necessity of a 10 CFR part 21 incident, ITT chose to define the event as a reportable defect. It is not possible to predict the amount of damage for a given diaphragm, or to conduct qualification testing on such diaphragms that would ensure safe operation at all necessary conditions. Thus, the decision was made to define this problem as a reportable defect.



Figure 2: Delamination of fabric from elastomer

Proof of root cause – simulation test

During the first week of the investigation a simulation test was started, with the intention of trying to replicate the damage seen on these valves. Using the same valve hardware as before, one brand new #25 airmotor diaphragm of March 2019 construction date was installed in a valve assembly. This assembly was intentionally over torqued to 300 in-lb in order to accelerate the effect seen on the problematic valves. The airmotor diaphragm was examined at the perimeter to see if the same cracks and delamination as seen in the damaged diaphragms (Figure 1) could be observed. While the diaphragm was extruded beyond the diameter of the covers and some distortion was noted (see Figure 10 in Appendix A), no cracks or delamination was initially visible.

The valve assembly was set aside in the R&D lab, with the only force or pressure on the valve being the 300 in-lb assembly torque on the bolts. On the theory that cracks would develop over time, the diaphragm was monitored and examined closely over a period of eight weeks. Prior to four weeks, no cracks were observed, although there was a great deal of radial extrusion of the diaphragm and warpage of the edge of the diaphragm that was observed to grow worse over

time. At the four week point, cracks were observed on the outer edge of the diaphragm that were not present at initial assembly, similar to those that were seen on the damaged diaphragms (see Figure 3). Repeated observations of the diaphragm over time showed that at week seven more cracks were found that had not been previously seen. In addition, some delamination was observed on the edge of the diaphragm, corresponding to the bolt location, see Figure 4. It became apparent that as time went on more cracks would initiate and existing cracks would deepen. This was seen as clear evidence that the cause of the damage was the high level of assembly torque that in time would manifest itself in permanent damage.

