TECHNICAL GUIDANCE

PIPING – IMPLEMENTATION OF EXPANSION LOOPS

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Contents

1. INTRODUCTION

1.1. SCOPE

This document specifies requirements and gives recommendations for expansion loops in piping systems built in accordance with ASME B31.3. It applies to piping for all types of process fluids and all utility fluids.

Expansion loops are mechanical barriers/arrangements to absorb over stress due to thermal expansion increasing the flexibility of the pipelines without decreasing their mechanical strength.

This document is prepared to improve the safety of construction in the site and so process. This document covers the piping systems in which the connection parts of elbows, fittings, and pipe ends are all welded.

This document contains the requirements of the regular expansion loops and three dimensional expansion loops.

1.2. DEFINITIONS

1.2.1. General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.2.2. Specific definitions

Term	Definition
CAD	Computer Aided Drafting
DN	Diameter Nominal. The DN prefix indicates the nominal diameter of a piping system component in millimetres.
EJMA	Standards of the Expansion Joint Manufacturers Association
Fluid	Gas, vapour, liquid or combinations thereof
Site	The area where welding joint of the spool parts are conducted
GTAW	Gas Tungsten Arc Welding
Long-Run Piping	Piping with length more than one pipe support span.
MESC	Materials and Equipment Standards and Code. The MESC codes are contained in the Catalogue Management Tool (CMT) system.
NPS	Nominal Pipe Size
PEFS	Process Engineering Flow Scheme
PFD	Process Flow Diagram

Term	Definition
PFS	Process Flow Scheme
PipeStress Engineer	The engineer(s) approved by the Principal to undertake pipe stress analysis for a project. The engineer is responsible for obtaining data from disciplines as appropriate, creation, maintenance and issue of the pertinent pipe stress analysis documentation detailed within this standard, analysis and approval of all stress critical lines and the timely dissemination of pipe support/restraint information.
Pipeline	A pipeline is a system of pipes and other components used for the transportation of fluids between (but not within) plants. A pipeline typically extends from pig trap to pig trap (including the pig traps). If no pig trap is fitted, the pipeline extends to the first isolation valve within the plant boundaries.
Piping	Piping is an assembly of straight and bent pipes, fittings, flanges, gaskets, valves and other components (e.g., expansion joints, swivel joints, strainers, devices for mixing, separating, distributing, metering and flow control). It also includes pipe supporting elements and insulation. NOTE: Piping does not include supporting structures (such as frames of buildings, stanchions or foundations) or equipment (e.g., heat exchangers, vessels, columns, pumps) or instrument impulse pipes. Instrument specifications apply downstream the last joint of the last process to instrument valve or valve assembly, defined for the instrument connection in the mechanical piping class. This can include the 5 mm restriction nipple where applicable.
Piping Class	Piping Class is an assembly of piping components, suitable for a defined service and design limits, in a piping system. The piping classes are contained in the following DEP binders: DEP 31.38.01.12-Gen. - Piping classes developed primarily for oil refineries, chemical plants and gas plants; also suitable for onshore exploration and production facilities. DEP 31.38.01.15-Gen. -This binder contains piping classes developed primarily for exploration and production facilities. NOTE: Taking into account different material/component selection philosophies, for E&P and R&C facilities, both sets of piping classes apply as referenced in the service index.
Spec Break	The physical location as a single point dividing one piping class from another.
Site	The area where welding joint of the spool parts are conducted
Shop	The area where the spool parts are manufactured

2. TYPES OF EXPANSION LOOPS

Expansion loops are one of the most effective methods to increase the flexibility of the pipelines. The thermal stress due to thermal expansion is damped mounting arms of the loops vertically to the main line. The clause of 319.7 of ASME B31.3 refers that the expansion loops (Figure 2.1) are one of the most common method used in industry for this purpose. The expansion loops are occupying larger spaces than some other methods (i.e. expansion joints in Figure 2.2.), however the expansion loops are more reliable and long lasting especially when they are exposed to a certain level of torsional loads frequently [1]. Also in Shell Engineering and Design Practice document of DEP 31.40.10.10, it is stated that if pipeline expansion results in loads and stresses that exceed acceptable limits, an expansion loop or other methods of reducing the expansion effects shall be provided.

Figure 2.1: An expansion loop over the supports

Figure 2.2: A typical expansion joint

The expansion loads can be symmetrical (Figure 2.3) or asymmetrical (Figure 2.4) in terms of their position in between the anchors. The symmetrical loops are more effective since they damp the stress equally from both sides [2]. However, the asymmetrical ones are also used commonly in the field depending on the spacing of pipe ways or to utilize existing loops.

