

# Analysis of the Damage of Flexible Joint in Fuel Oil Pipelines Directed to Storage Tanks at PT X

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**Abstract** - In piping systems, flexible joints can mean connections or elements designed to absorb movement or pressure that can occur in pipes, such as temperature changes or ground movements. This function can help prevent cracks or damage to the pipe system. The use of flexible joints in oil piping aims to maintain the integrity of the pipe system, prevent leaks, and reduce pressure that can damage pipes or other devices. This is critical especially in the oil and gas industry environment which has dynamic operational conditions. The purpose of this study was to find out how to maintain flexible joints and handle damage that occurs to flexible joints in storage tanks at PT X. The results of the study showed that damage of Flexible Joints occurred due to the installation of Motor Operated Valves (MOVs) that did not meet standards and Pressure Safety Valves (PSVs) was not calibrated everyday that experienced corrosion and broken springs due to lack of maintenance. Therefore, routine inspections were needed to prevent damage to the Pressure Safety Valve.

**Keywords:** Flexible joint, Pressure safety valve, Oil piping, Pressure Safety Valves, PSV, Motor Operated Valves.

## I. INTRODUCTION

Analysis of the piping system in the distribution of fuel oil involves several components in order to identify the phenomenon of damage that occurs in the system. Some things that need to be known are the piping system, Piping and Instrumentation Diagram (P&ID), type of fuel storage tank, type of pipe, connection or flange for pipe, valve, support and safety equipment, such as Pressure safety Valve (PSV).

Piping system is one of the vital systems used to flow or deliver a fluid from a lower place to the desired destination. In general, piping system consists of various components, including pipes, valves, fittings (such as elbows, reducers, tees), flanges, nozzles, instrumentation (equipment to measure and control fluid flow parameters such as temperature, pressure, mass flow rate, and height level), equipment (such as heat exchangers, pressure vessels, pumps, and compressors),

pipe supports (pipe supports and pipe hangers), and special components such as strainers, drains, and vents.

Piping and Instrumentation Diagram (P&ID) serves to provide complete and detailed information about the layout and relationship of all components in a system. P&ID is very much needed in the petroleum industry to help Supervisors and Operators analyze fluid flow (fuel) and identify critical points in order to overcome problems that may arise.

Storage tanks function to store oil or fuel products such as gasoline, diesel, aviation fuel, and others. In addition, to maintain the availability of oil or fuel supplies to always meet consumer demand. There are several types that can be considered in selecting a tank, namely the Fixed Roof Tank type, which is a cylindrical tank with a roof configuration that is united with its walls. While the floating Roof Tank is a cylindrical tank that has a different construction from the fixed roof.

Flange on a pipe is a component used to connect a pipe to a valve or tank in a piping network system. Flange components consist of various types, such as slip on, weldneck, blind, socket, lap joint, and threaded (Ansori, 2013). Flanges allow for easy installation and separation, and allow for efficient inspection and maintenance of the piping system.

One of the important components in a piping system is a valve. A valve is a tool that functions to regulate the flow of a fluid by closing, opening or partially blocking the path of the fluid flow. While fittings are components in a piping system that allow changes in the direction of the piping path, branching of the pipe, and changes in diameter (Sherwood, 1973)

Support is a tool used to hold or support a piping system. Support is designed to withstand various forms of loading both due to the design and weight of the pipe (Sustain Load) and due to temperature (Muhammad, 2017).

Pressure Safety Valve is a crucial device designed to protect the system from potential damage due to excess

pressure. The main function of this tool is to automatically reduce pressure that exceeds unexpected limits.

## II. MATERIAL AND METHOD

At the Fuel Oil terminal, there was damage to the flexible joint in the storage tank pipe 43. This flexible joint plays an important role in maintaining the performance and reliability of the oil pipeline system with functions such as thermal expansion compensation, stress reduction, shift compensation, prevention of damage due to pressure fluctuations, sound and vibration dampening, and prevention of material fatigue. Flexible joints help extend the service life of the oil pipeline system by absorbing pressure, adjusting temperature changes, and dampening vibrations, thereby increasing operational safety and efficiency. Therefore, handling and repairing flexible joints is very important for the smooth and sustainable operation at the Fuel Oil terminal.



Figure 1: Flexible Joint at the piping system

By analyzing the causes of damage, we can identify the factors that cause damage to flexible joints. Preventive measures can include design improvements, more intensive routine maintenance, or the use of materials that are more resistant to environmental conditions.

To perform the analysis, the component data given in the description below is given. The specification data for the Pressure Safety Valve (PSV) is given in table 1.

