# Design & Analysis of Filled Coating Piping System

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**Abstract:** *Piping design is the basis for every aspect of material flow within and outside the plant. For example, in many processing plants, material movement inside the various units must be optimized to ensure that it travels the shortest distance and over the fewest bends possible to be processed quickly. Basically, a piping system is a closed system having several components that carry or transfer the fluids (liquids, gases, or slurry) from one piece of equipment to another or from one place to another. For a complex or an industrial plant. There are many aspects to be considered while it is designed, and one of the most prominent is piping design and its modeling. The basic design code used for the above plant is the ASME B31.3 process piping code.*

*The main objective of this paper is to provide an aesthetic and optimized piping design that fulfills the required process with a sustainable, long-lasting design with the help of stress analysis by using CAESAR II software. Stress aims to resolve all the forces in the components and check the load and flexibility of the piping system that could work during conditions such as sustained operation, hydrostatics, and seismic. To provide suitable supports to make the system balance with all working conditions. Here in this project, we have taken one example of a filled coating piping system, which is one of the more complicated processes in the roof singles manufacturing process and has a normal temperature of 425 °C.*

***Keywords-*** *Piping design, 3d modeling, Filled Coating system, Stress Analysis, CAESAR II optimized & sustainable design.*

## INTRODUCTION

**Piping Design** is the one of the engineering discipline of mechanical engineering that covers the design of piping and the layout of equipment and process units in chemical, petrochemical, or hydrocarbon facilities. To ensure the safe functioning of the facilities for the design life, piping engineers oversee the layout of the overall plant facilities, the positioning of equipment and process units on the plot, and the design of the associated piping. To transfer or distribute process fluid from one piece of equipment to another in a process plant, pipework is an assembly of pipeline components. This assembly's pipeline components include pipes, fittings, flanges, valves, piping specialties, bolts, and gaskets. This definition also covers pipe-supporting components like pipe shoes, but it excludes support buildings like foundations, racks, and sleepers for pipes. As per ASME B31.3, the piping designer is responsible to the owner for ensuring that the engineering design of the piping complies with the requirements of this code and any additional requirements established by the owner. Piping engineering is an important aspect in creating a plant facility and goes much beyond simply designing piping in accordance with ASME rules. There are numbers of different ASME codes available to use to understand standard procedure to follow while design the plant. Most of the plant facilities in the petrochemical and hydrocarbon industries will use the ASME B31.3code for the design of process piping. **Piping stress analysis** is one of the most crucial activities need to perform in piping design. At largely process critical pipes are once routed by design guidelines, process requirements those needs to be verified or analysis by piping stress engineers by analysis to ensure that the system will work smoothly without failure throughout their design life cycle. A pipe stress analysis, also known as a thermal flexibility analysis, forecasts and checks stresses in piping systems as well as any access loads placed on equipment because of weights, pressure, temperature fluctuations, thermal gradients, and bolt-up strain. This study is normally required for major process piping those experiences high temperature fluctuations take place or for long pipe runs through the pipe rack, such as hot piping to coolers or headers, Steam piping, Reactor, Column piping. Cases where equipment's are more sensitive to external loads may also require checking the pipe stress analysis. For the primary process piping, analysis determines the various piping stresses brought on by temperature cycles, pipe and fitting weights, and static pressure. CAESAR II stress analysis software is used for modeling the piping system one by one with number of cases to be check separately., there are other specialty computer programs are also available to check stress analysis in piping system such as NozzlePRO and FETee.

Stress is frequently generated in piping systems by weight, internal/external pressure, temperature change, irregular loads from the wind, seismic occurrences, PSV discharge, etc. force is generated by vibration.

## METHOLOGY

**F**illed Coating piping System: Filled Coating it is one of the systems known as Roof coating application is the process used to protect and extend the life of an installed roofing system. Roof coverings, also known as roof coatings, are made of a thick coating material that typically comprises high-quality resins. Each application of a business roof coating adds an additional layer of defense. a coating made entirely of acrylic that has been particularly developed for use on asphalt shingles. Its distinctive recipe offers outstanding longevity, improved fading resistance, and a smooth, low sheen that binds the tiles together to prevent wind lift-up while resisting cracking, peeling, and chipping. Roof coating systems have a lifespan of 10 to 20 years, but after their warranty expires, they can be recoated, at which point a new warranty will apply. Roof coating systems are a renewable and sustainable roofing technology since the procedure may be repeated. For UV protection and resistance, silicone roof coatings are the best option.


Fig.1: Roof Shingles with numbers of layers.

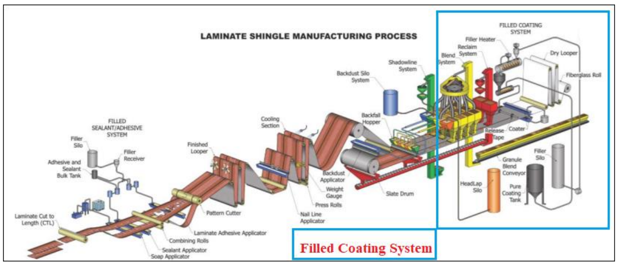



Fig.2: Roof Shingles manufacturing process plant

## DESIGN: PIPING LAYOUT AND ROUTING

Filled Coating system is the one of the systems which is involved in the manufacturing of roof shingles. Basically, Coating is the mixture of oxidizing asphalt flux which is use for shingle plant. The Filled Coating Mixer receives heated coating that is metered into the mixer along with heated filler from the Filler Heater screw conveyor. Coating and filler enter the mixer and are blended to produce filled coating with a nominal temperature of 425°F. The filled coating is discharged from the Filled Coating Mixer into the aboveground 6,000-gallon Filled Coating Surge Tank which provides short-term storage of filled coating. The surge tank is provided with an agitator to maintain the suspension of the filler. Filled coating temperature is maintained by the HTM system. Filled coating is supplied to the Coater on the shingle machine by the Filled Coating Supply Pump after first being processed through a homogenizer.