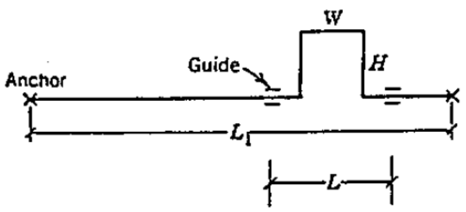

Figure 2.3: Asymmetrical expansion loop [3]

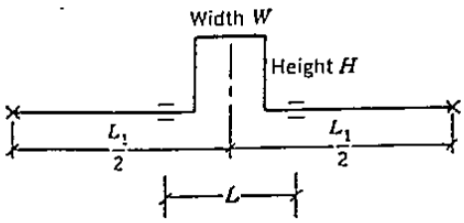

Figure 2.4: Symmetrical expansion loop [3]

The points below should be considered during the engineering phase of the loops:

1. The layout of the main line
2. Process conditions
3. Standards & Procedures
4. Stress level on the fittings
5. Process safety rules
6. Cost-wise approach

3. IMPLEMENTATION OF EXPANSION LOOPS

3.1. MATERIALS

This document does only cover the materials of carbon steel pipes and fitting elements. The material types different than carbon steel should be consulted to subject matter experts complying with the related industrial norms and standards.

The material specifications of pipes, elbows and all fitting elements to be used in expansion loops should be align with main line specification details.

The expansion joints are only recommended to be used if there is not enough space available in the site for expansion loops.

3.2. CONSIDERATIONS

The loops on the line affects all the other lines in the pipe way, therefore the sizes of the arms of the loops should be calculated accurately using the methods mentioned below or similar methodologies.

In the pipe rack, there are generally several lines standing side by side and so the arms of the loops travel along these parallel lines (Figure 3.1). The course of these arms existing in the site previously may cause to abandon the implementation of optimum length/width, L/W (Equation 3.2) ratio, to the new loops. In such cases, the total length of the loops mounted in the site, L_D, should be longer than the calculated total length.

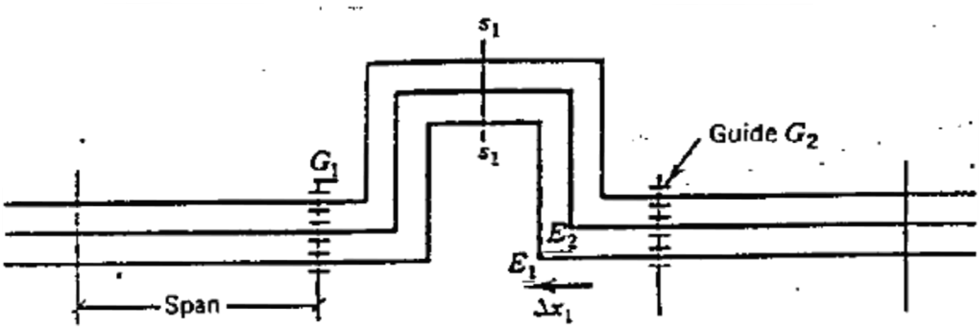

Figure 3.1: The parallel lines in the pipe rack [3]

In the design phase of pipelines, the line which exposed to the maximum thermal expansion due to process conditions is located in the most outer position in the rack. In the same way, the lines exposed to the lower thermal expansions can be positioned in the inner sides.

3D loops (Figure 3.2), are commonly preferred because they prevent the possible conflicts to the other lines and do not disturb the basic design of the route of the new line. In these kind of loops, the height of the rising arm, H, are commonly accepted as 1m [2].

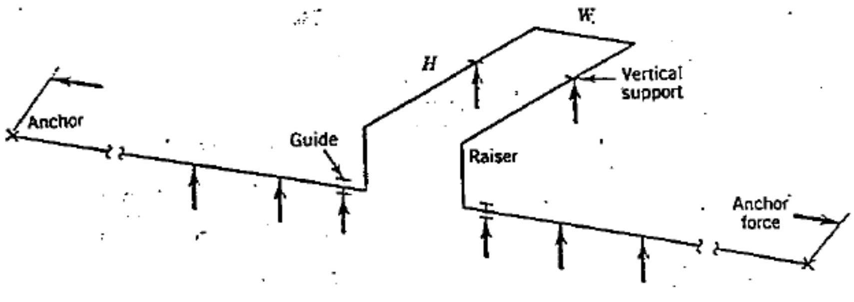

Figure 3.2: 3D Loop [3]

The rising arms in the 3D loops are very functional reducing the overall stress level in the elbows as well as adapting the loop's design into site conditions. On the other hand, they do not contribute to the flexibility of the main line since they do not change the position centre of gravity with respect to the base line of Mitchell shown below (Figure 3.3).