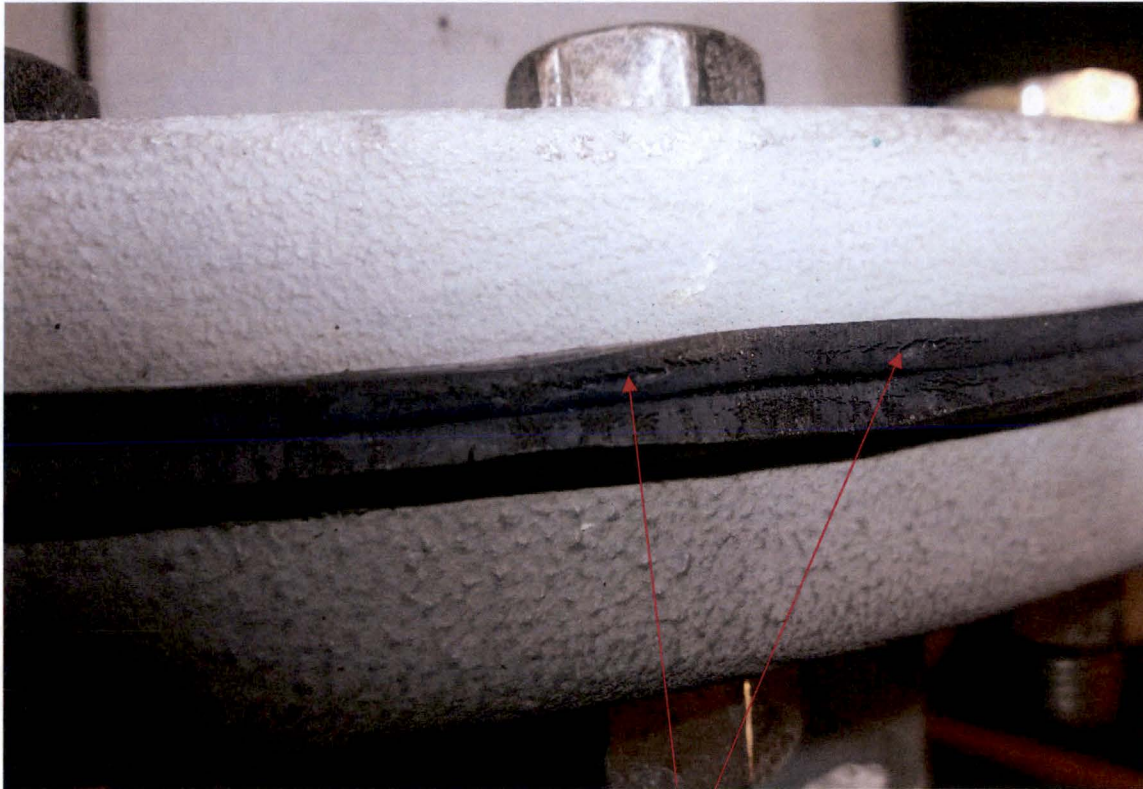


Figure 3: Splitting of diaphragm on simulated test unit

The simulation test proved that over time, the effect of the high bolt torque generates forces that have a long term, deleterious effect on the airmotor diaphragm such that the elastomer material will split and the fabric will delaminate from the elastomer.

On August 9, after the 8th week of observation, it was concluded that the root cause of the diaphragm damage was the excessive torque.

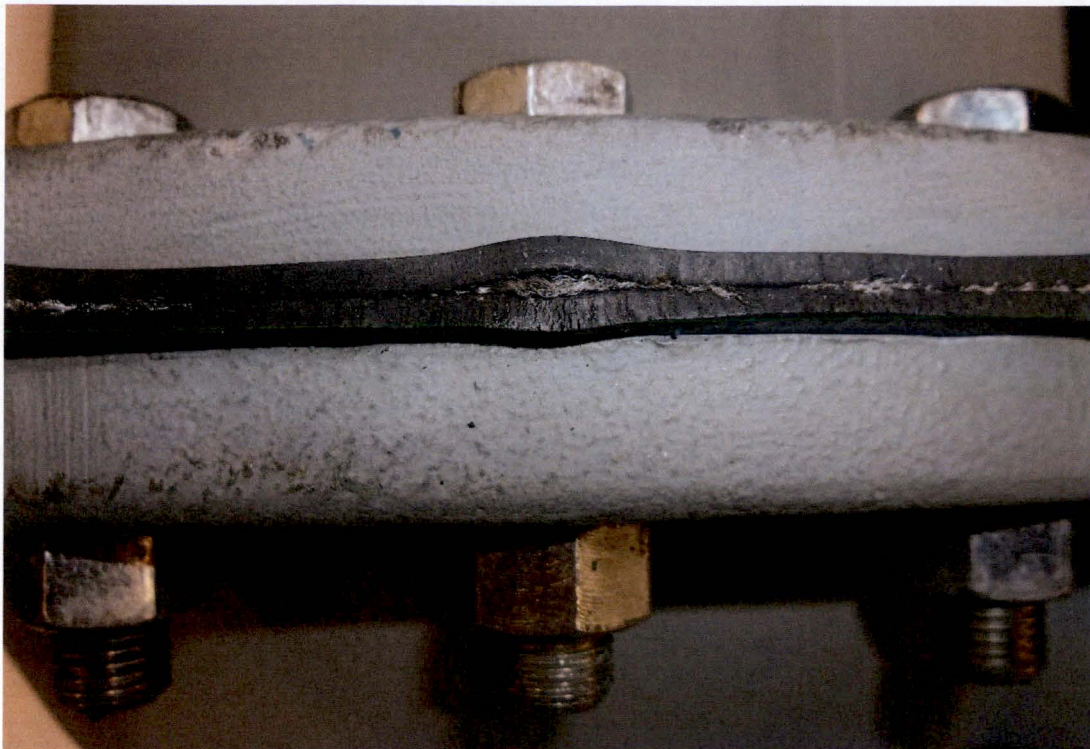


Figure 4: Delamination of simulation unit

4.0 CORRECTIVE ACTIONS

Valve assembly process

Steps will be taken to ensure that the airmotor diaphragm damage will not recur with future #25 valve assemblies. In the short term,

1. A finishing step will be added to address the actuator covers, to ensure flat sealing surfaces.
2. A routing step will be installed to specify that the airmotor torque is to be recorded as part of the shop order documentation.
3. If the 110 psig proof test cannot be successfully completed with the specified torque, production shall halt and the assembly disassembled and examined.