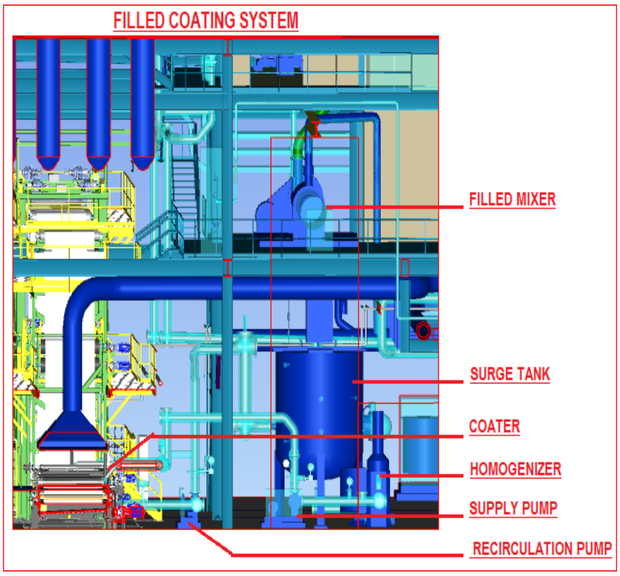



Fig.3: Filled Coating piping system.

Now that we have one of the piping connections in the system mentioned above, from the surge tank bottom nozzle connection to the homogenizer inlet nozzle connection, we can use CAESAR II software to check stress feature to see if our design is feasible by given the design parameters.

**Data use:** Piping & instrumentation diagram (P&ID), Piping metrical specification (PMS), Piping 3D Model, Piping Isometric, Mechanical Data sheet(MDS), Line list (Critical line List), Piping Layout, Equipment Layout. **Design Details:** ASME 31.3 process Piping, Pipe diameter 6" Pipe Material CS, Class 150# ASTM A53 Grade B, Operating & Design Pressure 15 PSIG / 100 PSIG, Operating & Design Temperature 435 F / 500 F.

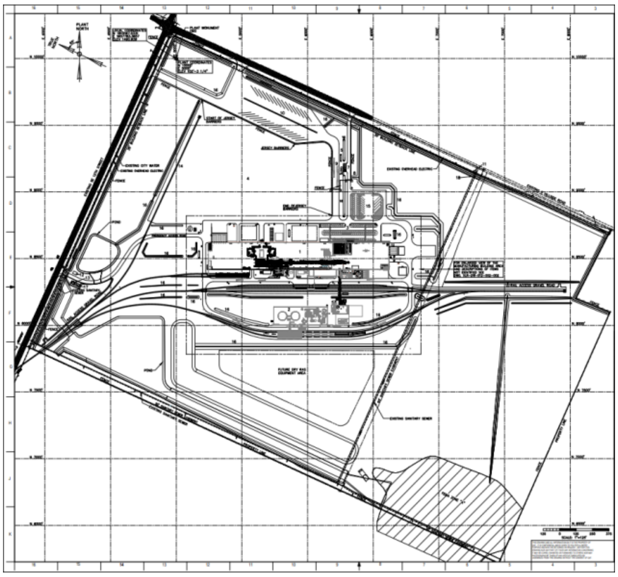


Fig.4: Over all Layout.

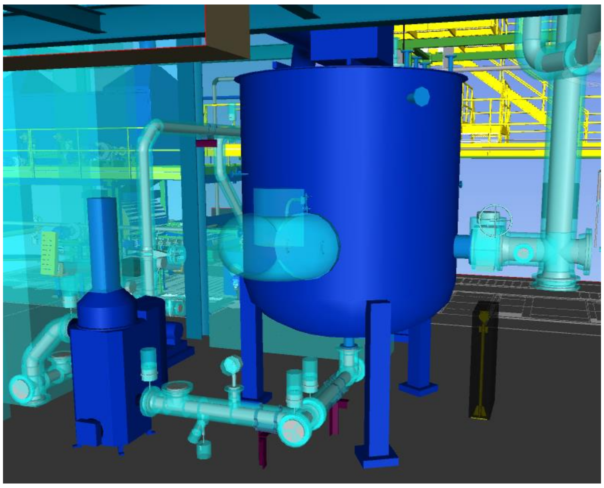


Fig.5: First Case study with Preliminary 3D design.

The design was approved by the client from an operational and maintenance physibilty point of view, and the layout engineer had completed preliminary routing in accordance with the minimum pipe routing suggested by the process team. However, when it came to the stress department, the routing was ineffective because it had become rigid and there had been no flexibility during the normal operation condition of the plant. Once the plant started and it reaches to its highest temperature, the connection between the tank & the homogenizer will be pushed out of its original position after a few cycles and break the nozzles OR the line between the surge tank and homogenizer will begin to spread towards the homogenizer right at the connection and back side of the tank. To avoid such breakdown during the operation we need to think different ways.

Hence there were two options, one is to change the location of equipment's and second is to change the pipe routing. Then to utilize the CAESAR II software programme to check stress characteristic on the system demonstrated above, from the surge tank bottom nozzle connection to the homogenizer inlet nozzle connection. Refer the below fig. for the same.

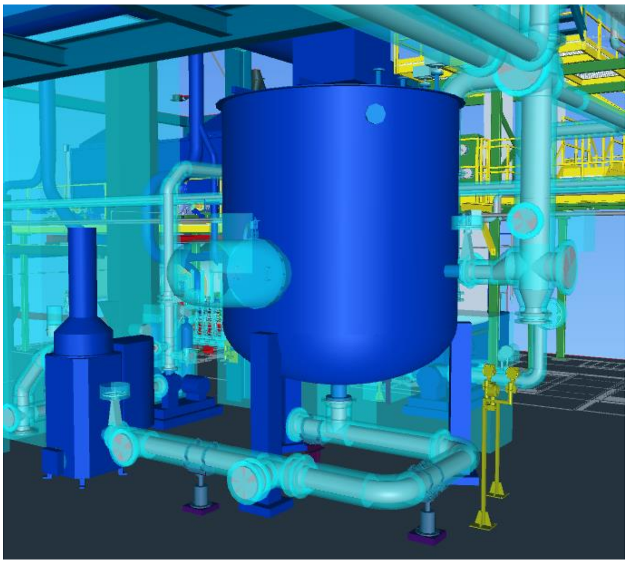


Fig.6: Second Case study with change routing

Due to space and process limitations in the aforementioned scenario, we had to replace the pipe routing with a C-type position by increasing the number of bends while keeping the position of the equipment in place. When we used the CAESAR II software, the supports were the only obstruction during the initial cut. Stress advised against using rigid, typical support to use Variable spring support with clamp shoe to avoid failure. Because in the above case the line would probably lift as a result of the high temperature during plant operation, further disrupting the system.