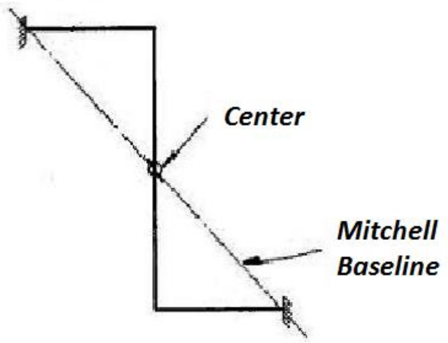

Figure 3.3: The Mitchell base line of the pipe

The guide supports mounted on the both sides of the loop, G_1 and G_2 in Figure 4.4, have the critical role for the functionality of the loop. The elbows of line slip through the main axis of the line instead of slipping laterally thanks to the guide supports.

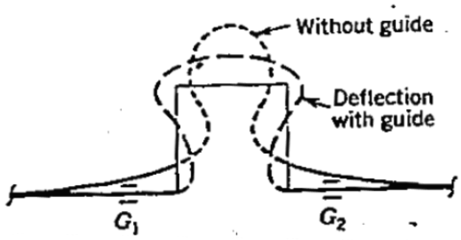

Figure 3.4: The effects of guide supports [3]

Another main concern encountering in the site is that the pipes collides after thermal expansions since the spacing is not being designed adequately. In order to eliminate this problem, the spacing between the adjacent pipes shall be bigger than the expansion differences as below:

Spacing > ($\Delta x2 - \Delta x1$); where $\Delta x1$ and $\Delta x2$ are the expansions in the same direction

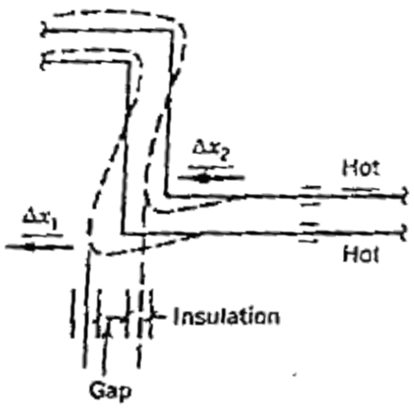

Figure 3.5: The post expansion situation in the pipe rack [3]

3.3. CALCULATON OF THE LOOPS

The total length of the expansion loop consists of, 1 width (W), 2 lengths (L) and 2 heights (H) if available (Figure 3.2). The equation of total length of the loop, L_L, in terms of arm geometry is shown below:

$$L_L = W + 2L \qquad \text{(Equation 3.1)}$$

The optimum L/W ratio is specified generally in the literature as below [4 & 5]:

$$L = 2W \qquad \text{(Equation 3.2)}$$

From the equation 3.1 and the equation 3.2:

$$L_L = 5W \qquad \text{(Equation 3.3)}$$

In order to calculate the minimum required loop length, L_L, there are 3 common methods given below:

- Calculating with Kellogg's Chart
- Calculating with Nomogram
- Calculating with one-step formula

The arm size values of new horizontal loops are directly used in the field to implement. However the 3D loops can be selected for implementation if there is not available space for those calculated arm lengths.

The inputs required for the calculation are listed below in US units:

- Total length of the loop, L_L, ft
- Width of the loop W, ft
- Length of the loop L, ft
- The distance between two fix supports, L_F, ft
- The distance between two guide supports, L_G, ft
- Elasticity of Modulus, E, psi (ASME B31.3 Table C-6)
- Outer diameter of the pipe, D, in
- Thermal expansion, Δ, in
- Thermal expansion coefficient, α, in/100ft (ASME B31.3 Table C-1)
- Maximum temperature difference, ΔT, °F
- Maximum allowable material stress, S, psi (ASME B31.3 Table A-1)

In downstream businesses, due to the construction of the pipe racks, the distance between guide supports can be assumed as 20ft (6mt) in general where the support elements are mounted on the main support columns of the pipe rack.