In the long term, ITT will investigate the surface finish of the lower airmotor cover to determine how to ensure a consistent surface flatness for pressure retention capability.

Remedial action – shipped valves

As for the five valves that were constructed in May of 2018 and shipped, it seems likely that the same forces that were used to assemble the joint that led to the damaged diaphragms were

applied to those five shipped valves as well. Therefore, it is possible that the diaphragms thus affected could develop the same damage. However, the end user may want to positively verify whether the #25 airmotor valves in their possession are properly assembled. Here is a guide to determine whether the conditions that caused reportable defect are present:

1. Measure the bolt torque on the joint. If the value for each cap screw is measured to be 72-79 in-lb, the joint was assembled correctly and the diaphragm is likely to be functional.
2. Observe whether there is significant extrusion of the outer perimeter of the diaphragm. If the diaphragm extends beyond the OD of the covers by 0.12" around most of the circumference, the diaphragm is likely to be overtorqued.
3. Observe the edge of the diaphragm. The edge of the diaphragm should be square and straight (see figure 8). Examine the edge closely, looking for splitting lines within the elastomer or separation of the elastomer from the fabric outboard of each bolt. Any such damage indicates excessive torque.

Appendix A of this report shows a visual guide comparing a properly assembled valve with an over torqued one.

5.0 CONCLUSION

The defect that was first observed on June 14, 2019 was elevated to a reportable defect on August 9, 2019. The defect involves improper assembly of a pneumatically actuated diaphragm valve powered by ITT's #25 airmotor, and the excessive assembly torque applied to the bolts that are used in the cover/airmotor diaphragm/cover joint. The cause of the diaphragm failure was successfully simulated in ITT's R&D lab. Corrective and remedial actions are summarized in this report. The customer who received the five valves constructed in May of 2018 is

Korea Hydro & Nuclear Power Co.
of Seoul, Korea
Hanbit site

ITT is in the process of formally notifying this site of the defect, and a copy of this report will be included.

APPENDIX A

Excessive bolt torque causes damage to the airmotor diaphragm, but it also provides visual indications that enable a user to identify problematic assemblies. See Figures 5 and 6 for a comparison of a properly assembled airmotor versus one with a known excessive bolt torque. Normally the OD of the assembled diaphragm is the same diameter as the metal covers. If excessive torque is applied the elastomer diaphragm may extrude and extend as much as 0.12" beyond the OD of the covers, see Figures 6 and 7.

Another indicator that is visible is the shape of the edge of the diaphragm. The elastomer surface on the OD should remain square if the assembly was properly assembled, see Figure 8. If excessive torque is applied the edge of the diaphragm will not remain square, instead the outer edges will grow out further than the part of the edge that contacts the fabric in the middle, see Figure 11 and the comparison between Figures 9 and 10.