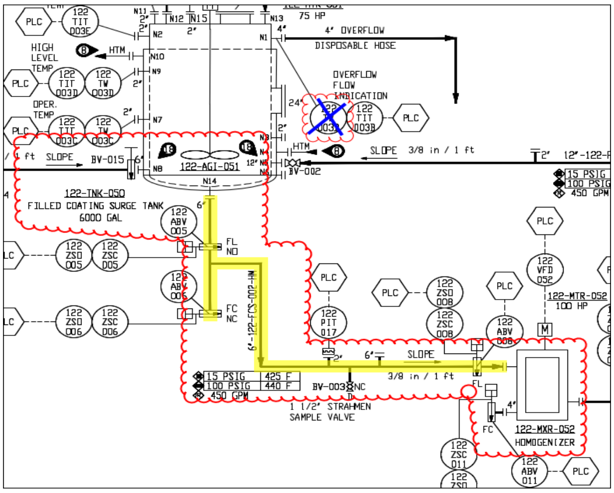


Fig.7: Piping & instrumentation diagram (P&ID)

## STRESS ANALYSIS

A "piping stress engineer" is a pipe engineer that gives technical advice on piping design. They use software to construct static and dynamic piping models and analyses the piping system stresses. By performing listed activities. To model the line in CAESAR II software, Determine potential failure cases, Check and qualify the behavior of the piping under various reasons such as high temperatures, high pressures, wind effects, and seismic conditions. Recommend pipe supports with proper span, locations. Ensure piping loads are within the allowable range by using the ASME 31.3.

**1.1 Load Categories:**

Sustained loads: The presence of these loads is anticipated during regular plant operation. When working under regular conditions, pressure and weight loads are typical sustained loads. Expansion loads: Expansion loads are those resulting through pipe displacements. Examples involve structure settlement, seismic anchor movements, thermal anchor movements, and thermal expansion. Occasional loads: These loads are present at infrequent intervals during plant operation. Occasional loads include things like earthquakes, wind, and fluid transients like water hammer and relief valve release.

**1.2 Flexibility analysis:**

In order to find the most cost-effective designs with sufficient safety, flexibility analysis is performed on a piping system to examine its behavior when its temperature varies from ambient to working. The following are the considerations that decide the minimum acceptable flexibility on a piping configuration. 1) Maximum allowable stress range in the system. 2) The upper and lower limits of forces and moments that the pipe system is permitted to impose on the associated equipment. 3) The displacements within the piping system. 4) The maximum allowable load on the supporting structure.

**1.3 Stress Intensification Factor (SIF):**

The definition states that it is the ratio of maximum stress level to nominal stress. To take into consideration, the impact of localized stresses on piping caused by repeated loading, it is used as a safety factor. This factor is used in the design of pipes at welds, fittings, branch connections, and other places where there may be stress concentrations and a risk of fatigue failure. Typically, experimental techniques are employed to ascertain these variables.

$$\text{In-plane, } i = \frac{0.9}{h^{\frac{2}{3}}}$$

$$\text{Out-plane, } i_0 = \frac{0.75}{h^{\frac{2}{3}}}$$

**1.4 Static Analysis:** Static analysis is carried out to find the sorted code stresses, code compliance stresses, pipe support load, element forces and moments and displacement at all nodes and hangers. This comprehensive analysis is done by using a CAD package like CAESAR II software.

## USING CAESAR II DETAIL ANALYSIS REPORTS

Stress analysis assures the safety of the piping and its components, the safety of the connected equipment for and the stability of the supporting structure, as well as the compliance of piping deflections with predefined limitations.

CAESAR II® is stress analysis software which is used for piping system a mechanical engineering and evaluation. You can model the piping system and define the loading constraints applied to it.

**First Case study with Preliminary 3D design. (Fig.5)**

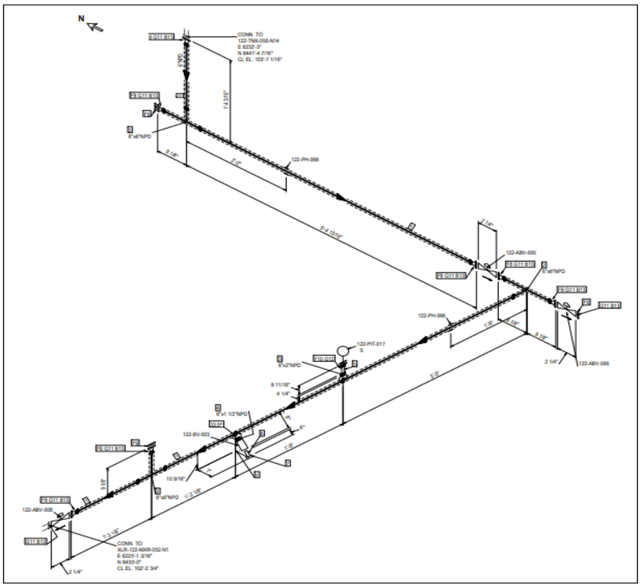


Fig.8: First Case Design Output – Isometric-1

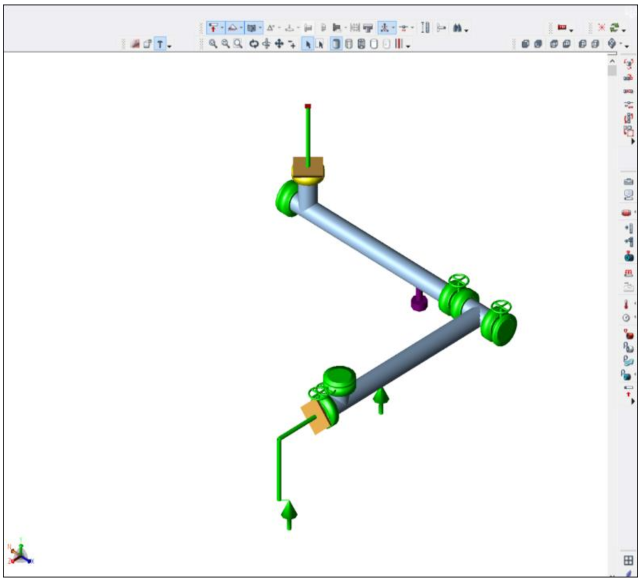


Fig.9: First Case CAESAR II Modelling details.