The maximum temperature to be used in thermal expansion calculation is also the max design temperature of the pipe. For the minimum temperature, the minimum ambient temperature recorded value can be used.

I.e. The lowest recorded temperature for Adana in Turkey was −8.1 °C (17.4 °F).

3.3.1. Calculation with Kellogg Chart

The value should be read in y- axis in the chart is formulated below:

$$\frac{(L_G)^2 S}{10^7 D\Delta} \qquad \text{(Equation 3.4)}$$

The equation of thermal expansion is shown below:

$$\Delta = L_F.\alpha.\Delta T \qquad \text{(Equation 3.5)}$$

The K_1 and K_2 values to be used in the chart are the inverse ratios of the distance between guide supports to the loop width and the loop length respectively:

$$W = K_1.L_G \qquad \text{(Equation 3.6)}$$

$$L = K_2.L_G \qquad \text{(Equation 3.7)}$$

The designer of the loop should select one of the K_1 or K_2 values with respect to the physical conditions in the site. The chosen value and the value to be read in the y- axis of the chart are used to determine the loop width, W, and the loop length, L, values.

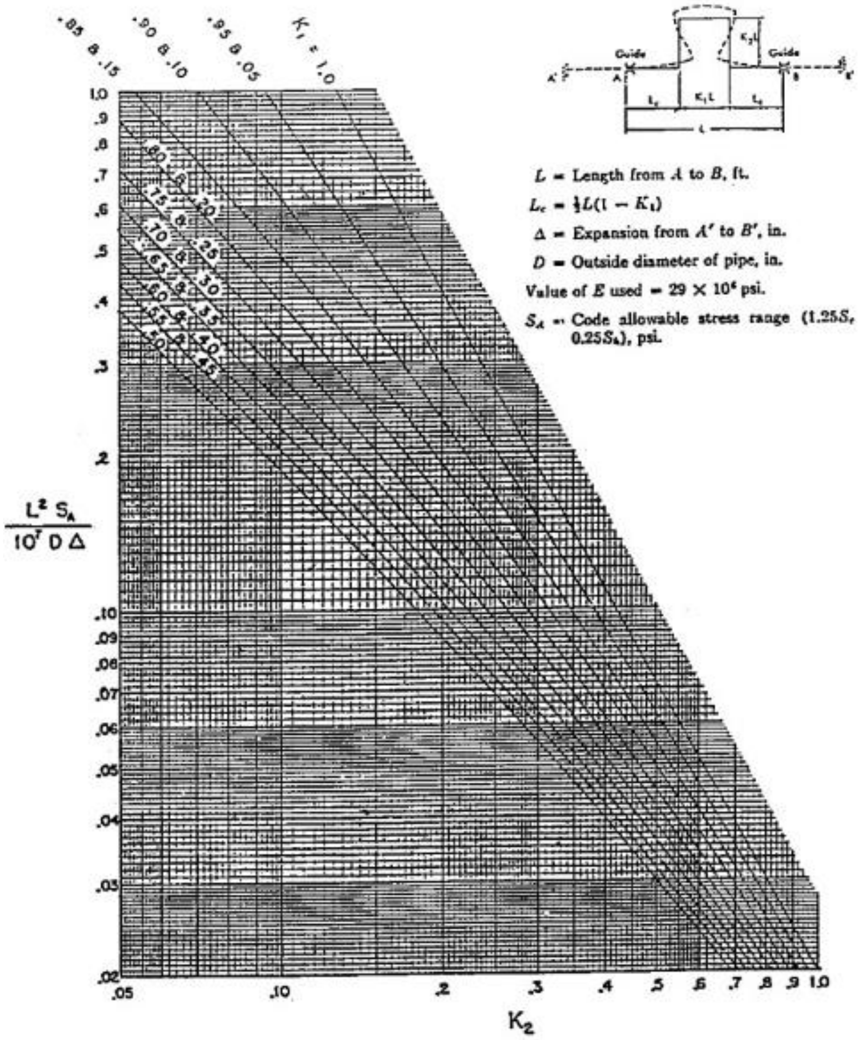

Figure 3.6: The Kellogg Chart [3]

3.3.2. Calculation using Nomogram

In the nomogram below, there are 3 vertical scales available:

- Left Scale: Outer diameter of the pipe, D, in
- Middle Scale: Expansion to be absorbed Δ, in
- Right Scale: Total length of the loop, L_L, ft