Figure 5: Diaphragm with 72 in lbs of applied torque

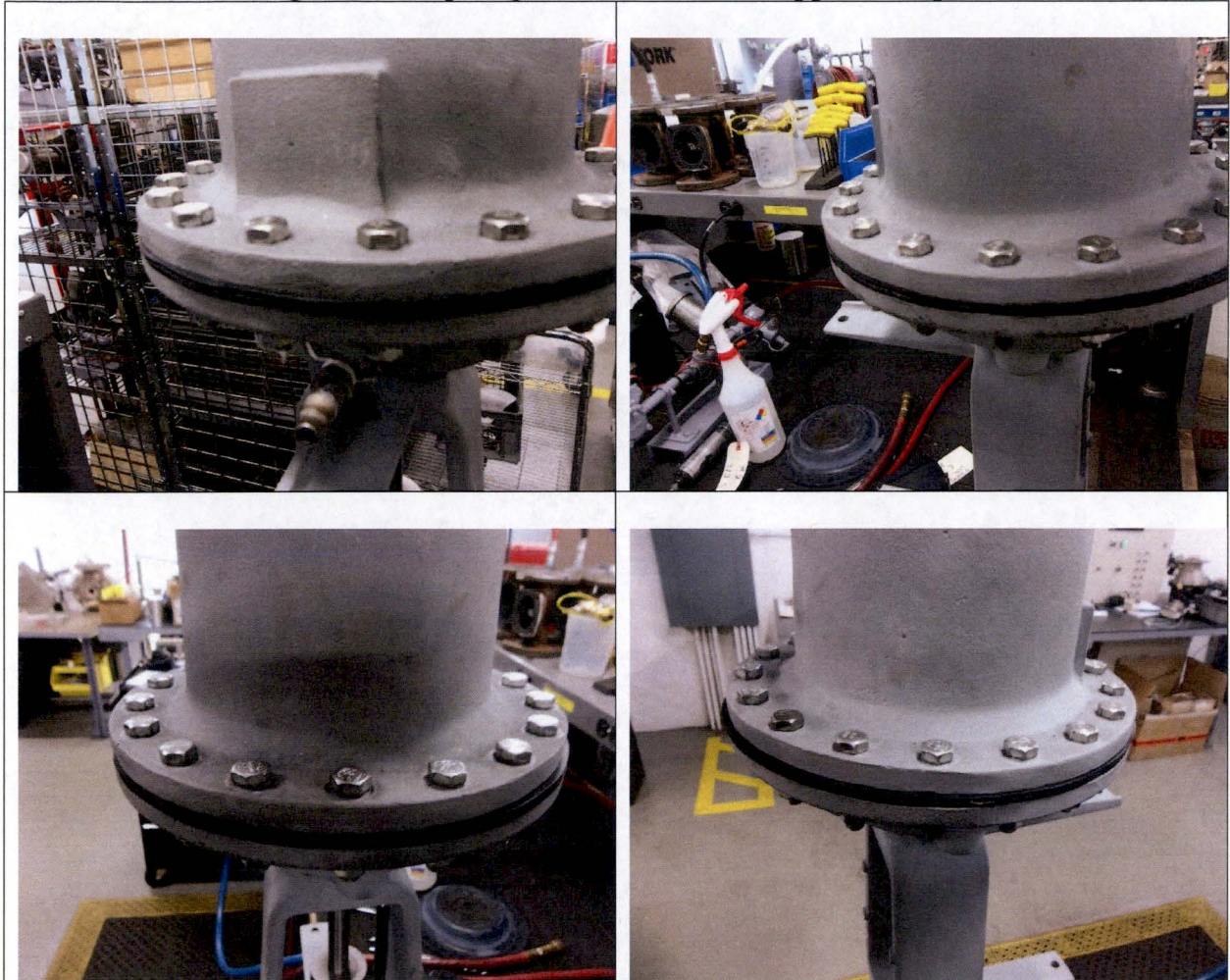
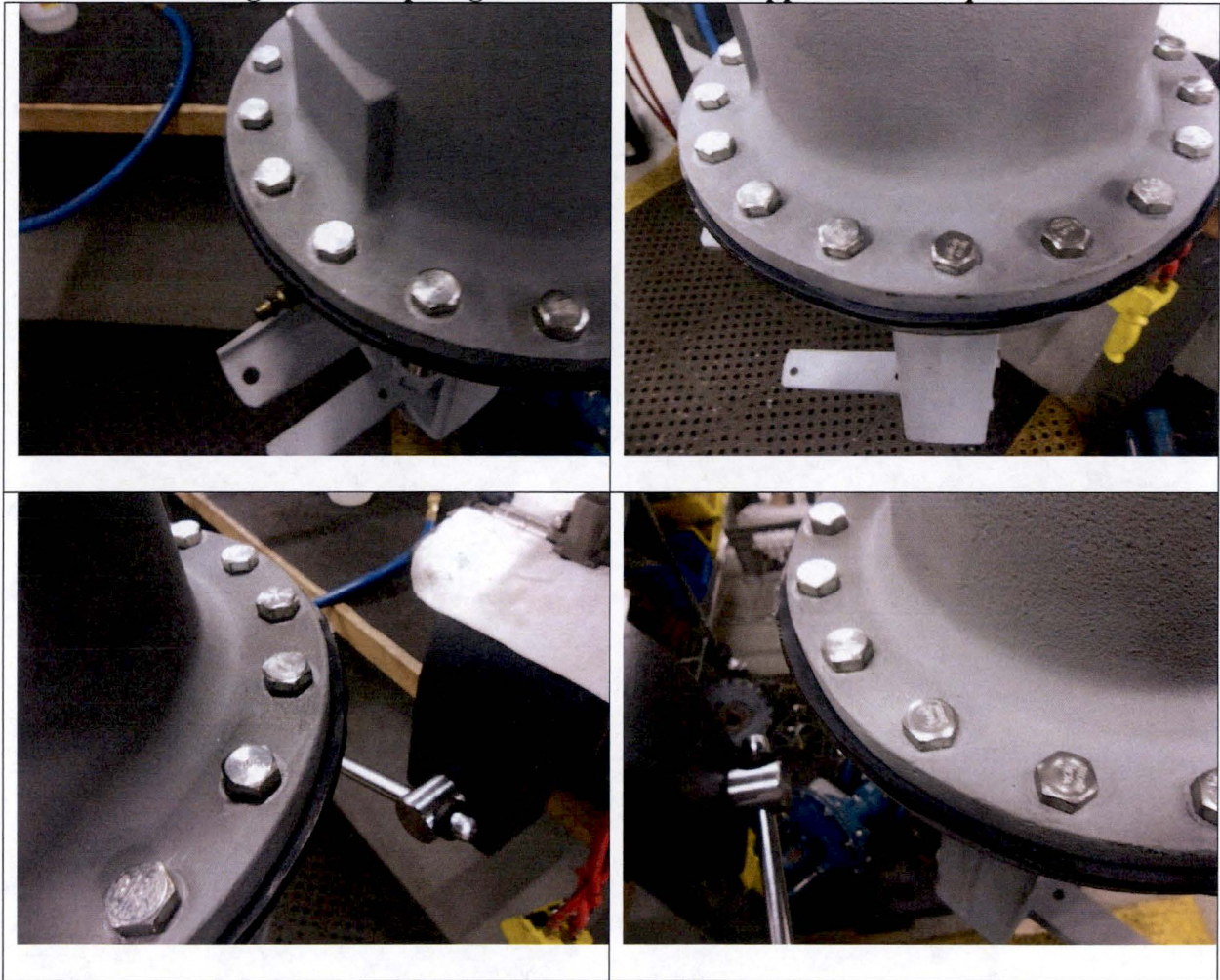