1.1Stress analysis Result: Stress Summary report.

STRESS SUMMARY (LEGACY) REPORT: Highest Stresses Mini Statement
Various Load Cases

Highest Stresses: (lb./sq.in.) LOADCASE 3 (HYD) WW+HP+H

| | | | | |
|---|---|---|---|---|
| Ratio (%): | 8.0 | @Node | 120 | |
| Code Stress: | 2784.8 | Allowable Stress: | | 35000.0 |
| Axial Stress: | 777.4 | @Node | 20 | |
| Bending Stress: | 2685.0 | @Node | 120 | |
| Torsion Stress: | 65.9 | @Node | 70 | |
| Hoop Stress: | 1624.6 | @Node | 30 | |
| Max Stress Intensity: | 3469.3 | @Node | 120 | |

CODE STRESS CHECK PASSED : LOADCASE 25 (SUS) W+P1+H

Highest Stresses: (lb./sq.in.) LOADCASE 25 (SUS) W+P1+H

| | | | | |
|---|---|---|---|---|
| Ratio (%): | 17.0 | @Node | 120 | |
| Code Stress: | 3315.4 | Allowable Stress: | | 19540.0 |
| Axial Stress: | 682.0 | @Node | 20 | |
| Bending Stress: | 3524.0 | @Node | 120 | |
| Torsion Stress: | 88.4 | @Node | 70 | |
| Hoop Stress: | 1405.7 | @Node | 30 | |
| Max Stress Intensity: | 4212.7 | @Node | 120 | |

CODE STRESS CHECK FAILED : LOADCASE 49 (EXP) L49=L4-L8

Highest Stresses: (lb./sq.in.) LOADCASE 49 (EXP) L49=L4-L8

| | | | | |
|---|---|---|---|---|
| Ratio (%): | 115.9 | @Node | 120 | |
| Code Stress: | 34683.8 | Allowable Stress: | | 29918.8 |
| Axial Stress: | 52.6 | @Node | 70 | |
| Bending Stress: | 34666.9 | @Node | 120 | |
| Torsion Stress: | 540.7 | @Node | 70 | |
| Hoop Stress: | 0.0 | @Node | 20 | |
| Max Stress Intensity: | 43013.1 | @Node | 120 | |

1.2 Displacement Analysis Result:

DISPLACEMENTS REPORT: Nodal Movements
CASE 4 (OPE) W+D1+T1+P1+H

| Node | DX in. | DY in. | DZ in. | RX deg. | RY deg. | RZ deg. |
|---|---|---|---|---|---|---|
| 10 | 0.0001 | -0.0709 | 0.0001 | -0.0003 | 0.0001 | 0.0006 |
| 20 | 0.0001 | -0.0816 | 0.0001 | -0.0004 | 0.0001 | 0.0007 |
| 30 | 0.0016 | -0.1187 | 0.0010 | -0.0084 | 0.0020 | 0.0133 |
| 40 | -0.0147 | -0.1200 | 0.0012 | -0.0084 | 0.0020 | 0.0134 |
| 50 | -0.0254 | -0.1208 | 0.0013 | -0.0084 | 0.0020 | 0.0134 |
| 60 | -0.0283 | -0.1211 | 0.0013 | -0.0084 | 0.0020 | 0.0134 |
| 70 | 0.1610 | -0.0888 | 0.0002 | -0.0567 | -0.0055 | 0.0371 |
| 80 | 0.2036 | -0.0799 | 0.0023 | -0.0697 | -0.0122 | 0.0343 |
| 90 | 0.2143 | -0.0777 | 0.0031 | -0.0698 | -0.0123 | 0.0342 |
| 100 | 0.2210 | -0.0764 | 0.0036 | -0.0699 | -0.0123 | 0.0342 |
| 110 | 0.2317 | -0.0742 | 0.0043 | -0.0700 | -0.0124 | 0.0342 |
| 120 | 0.2479 | -0.0709 | 0.0057 | -0.0749 | -0.0159 | 0.0335 |
| 130 | 0.2642 | -0.0678 | 0.0072 | -0.0749 | -0.0159 | 0.0331 |
| 140 | 0.2749 | -0.0657 | 0.0082 | -0.0749 | -0.0159 | 0.0331 |
| 150 | 0.2815 | -0.0644 | 0.0088 | -0.0749 | -0.0159 | 0.0331 |
| 160 | 0.2845 | -0.0638 | 0.0091 | -0.0749 | -0.0159 | 0.0331 |
| 170 | 0.2249 | -0.0000 | 0.1474 | -0.0850 | -0.0334 | 0.0319 |
| 180 | 0.2130 | 0.0289 | 0.2068 | -0.0817 | -0.0343 | 0.0312 |
| 190 | 0.2100 | 0.0451 | 0.1990 | -0.0817 | -0.0343 | 0.0312 |
| 200 | 0.2080 | 0.0559 | 0.1938 | -0.0817 | -0.0343 | 0.0312 |
| 210 | 0.2074 | 0.0588 | 0.1924 | -0.0817 | -0.0343 | 0.0312 |
| 220 | 0.2096 | 0.0367 | 0.2231 | -0.0819 | -0.0345 | 0.0310 |
| 230 | 0.2083 | 0.0399 | 0.2297 | -0.0819 | -0.0345 | 0.0310 |
| 235 | 0.2075 | 0.0419 | 0.2338 | -0.0819 | -0.0345 | 0.0310 |
| 240 | 0.2061 | 0.0451 | 0.2404 | -0.0819 | -0.0345 | 0.0310 |
| 250 | 0.0001 | -0.0709 | 0.0001 | -0.0003 | 0.0001 | 0.0006 |
| 260 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | 0.0000 | 0.0000 |
| 275 | 0.2061 | 0.0451 | 0.2404 | -0.0819 | -0.0345 | 0.0310 |
| 280 | 0.1953 | 0.0709 | 0.2936 | -0.0820 | -0.0345 | 0.0309 |
| 285 | 0.2082 | -0.0000 | 0.3279 | -0.0819 | -0.0345 | 0.0309 |