The nomogram is used with the equation of 3.3 to find the details of the loop such as width and length:

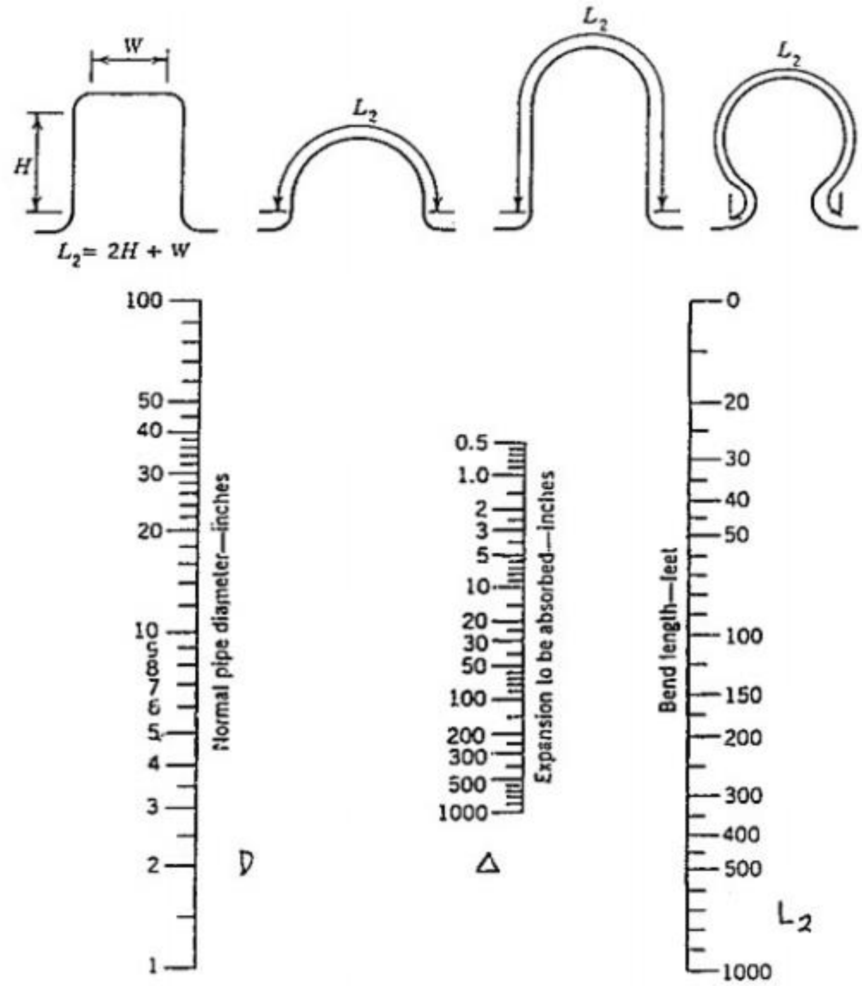

Figure 3.7: The Nomogram for expansion loop [3]

3.3.3. Calculation with One-Step Fomula

In order to absorb the thermal expansion stress, the minimum required length of the loop, L_L, can be calculated in one step as shown below:

$$L_L = \sqrt{\frac{3.E.D.\Delta}{144.S_A}} \quad \text{(Equation 3.8)}$$

Using L_L and the equation of 3.3, the details of the loop width and loop length can be found.

4. CONCLUSION

The expansion loops have crucial role to absorb the thermal stress and to sustain the layout of the pipe lines for years. The design phase for the expansion loops should be sensitively taken into account before the construction phase. All the three methods mentioned above are recommended to apply before the design of the expansion loops for comparison and affirmation purposes [6].

After the calculation phase of design, the stress levels of the high risk part of the loop should be checked. Caesar II v5.20 can be used to analyse stress levels especially on elbow parts to check whether there is an over-stress condition or not. If there is an over-stress available, the loop can be redesigned as a 3D loop model with rising arms or an additional horizontal loop can be considered providing in between same fix supports.

5. REFERENCES

[1] Website: http://www.usbellows.com/expansion-joint-catalog/torsiona.htm

[2] ASME B31.3, 2002: “ASME Code For Pressure Piping”

[3] Kellogg, M.W., 1956: “Expansion Loops and Expansion Joints”, Chapter 5

[4] Thermacor, 2002: “Expansion Calculations and Loop Sizing”, TDCD 16.103

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[6] Hayden, L.E.,“Grooved and Pressfit Piping Systems”, Chapter A9