Figure 6: Diaphragm with 300 in lbs of applied bolt torque



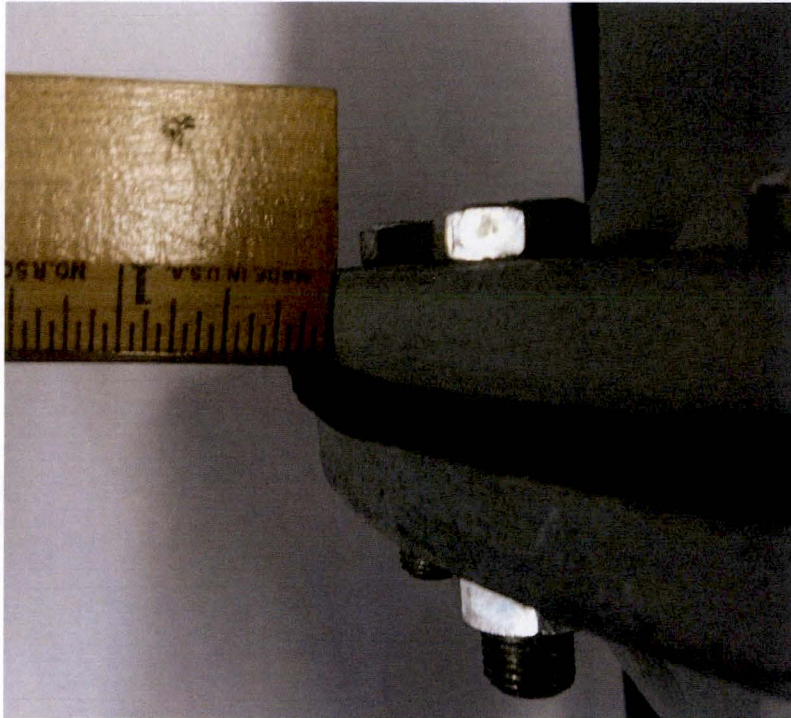


Figure 7: 300 in-lb - Extrusion of edge by 1/8"