Regarding pipe data, with reference to ASME B36.10 in 2015, pipe specifications with carbon steel material and schedule 40 type are obtained. The specifications are detailed in the table below, which includes various parameters and special characteristics that are relevant to the use of pipes in certain contexts. Pipe specification data is given in table 2.

Table 1: Data specification of PSV

Specification	Remarks
Type	Conventional
Model	S3W
Size	1”NPT x 1” NPT
Year of fabricated	1993

Req Capacity	500 gpm
Set pressure	113,78/8,00 kg/cm <sup>2</sup> g
Back pressure	- Psig/ - kg/cm <sup>2</sup> g
Popping test	113,78/8,00 kg/cm <sup>2</sup> g
Leak test pressure	102,40 psig/7,20 kg/cm <sup>2</sup> g
Test media	Nitrogen
Pressure indicator	Steins 350,00 psig (24,61 kg/cm <sup>2</sup> g)

Based on the data obtained and referring to the American Petroleum Institute 5L (API 5L), using pipes with grade L245 B made of Carbon Steel material. The pipe grade contained in API 5L has a difference only in the Carbon Steel material, and the grade is a factor that distinguishes it. Flexible metal with AISI 316 material is a component designed to provide high flexibility in the piping system. Made of AISI 316 stainless steel, this component offers optimal resistance to corrosion, high temperatures, and mechanical loads.

Table 2: Specification data of pipe SCH 40

Pipe grade	Pipe body Seamless			Weld Seam of Ew
	Yield strength MPa (psi) min	Tensile strength MPa (psi) min	Elongation % min	Tensile strength MPa (psi) min
L210 or A	210 (30 500)	335 (48 600)	c	335 (48 600)
L245 or B	245 (35 500)	415 (60 200)	c	415 (60 200)

The flexible joint used has a diameter of 12 inches and is shown in Figure 2 with the following parts:

1. Bellows
2. Wire Braids
3. Seal Rings
4. Flanges
5. Floating flange or fixed flange

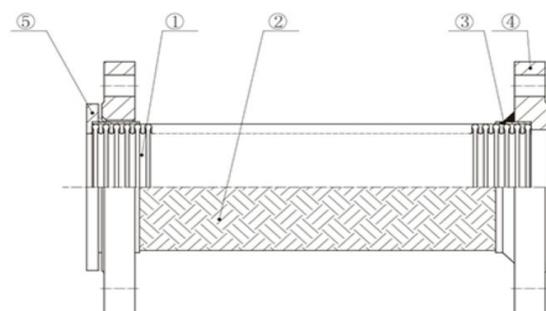


Figure 2: Flexible Joint Parts

This flexible joint has detailed specifications and reflects a high level of reliability and durability, with a diameter of 300 mm (12 inches), a length of 1000 mm, and an outer diameter of 340 mm. Its design is optimized to overcome the

challenges of the operational environment, flexible with a maximum offset of 50 mm to adapt to changes in load and pressure. In addition, a working pressure of 10-16 bar shows the strong performance of this component under external pressure.

Figure 3 is an actual design image of the Motor Operated Valve (MOV) layout in the storage tank, which functions to regulate the valve movement associated with the piping system. There is one motor operated valve installed near the tank at the oil inlet to the tank, the flexible joint is located before the pressure safety valve (PSV). It is estimated that the design of the storage tank layout is prone to damage, especially to the flexible joint. If there is excessive thermal expansion at the pipe flow rate accompanied by a pressure safety valve that is not functioning normally and the motor operated valve is 100% closed, it is estimated that damage will occur to the flexible joint, because when the pipe experiences excessive pressure, there should be a signal from the PSV to move the MOV to open the valve so that the pipe pressure is reduced. The diagram of the Motor Operated Valve is given in Figure 4.



Figure 3: Location of MOV and PSV in relation to the flexible joint of the storage tank

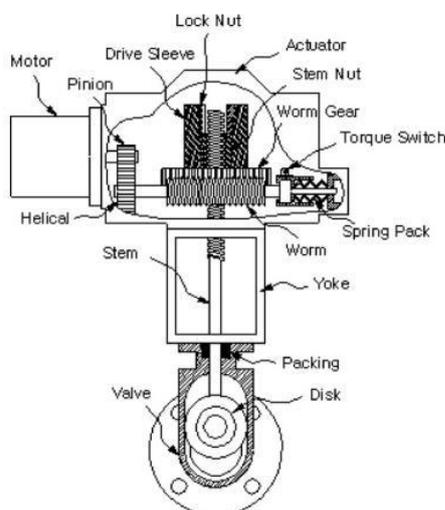


Figure 4: Diagram of Motor Operated Valve (MOV)

Flexible joints on tanks located elsewhere such as Figure 5 are better than the design in the tank being analyzed, namely if there is excessive thermal expansion, the PSV functions as a flexible joint safety. If the PSV is not calibrated normally, there is a MOV that signals the operator that there is excess pressure in the pipe so that the motor operated valve can be opened 10% to release excess pressure in the pipe so that there is no damage to the pipe or damage to the flexible joint. But this is not efficient in saving the budget, that 3 valves are needed consisting of 2 motor operated valves and 1 manual valve.