1.3 Restraint Summary Extended Report:

RESTRAINT SUMMARY EXTENDED REPORT: Loads On Restraints
Various Load Cases

CASE 25 (SUS) W+P1+H

| Node | Load Case | FX lb. | FY lb. | FZ lb. | MX ft.lb. | MY ft.lb. | MZ ft.lb. | DX in. | DY in. | DZ in. |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | -30 | -32 | -6 | -85.8 | 10.1 | 120.3 | 0.0000 | -0.0000 | 0.0000 |
| | 4(OPE) | -188 | 137 | -139 | -657.4 | 142.0 | 1067.4 | 0.0001 | -0.0709 | 0.0001 |
| | 6(OPE) | -190 | 143 | -139 | -688.3 | 140.3 | 1110.7 | 0.0001 | -0.0737 | 0.0001 |
| | 25(SUS) | -28 | -46 | -5 | -93.9 | 9.9 | 115.7 | 0.0000 | -0.0000 | 0.0000 |
| | MAX | -190/L6 | 143/L6 | -139/L6 | -688.3/L6 | 142.0/L4 | 1110.7/L6 | 0.0001/L6 | -0.0737/L6 | 0.0001/L6 |
| 70 | TYPE=Prog Design VSH; | | | | | | | | | |
| | 3(HYD) | 0 | -555 | 0 | 0.0 | 0.0 | 0.0 | 0.0002 | -0.0000 | -0.0001 |
| | 4(OPE) | 0 | -585 | 0 | 0.0 | 0.0 | 0.0 | 0.1610 | -0.0888 | 0.0002 |
| | 6(OPE) | 0 | -585 | 0 | 0.0 | 0.0 | 0.0 | 0.1674 | -0.0923 | 0.0003 |
| | 25(SUS) | 0 | -575 | 0 | 0.0 | 0.0 | 0.0 | 0.0002 | -0.0002 | -0.0000 |
| | MAX | | -585/L6 | | | | | 0.1674/L6 | -0.0923/L6 | 0.0003/L6 |
| 170 | TYPE=Rigid +Y; | | | | | | | | | |
| | 3(HYD) | 52 | -497 | 7 | 0.0 | 0.0 | 0.0 | 0.0001 | -0.0000 | 0.0000 |
| | 4(OPE) | 170 | -677 | 111 | 0.0 | 0.0 | 0.0 | 0.2249 | -0.0000 | 0.1474 |
| | 6(OPE) | 171 | -682 | 112 | 0.0 | 0.0 | 0.0 | 0.2345 | -0.0000 | 0.1533 |
| | 25(SUS) | 49 | -532 | 9 | 0.0 | 0.0 | 0.0 | 0.0000 | -0.0000 | 0.0000 |
| | MAX | 171/L6 | -682/L6 | 112/L6 | | | | 0.2345/L6 | -0.0000/L6 | 0.1533/L6 |
| 240 | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | -22 | -72 | -1 | 110.0 | -33.4 | -44.5 | 0.0011 | 0.0000 | 0.0000 |
| | 4(OPE) | 16 | -95 | 26 | 91.4 | 24.4 | 32.3 | 0.2061 | 0.0451 | 0.2404 |
| | 6(OPE) | 17 | -96 | 26 | 92.5 | 24.8 | 33.0 | 0.2154 | 0.0469 | 0.2501 |
| | 25(SUS) | -21 | -68 | -4 | 109.1 | -30.8 | -41.1 | 0.0010 | 0.0000 | 0.0000 |
| | MAX | -22/L3 | -96/L6 | 26/L6 | 110.0/L3 | -33.4/L3 | -44.5/L3 | 0.2154/L6 | 0.0469/L6 | 0.2501/L6 |
| 260 | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | -30 | -32 | -6 | -74.7 | 10.1 | 60.2 | -0.0000 | -0.0000 | -0.0000 |
| | 4(OPE) | -188 | 137 | -139 | -380.4 | 142.0 | 690.4 | -0.0000 | 0.0000 | -0.0000 |
| | 6(OPE) | -190 | 143 | -139 | -406.5 | 140.3 | 730.3 | -0.0000 | 0.0000 | -0.0000 |
| | 25(SUS) | -28 | -46 | -5 | -83.2 | 9.9 | 59.8 | -0.0000 | -0.0000 | -0.0000 |
| | MAX | -190/L6 | 143/L6 | -139/L6 | -406.5/L6 | 142.0/L4 | 730.3/L6 | -0.0000/L6 | 0.0000/L6 | -0.0000/L6 |
| 285 | TYPE=Rigid +Y; | | | | | | | | | |
| | 3(HYD) | -22 | -72 | -0 | 0.0 | 0.0 | 0.0 | -0.0028 | -0.0000 | -0.0000 |
| | 4(OPE) | 15 | -95 | 24 | 0.0 | 0.0 | 0.0 | 0.2082 | -0.0000 | 0.3279 |
| | 6(OPE) | 16 | -96 | 24 | 0.0 | 0.0 | 0.0 | 0.2182 | -0.0000 | 0.3411 |
| | 25(SUS) | -20 | -68 | -0 | 0.0 | 0.0 | 0.0 | -0.0031 | -0.0000 | -0.0000 |
| | MAX | -22/L3 | -96/L6 | 24/L6 | | | | 0.2182/L6 | -0.0000/L6 | 0.3411/L6 |