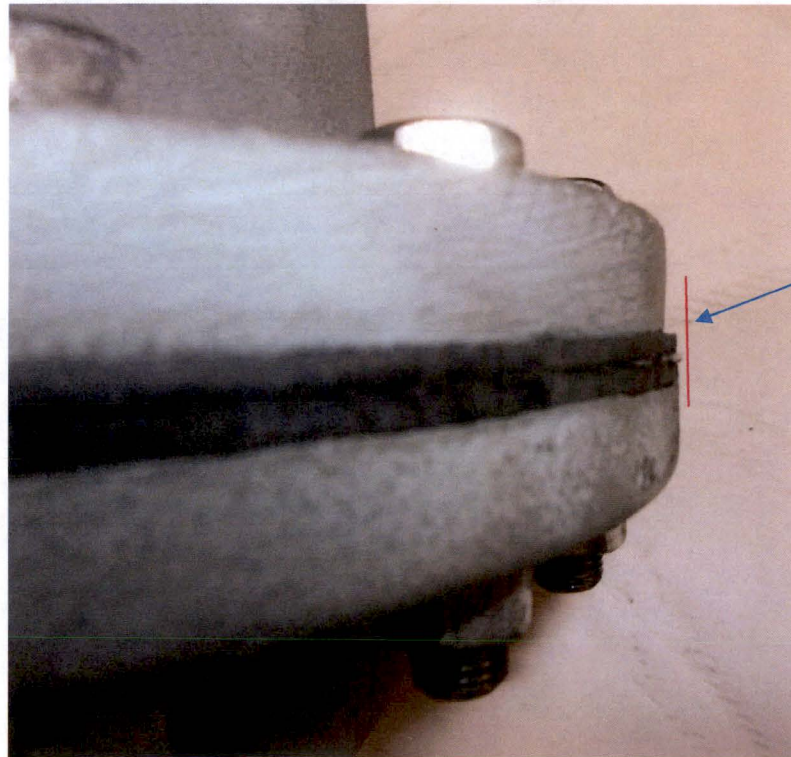


Figure 8: 72 in-lb – nominal extrusion, square edge

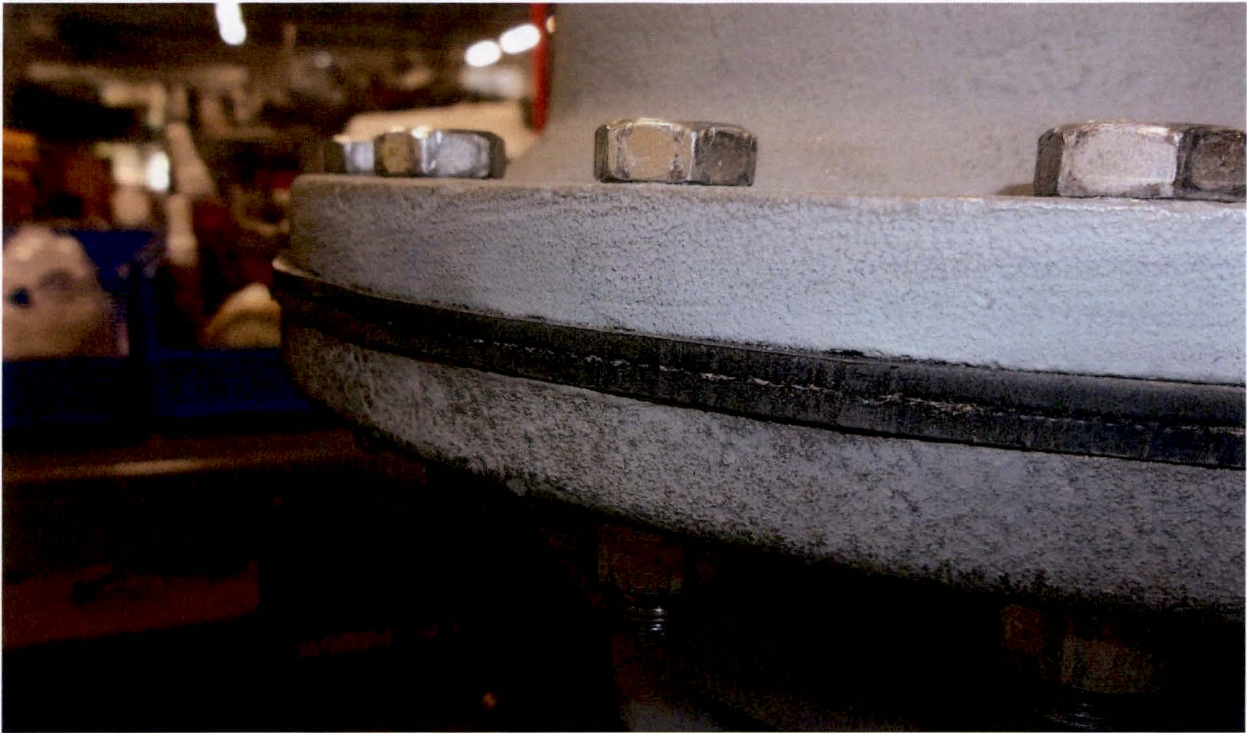


Figure 9: Diaphragm with 72 in-lb applied torque – undistorted, square edge