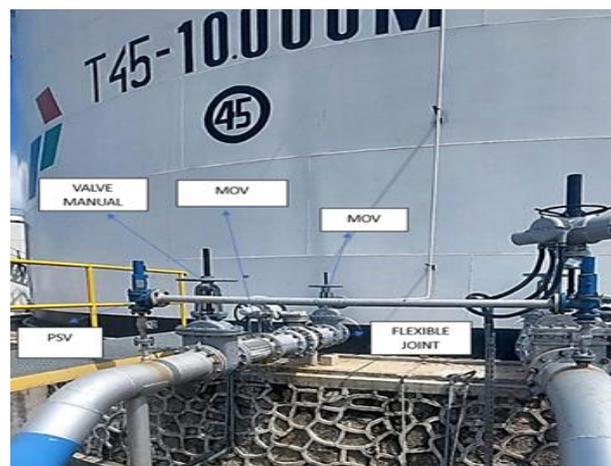


Figure 5: Location of MOV and PSV relative to flexible joints in other storage tanks

Referring to the Petroleum Research Journal published in 2021 on pages 77-90 by KeAi Chinese roots global impact, the journal makes inspection and protection for oil transmission pipelines based on cloud computing. In the sub-chapter of inspection and protection for oil transmission pipelines, this journal also discusses the design of the location of the motor operated valve in relation to the tank.

The illustration from the journal shows 2 (two) pressure transmitters before and after the control valve/motor operated valve which are useful for converting the measured pressure into an output signal that can be used to monitor, control, or record pressure data in industrial processes. Thus, pressure transmitters play an important role in observing and controlling industrial processes that require accurate pressure measurements.

### III. RESULTS AND DISCUSSIONS

At first, flexible joint strength analysis is carried out by conducting simulations using the Finite Element Method (FEM) which is a very useful numerical method for the analysis and design of structures and physical phenomena. FEM is used to analyze the strength, deformation, and response of materials to structures. In product design, FEM

helps engineers design and optimize structural performance before production. FEM is also applied in pipe analysis, pressure distribution, deformation, heat analysis, fluids, and electromagnetics. This method allows modeling and in-depth understanding of complex physical phenomena in various fields of engineering and science.

Regarding the flexible joint structure, simulations using the Finite Element Method are intended to find the stress that occurs due to the load of the movement of the end of the structure and the internal pressure given in figures 6, 7 and 8.

simulation, the structure has been programmed to experience downward movement at the end for figure 7 and programmed to experience tension at the end for figure 8. The visible red contour shows the peak stress point at the flexible joint after going through the analysis process. Related to the effect of structural movement from the end of the flexible joint in figure 7, it shows that the flexible joint structure is still in a safe condition for use.

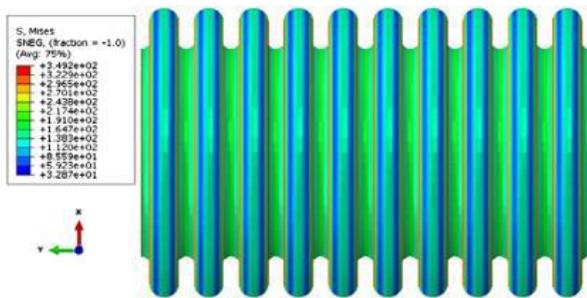


Figure 6: The stress of flexible joint structure in normal condition

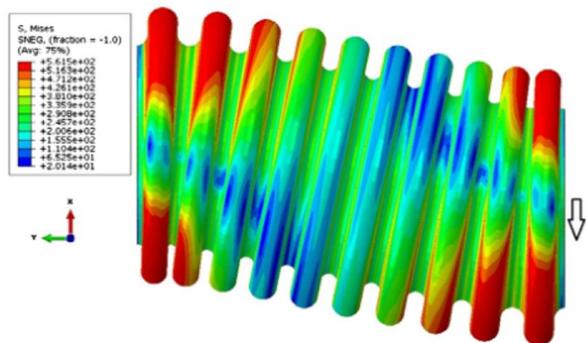


Figure 7: The stress of flexible joint structure due to shift displacement at its ends