**Second Case study with change routing (Fig.6)**

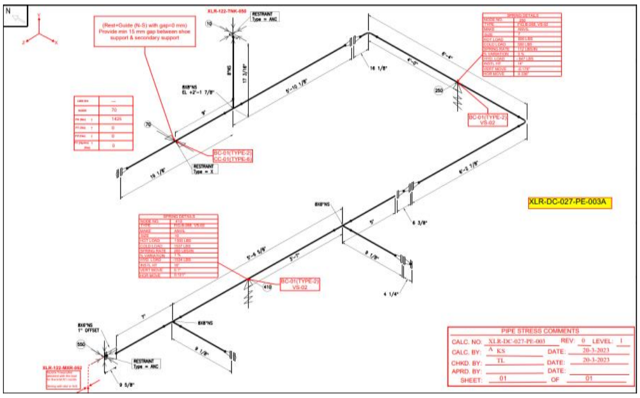



Fig.10: Second Case Design Output – Isometric-2

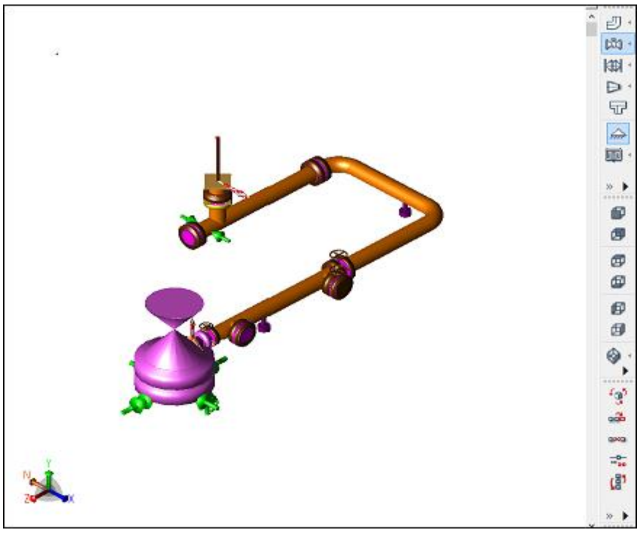


Fig.11: Second Case CAESAR II Modelling details.

1.4 Optimized Stress Summary Result:

STRESS SUMMARY (LEGACY) REPORT: Highest Stresses Mini Statement
Various Load Cases

```
CODE STRESS CHECK PASSED      : LOADCASE 3 (HYD) WW+HP+H

Highest Stresses: (lb./sq.in.) LOADCASE 3 (HYD) WW+HP+H
Ratio (%):                      6.7       @Node    390
Code Stress:                 2353.9       Allowable Stress:      35000.0
Axial Stress:                 963.4       @Node   1150
Bending Stress:              1938.4       @Node    390
Torsion Stress:               291.7       @Node   1220
Hoop Stress:                 1858.9       @Node     50
Max Stress Intensity:        2846.5       @Node    390

 CODE STRESS CHECK PASSED      : LOADCASE 25 (SUS) W+P1+H

Highest Stresses: (lb./sq.in.) LOADCASE 25 (SUS) W+P1+H
Ratio (%):                     29.8       @Node   1210
Code Stress:                 5796.8       Allowable Stress:      19450.0
Axial Stress:                1713.8       @Node   1220
Bending Stress:              3432.9       @Node   1210
Torsion Stress:              1333.7       @Node   1220
Hoop Stress:                 3481.1       @Node   1220
Max Stress Intensity:        5893.8       @Node   1210

 CODE STRESS CHECK PASSED      : LOADCASE 36 (OCC) L36=L25+L27

Highest Stresses: (lb./sq.in.) LOADCASE 36 (OCC) L36=L25+L27
Ratio (%):                     34.2       @Node   1210
Code Stress:                 8834.5       Allowable Stress:      25868.5
Axial Stress:                1755.4       @Node   1220
Bending Stress:              6428.6       @Node   1210
Torsion Stress:              1310.3       @Node   1220
Hoop Stress:                 3481.1       @Node   1220
Max Stress Intensity:        8931.5       @Node   1210

 CODE STRESS CHECK PASSED      : LOADCASE 49 (EXP) L49=L4-L8

Highest Stresses: (lb./sq.in.) LOADCASE 49 (EXP) L49=L4-L8
Ratio (%):                     18.0       @Node   1220
Code Stress:                 5381.2       Allowable Stress:      29918.8
Axial Stress:                  93.0       @Node   1220
Bending Stress:              5189.4       @Node   1220
Torsion Stress:               727.0       @Node     50
Hoop Stress:                    0.0       @Node     30
Max Stress Intensity:       14967.2       @Node   1220
```

1.5 Optimized Displacement Analysis Result:

Piping Flexibility analysis according to the basic assumptions and requirements of B31.3, displacement stress and sustained stress are the two types of stress that piping flexibility analysis considers. Both stresses must be considered separately because displacement stress is related to fixed displacement and sustained stress is related to sustained force.

DISPLACEMENTS REPORT: Nodal Movements
CASE 4 (OPE) W+T1+P1+H

| Node | DX in. | DY in. | DZ in. | RX deg. | RY deg. | RZ deg. |
|---|---|---|---|---|---|---|
| 10 | -0.0007 | -0.1191 | -0.0001 | 0.0003 | 0.0053 | -0.0038 |
| 30 | -0.0009 | -0.1313 | -0.0001 | 0.0003 | 0.0054 | -0.0039 |
| 50 | -0.0023 | -0.1699 | -0.0001 | -0.0020 | 0.0164 | -0.0040 |
| 70 | 0.0000 | -0.1696 | 0.0265 | -0.0016 | 0.0153 | -0.0040 |
| 90 | 0.0016 | -0.1695 | 0.0442 | -0.0015 | 0.0153 | -0.0040 |
| 110 | 0.0027 | -0.1693 | 0.0564 | -0.0015 | 0.0153 | -0.0040 |
| 130 | 0.0032 | -0.1693 | 0.0623 | -0.0015 | 0.0153 | -0.0040 |
| 150 | -0.0055 | -0.1704 | -0.0267 | -0.0048 | 0.0241 | -0.0017 |
| 170 | -0.0496 | -0.1819 | -0.1952 | -0.0178 | 0.0603 | 0.0133 |
| 190 | -0.0539 | -0.1832 | -0.2073 | -0.0178 | 0.0603 | 0.0133 |
| 210 | -0.0583 | -0.1845 | -0.2195 | -0.0178 | 0.0604 | 0.0134 |
| 229 | -0.0583 | -0.1871 | -0.2491 | -0.0285 | 0.0787 | 0.0133 |
| 230 | -0.0383 | -0.1868 | -0.2722 | -0.0328 | 0.0904 | 0.0161 |
| 250 | 0.0679 | -0.1761 | -0.3294 | -0.0484 | 0.0876 | 0.0150 |
| 268 | 0.1152 | -0.1724 | -0.3532 | -0.0553 | 0.0810 | 0.0122 |
| 269 | 0.1437 | -0.1674 | -0.3522 | -0.0604 | 0.0421 | 0.0099 |
| 270 | 0.1570 | -0.1565 | -0.3289 | -0.0783 | 0.0005 | 0.0132 |
| 290 | 0.1570 | -0.1564 | -0.3285 | -0.0784 | 0.0005 | 0.0131 |
| 310 | 0.1434 | -0.0660 | -0.1551 | -0.0959 | -0.0227 | 0.0032 |
| 330 | 0.1417 | -0.0591 | -0.1430 | -0.0959 | -0.0227 | 0.0032 |
| 350 | 0.1408 | -0.0553 | -0.1363 | -0.0959 | -0.0227 | 0.0032 |
| 370 | 0.1392 | -0.0484 | -0.1241 | -0.0959 | -0.0227 | 0.0032 |
| 390 | 0.1372 | -0.0400 | -0.1094 | -0.0960 | -0.0233 | 0.0023 |
| 410 | 0.1195 | 0.0260 | 0.0175 | -0.0679 | -0.0211 | 0.0009 |
| 430 | 0.1119 | 0.0477 | 0.0873 | -0.0384 | -0.0146 | 0.0001 |
| 450 | 0.1267 | 0.0477 | 0.0885 | -0.0384 | -0.0146 | -0.0000 |
| 470 | 0.1389 | 0.0477 | 0.0896 | -0.0384 | -0.0146 | -0.0000 |
| 490 | 0.1448 | 0.0477 | 0.0901 | -0.0384 | -0.0146 | -0.0000 |
| 510 | 0.1103 | 0.0519 | 0.1079 | -0.0301 | -0.0119 | 0.0000 |
| 530 | 0.1092 | 0.0575 | 0.1252 | -0.0182 | -0.0076 | 0.0002 |
| 550 | 0.1087 | 0.0586 | 0.1359 | -0.0179 | -0.0075 | 0.0002 |