Figure 10: Diaphragm with 300 in-lb applied torque – Distorted, edge not square

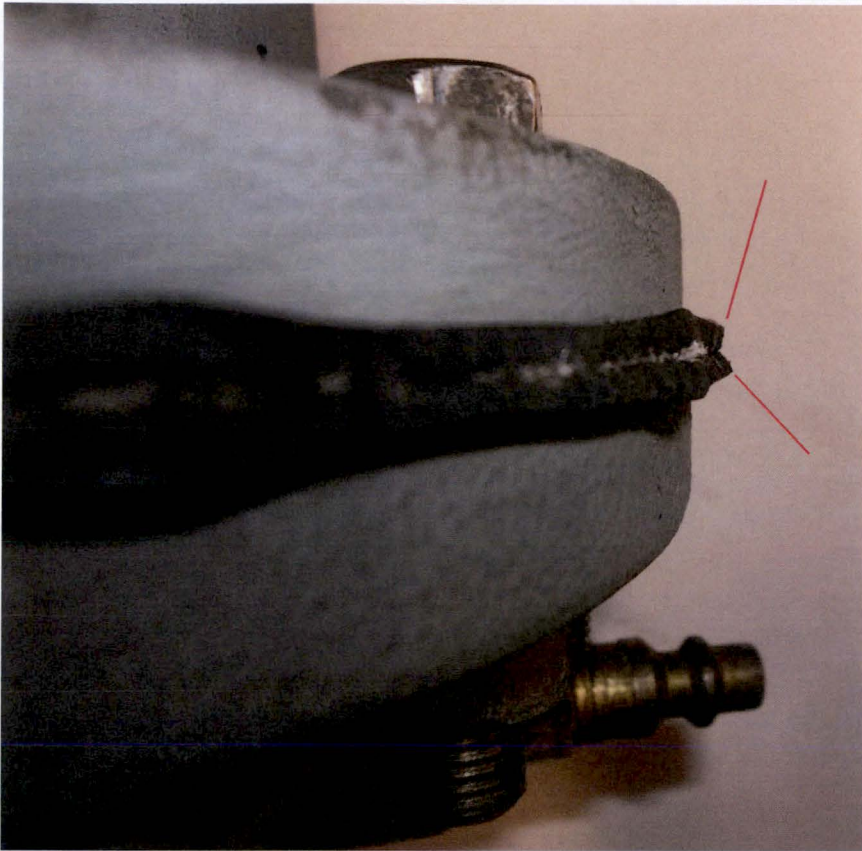


Figure 11: Diaphragm with 300 in-lb applied torque – Distorted, edge not square