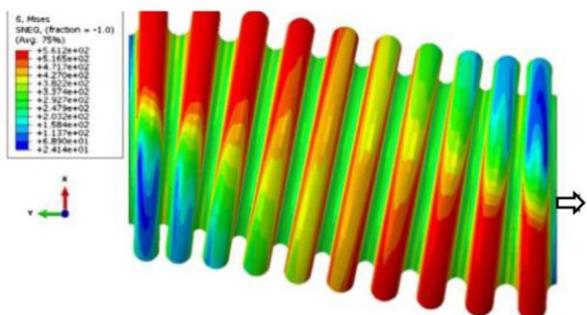


Figure 8: The stress of flexible joint structure due to tensile and compressive force

Figure 6 is the flexible joint stress under normal conditions, that is, there is no shift at the end and no tension or pressure on the flexible joint. Figure 7 and figure 8 visualize the results of finite element simulations of the stress due to fatigue cycles applied to the flexible joint structure. In this

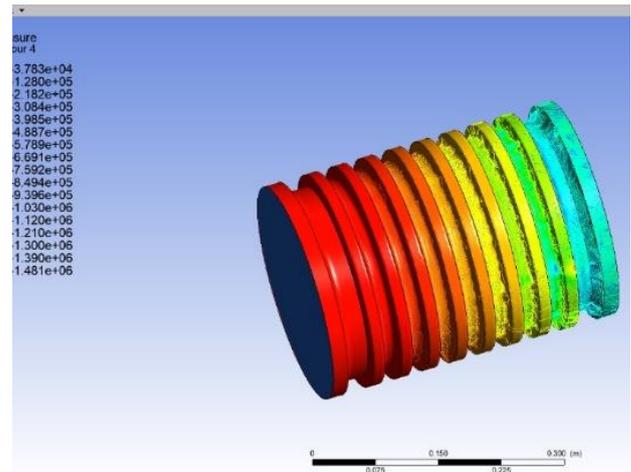


Figure 9: The stress of flexible joint structure due to internal pressure

The analysis of flexible joint structure stress due to normal internal pressure from the fluid is given in Figure 9. The stress distribution that occurs in the structure is shown. The results of the analysis show that the stress that occurs in the structure is still safe to use. So from the simulation it can be concluded that the flexible structure stress that occurs due to fatigue load (end shift) and internal pressure load provides a safe value for operation. So that the damage that occurs in the flexible joint is not due to the working load but due to inaccuracy in installation and due to the corrosion effects that occur as has been obtained from observations in the field.

Based on the data of the installed flexible joints as explained above, field observations show that the temporary conclusion is that damage to the flexible joint is influenced by the installation of MOV (Motor Operated Valve) to the tank that does not meet standards, where aspects that need to be considered such as, accessibility for maintenance, position of the motor operated valve to the inlet/outlet, position of the pressure safety valve to the motor operated valve, and position of the flexible joint to the pressure safety valve, do not meet standards so that damage to the flexible joint does not occur. The use of metal flexible joints is the most flexible material, suitable for use at high temperatures, and has strong properties and is not easily damaged. On the other hand, it is proven that damage to the flexible joint is also caused by PSVs that are not maintained and not calibrated normally so that they experience corrosion and broken springs. Because they are not

calibrated normally, if there is excessive pressure, the valve in the PSV cannot open automatically. Excessive pressure will cause the flexible joint to potentially be damaged because it is the weakest component.

#### IV. CONCLUSION

Continuous production activities, especially on equipment that plays an important role in the production process, must always be in optimal condition and always maintained. Maintenance on Flexible Joints is carried out to keep the pipe working optimally without reducing production quality and preventing fatal damage that can hinder function in the production process. Based on the analysis that has been carried out above, several conclusions can be drawn as follows:

1. Damage to the flexible joint at PT X is influenced by the installation of MOV to the tank that does not meet the standards, where aspects that are considered such as, maintenance accessibility, position of the motor operated valve to the inlet/outlet, position of the pressure safety valve to the motor operated valve, and position of the flexible joint to the pressure safety valve, must meet the standards so that damage to the flexible joint does not occur.
2. Metal flexible joints are the most flexible materials, suitable for use at high temperatures, and have strong properties and are not easily damaged.
3. In this study, it was proven that damage to the flexible joint was caused by the PSV not being calibrated normally.

Related to the conclusion above, there are several suggestions that must be done to overcome the emergence of flexible joint damage, namely:

1. It is necessary to update the MOV layout design on the piping system in the tank.
2. Routine checks on the PSV are needed, so that the PSV is always in normal calibration every day.

3. Testing is needed with a computational method so that we can find out the worst impact when damage occurs to existing components.

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