1.6 Optimized Restraint Summary Extended Report:

The Restraint products allow for the quick and secure restraint of fittings at bends, dead ends, tees, valves, and reducers without the use of tie rods or concrete thrust blocks. The pipeline becomes its own thrust block thanks to these joint restraint products. Understanding how to apply pipeline restraint correctly is essential for using these new goods. Identifying the force to be restrained the resultant thrust force is the first step in designing any pipeline restraint. It is necessary to isolate the pipe segment holding the fitting restraint to define this force at a specific fitting.

RESTRAINT SUMMARY EXTENDED REPORT: Loads On Restraints
Various Load Cases

| Node | Load Case | FX lb. | FY lb. | FZ lb. | MX ft.lb. | MY ft.lb. | MZ ft.lb. | DX in. | DY in. | DZ in. |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | 2 | -513 | -1 | -84.2 | 2.9 | -3.8 | -0.0000 | -0.0000 | 0.0000 |
| | 4(OPE) | -1224 | -469 | -515 | -89.2 | 1996.6 | -1117.1 | -0.0006 | -0.1191 | -0.0001 |
| | 6(OPE) | -1258 | -451 | -520 | -28.8 | 1999.1 | -1096.9 | -0.0006 | -0.1270 | -0.0001 |
| | 25(SUS) | 195 | -769 | -4 | -1675.9 | 148.0 | -267.8 | -0.0000 | -0.0000 | 0.0004 |
| | MAX | -1258/L6 | -769/L25 | -520/L6 | -1675.9/L25 | 1999.1/L6 | -1117.1/L4 | -0.0006/L6 | -0.1270/L6 | 0.0004/L25 |
| 70 | TYPE=Rigid GUI; | | | | | | | | | |
| | 3(HYD) | -2 | 0 | 0 | 0.0 | 0.0 | 0.0 | -0.0000 | -0.0000 | 0.0001 |
| | 4(OPE) | 1008 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0000 | -0.1696 | 0.0264 |
| | 6(OPE) | 1041 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0000 | -0.1797 | 0.0274 |
| | 25(SUS) | -193 | 0 | 0 | 0.0 | 0.0 | 0.0 | -0.0000 | 0.0015 | 0.0022 |
| | MAX | 1041/L6 | | | | | | 0.0000/L6 | -0.1797/L6 | 0.0274/L6 |
| 250 | TYPE=Prog Design VSH; | | | | | | | | | |
| | 3(HYD) | 0 | -847 | 0 | 0.0 | 0.0 | 0.0 | -0.0001 | -0.0000 | 0.0000 |
| | 4(OPE) | 0 | -600 | 0 | 0.0 | 0.0 | 0.0 | 0.0669 | -0.1758 | -0.3368 |
| | 6(OPE) | 0 | -601 | 0 | 0.0 | 0.0 | 0.0 | 0.0721 | -0.1827 | -0.3479 |
| | 25(SUS) | 0 | -587 | 0 | 0.0 | 0.0 | 0.0 | -0.0022 | -0.0578 | 0.0009 |
| | MAX | | -847/L3 | | | | | 0.0721/L6 | -0.1827/L6 | -0.3479/L6 |
| 410 | TYPE=Prog Design VSH; | | | | | | | | | |
| | 3(HYD) | 0 | -1534 | 0 | 0.0 | 0.0 | 0.0 | -0.0000 | -0.0000 | -0.0000 |
| | 4(OPE) | 0 | -1500 | 0 | 0.0 | 0.0 | 0.0 | 0.1451 | 0.0260 | 0.0045 |
| | 6(OPE) | 0 | -1499 | 0 | 0.0 | 0.0 | 0.0 | 0.1537 | 0.0286 | 0.0083 |
| | 25(SUS) | 0 | -1509 | 0 | 0.0 | 0.0 | 0.0 | -0.0003 | -0.0090 | 0.0001 |
| | MAX | | -1534/L3 | | | | | 0.1537/L6 | 0.0286/L6 | 0.0083/L6 |
| 570 (HOMOGENIZER/ INLET) | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | -0 | 177 | 1 | 213.2 | 2.2 | -413.0 | -0.0000 | 0.0002 | 0.0000 |
| | 4(OPE) | 215 | -232 | 515 | -3768.1 | -1026.6 | 24.2 | 0.1376 | 0.0593 | 0.1295 |
| | 6(OPE) | 217 | -250 | 520 | -3942.4 | -1032.2 | 68.0 | 0.1462 | 0.0633 | 0.1383 |
| | 25(SUS) | -1 | 64 | 4 | -888.7 | 30.2 | -679.6 | -0.0000 | -0.0004 | 0.0000 |
| | MAX | 217/L6 | -250/L6 | 520/L6 | -3942.4/L6 | -1032.2/L6 | -679.6/L25 | 0.1462/L6 | 0.0633/L6 | 0.1383/L6 |
| 1150 (150-TNK-050 / N14) | TYPE=Rigid ANC; | | | | | | | | | |
| | 3(HYD) | 2 | -586 | -1 | -83.7 | 2.9 | -2.3 | 0.0000 | -0.0000 | 0.0000 |
| | 4(OPE) | -1224 | -545 | -515 | 353.3 | 1996.6 | -2168.7 | -0.0000 | -0.0886 | -0.0000 |
| | 6(OPE) | -1258 | -527 | -520 | 418.3 | 1999.1 | -2178.2 | -0.0000 | -0.0945 | -0.0000 |
| | 25(SUS) | 195 | -845 | -4 | -1672.6 | 148.0 | -100.6 | 0.0000 | -0.0000 | 0.0000 |
| | MAX | -1258/L6 | -845/L25 | -520/L6 | -1672.6/L25 | 1999.1/L6 | -2178.2/L6 | -0.0000/L6 | -0.0945/L6 | -0.0000/L6 |

1.7 Nozzle Load Summary:

| Nozzle Load Summary | Page 1 of 1 | Doc. No.: 1 | Rev.: 0 |
|---|---|---|---|
| Customer | GAF | Date: 2/7/2023 | By: KS |
| Project | GAF PROJECT XLR8 | Job No.: 318008-00011 | Checked: TL / Approved: CR |

| Equipment Tag Number | Nozzle Tag | NPS | Line Number | Pressure Class | Stress File Number | Node Number |
|---|---|---|---|---|---|---|
| XLR-122-MXR-052 | N1/N2 | 6" | 122-FCS-002/003 | 150 | XLR-DC-027-PE-003 | 1220/1280 |

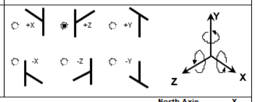
Nozzle Loads Approved by Stress Engineer (selected)
Nozzle Loads Submitted to Mechanical Dept.
Nozzle Loads Approved by Mechanical Dept./Vendor

| Load Case | Forces (lb) Fx | Fy | Fz | Fr | Moments (ft lb) Mx | My | Mz | Mr | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SUS | 1214 | 1619 | 1619 | 2592 | 2071 | 1593 | 1100 | 2835 | |
| OPE | 1214 | 1619 | 1619 | 2592 | 4600 | 3300 | 1100 | 5767 | |
| OCC | 1214 | 1619 | 1619 | 2592 | 5650 | 2700 | 1100 | 6358 | |
| | | | | 0 | | | | 0 | |
| | | | | 0 | | | | 0 | |
| | | | | | | | | | |
| Allowable Loads | 1214 | 1619 | 1619 | 2592 | 2071 | 1593 | 2390 | 3541 | |

Notes:
1. Nozzle loads are applied at: Flange Face / Nozzle / Shell Junction (selected)
2. This Nozzle load Sheet is applicable for Pressure Vessels and Static Equipment.
3. All loads are bi-directional
4. The Operating, Sustained Loads do not include any Occasional Loads
5. Occasional loads are mentioned as OPE+OCC

Equipment Orientation: X - Axis / Y - Axis (selected) / Z - Axis

Nozzle Orientation




North Axis -X

## NOTES AND ASSUMPTIONS

1. Location of new supports have been used as provided in the stress isometrics.
2. Hydrotest pressure has been taken as 1.5 times of highest design pressure for whole system.
3. Line size 6” as discussed
4. Weight of the Homogenizer assembly assumed as 850 lbs.
5. Allowable nozzle load data is considered from nozzle load std.
6. Surge Tank 122-TNK-050 and Homogenizer 122-MXR-052) are modelled from reference data.
7. 122-TNK-050 assumptions:
a) Diameter assumed (from ref) = 10’-0”
b) Tank Thickness assumed = 1”
c) Caesar Material used for Tank = A53 Grade B
This is based on the nearest material available in Caesar database as per the provided
Snapshots to A283 Grade C (from ref) which is not available in Caesar database
d) Corrosion allowance assumed (from ref) = 3/16”
d) Elevation of nozzle from Tank base assumed = 1’-9 1/8”
e) Material of construction of Tank Nozzle = A53 Gr B (same as pipe)
d) Diameter of Nozzle = 12” (same as pipe)
e) Thickness of Nozzle = 0.375” (same as pipe)
f) Length of the Nozzle from the shell connection (assumed) = 10 5/16”
g) Corrosion allowance of Nozzle = 0.06” (same as pipe)
8. 122-MXR-052 Homogenizer assumptions:
North-South and East-West dimension of Homogenizer assumed= 24” (equivalent cylindrical model assumed)
Thickness of shell assumed = 1”
Corrosion allowance of shell assumed = 0.1875”
Height of the Nozzle from the base of the Homogenizer (assumed) = 1’-8 ¾”
Diameter of Nozzle assumed = 6”
Thickness of Nozzle assumed = 0.28”
Corrosion allowance of Nozzle = 0.1875” (same as pipe)
Length of nozzle assumed (from Navis) = 9”

## RESULTS

1. All stresses are within ASME B 31.3 allowable.
2. All flanges are qualified as per NC-3658.3.
3. Piping exerted loads at nozzle junction are less than allowable nozzle loads as per Worley nozzle load std. for filled coating surge tank (122-TNK-050)
4. Piping exerted loads on homogenizer (122-MXR-052) nozzle is more than allowable nozzle loads. Same is mentioned in attached nozzle transmittal sheet.

## CONCLUSION

The stress analysis and flexibility analysis of the pipe system in the chemical plant are described in the analytical results of this piping arrangement, which are found to be good and economically valuable. The CAESAR II Software was used to analyze and design this piping configuration. Consequently, our project's goal was achieved.

The analytical study of piping systems is done using the process piping code ASME B 31.3 and 3D software tool CAESAR II is used for piping system modeling and stress analysis purpose. The analytical and software output is observed. The flexibility analysis requirement for the piping system is checked analytically using the design code ASME B 31.3 and the system is stress analyzed using CAESAR II software.

The Final results are analyzed and found that as follow:

1. Piping system case study 2 is safer than the Piping system case study 1.

2. Piping system case study 2 is more flexible than the piping system case study 1.

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